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The effects of ambient music on simulated anaesthesia monitoring

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Summary

We examined the effect of no music, classical music or rock music on simulated patient monitoring. Twenty-four non-anaesthetist participants with high or low levels of musical training were trained to monitor visual and auditory displays of patients' vital signs. In nine anaesthesia test scenarios, participants were asked every 50–70 s whether one of five vital signs was abnormal and the trend of its direction. Abnormality judgements were unaffected by music or musical training. Trend judgements were more accurate when music was playing ($p = 0.0004$). Musical participants reported trends more accurately ($p = 0.004$), and non-musical participants tended to benefit more from music than did the musical participants ($p = 0.063$). Music may provide a pitch and rhythm standard from which participants can judge changes in vital signs from auditory displays. Nonetheless, both groups reported that it was easier to monitor the patient with no music ($p = 0.0001$), and easier to rely upon the auditory displays with no music ($p = 0.014$).

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Ambient noise in the operating theatre may distract anaesthetists from core tasks and may mask important auditory information [1, 2]. Several researchers have examined music as a specific form of ambient noise that could present a hazard. In a UK survey, 72% of anaesthetists reported that music is regularly played in the operating theatre [3]. Fifty-one percent reported that they found music distracting, mostly in times of anaesthetic crisis, and 26% reported that they preferred to work in silence. The effect of music may depend on a number of factors: the sound pressure level (volume), whether a vocal track is present, the listener's familiarity with the piece and the listener's preference for the style of music.

Few direct empirical tests have been performed to examine the effects of noise on anaesthesia performance. Radocy and Boyle [4] found that music increases anaesthetists' arousal and attention during vigilance tasks. However, Hawksworth *et al.* [5] investigated the effect of silence, white noise, Pachelbel's Canon and self-chosen music on anaesthetists' ability to perform a general manual control task and found no effect. Further evidence for the effect of music comes from surgery rather than from anaesthesia. In accordance with findings that familiar music increases arousal and task performance [6], Allen and Blascovitch [7] found that surgeons performed mental subtraction tasks faster and more accurately with familiar, self-selected music than with experimenter-selected music or no music. As many as 46 of the 50 pieces that the surgeons selected were classical, so better performance with self-selected music may have been because the music was classical rather than because it was familiar. In addition, the participating surgeons were selected because they liked to play music in the operating theatre, possibly biasing the results.

In contrast, in a statistically well-powered experiment, Moorthy *et al.* [8] found that a sample of surgeons selected for varying degrees of laparoscopic experience performed laparoscopic tasks equally well in quiet, in recorded operating theatre noise at 80–85 dB, and in experimenter-selected classical music played at each surgeon's preferred volume.

In this study, we investigated whether music added to other tasks affects patient monitoring performance, and whether the kind of music played makes any difference to performance. Classical and rock music were tested because previous studies indicated that they are two of the most popular forms of music in the operating theatre [3]. We also investigated the role of individual differences on monitoring accuracy. Because monitoring was supported by variable-tone pulse oximetry and by a novel auditory display of respiratory vital signs [9, 10], we tested whether participants with high musical ability would monitor more accurately. In an early study, Fitch and Kramer [11] found that musicians were better than physiologists at identifying a simulated patient's status from an auditory display of vital signs.

Methods

The study was approved by The University of Queensland's Ethics Committee and written, informed consent was obtained from all participants. Participants were 24 senior undergraduate or postgraduate students at The University of Queensland. The sample size of 24 was justified on the basis that we had previously achieved significant results with a sample size of 21 for the same dependent measure when comparing monitoring accuracy of professional groups using different display modalities [10]. An *a priori* power analysis based on the means and standard deviations of the previous study showed that the present study would have the power to detect an 8% improvement in accuracy with a power of > 0.8 for all effects.

None of the 24 participants had training in physiology or health sciences. Twelve participants had 3 years of formal music training (mean (SD) = 9.7 (4.5) years) and currently played a musical instrument at least once a month, thereby satisfying our criterion for being classified as musical, whereas the other 12 who did not meet these criteria for musical training (mean (SD) = 1.1 (1.4) years) were classified as non-musical. All participants reported normal hearing.

The anaesthesia simulator used was Advanced Simulation Corporation's Body^{TM} physiological and pharmacological engine, connected to an interface largely similar to the Body^{TM} Anaesthesia Simulator interface but including some extensions developed in our laboratory (the 'Arbiter' simulator). Nine 9-min anaesthesia scenarios based on observed anaesthesia incidents were created. The scenarios were:

- oxygen and nitrous pipeline swap-over with a mechanically ventilated patient;
- oesophageal intubation of a spontaneously breathing patient;
- rapid blood loss followed by intravenous fluid replacement in a spontaneously breathing patient;
- patient spontaneously breathing against the ventilator;
- isoflurane overdose in a spontaneously breathing patient;
- oxygen and mains electricity supply failure;
- placement of a tracheal tube in the right main bronchus;
- drug-induced cardiac arrest;
- soda lime exhaustion.

Arbiter presented a visual display of the patient data with ECG and capnography waveforms as well as a variable-tone pulse oximetry display of heart rate and $S_{p}O_2$. Arbiter also presented a continuous auditory display of respiratory rate, tidal volume and $F_{\acute{E}}CO_2$ [10]. Inspiration was represented as a tone at one musical pitch and expiration as a tone one musical minor third below the inspiration pitch. Respiratory rate was mapped to breath cycle length, tidal volume to sound pressure level, and $F_{\acute{E}}CO_2$ to the relative pitch of the inspiration: expiration pair. Although the particular auditory display used is novel and is the subject of ongoing research [10, 12], auditory displays of respiration are being introduced to anaesthesia equipment (for example, Draeger^{TM} (Lubeck, Germany) has introduced a custom breathing tone to a new anaesthesia machine).

Participants could view vital signs on the visual monitor as well as hear the pulse oximetry and respiratory auditory display. Participants sat at a table with the patient monitoring screen behind them, as might happen when engaged in other tasks in the operating theatre. They turned when they wished to view the monitor. The auditory display came from speakers next to the patient monitoring screen.

The rock music played was selected tracks from the Bryan Adams albums 'Cuts like a knife' and 'Waking up the neighbours'. The classical music was J. S. Bach violin concertos and sinfonias in D minor. Within each category, all tracks selected had a relatively even dynamic range and a similar tempo. Any extremes of volume were digitally corrected with Sonic Foundry Sound Forge Studio^{TM} (Madison, WI, USA). The sound pressure level for the auditory displays was set at 73 dB(A) which was approximately 8 dB(A) more than the background music at 65 dB(A). An experienced consultant anaesthetist set these sound levels as representative of how music is played in the operating theatre.

The experiment had a between-subject factor of musicality and a within-subject factor of music (no music, classical, rock). Participants completed three clusters of three scenarios each – nine different scenarios in all. Within each scenario they responded to 10 prompts for the status of a vital sign. Each cluster of three scenarios included one scenario during which no music played, one during which classical music played, and one during which rock music played. The order of music conditions was counterbalanced across clusters and across participants to avoid order effects.

After providing written, informed consent, the participants completed a questionnaire on their musical training and musical preferences. They then completed approximately 2 h of training on the patient monitor. They learned normal ranges for the five vital signs they were to monitor, they learned how to register their responses on the answer sheet, and they received intensive training on monitoring with the auditory displays.

During each scenario in the main part of the experiment, every 50–70 s, a recorded voice asked after a single vital sign, such as 'carbon dioxide?'. Participants indicated vocally whether that vital sign was normal, high or low (S_pO_2 could only be normal or low) and whether it was steady, increasing, decreasing or fluctuating. The experimenter recorded the participant's response on a specially prepared sheet. The probability of a correct response by chance, given the number of answer alternatives, was p = 0.33 for abnormality judgements (except for S_pO_2, where it was p = 0.5) and p = 0.25 for judgements of trend.

After each scenario, participants used seven-point Likert scales to rate the ease of monitoring, ease of monitoring with the auditory displays, and their reliance on the auditory displays. After each cluster, participants noted which of the three music conditions was the easiest to work with, whether music improved or reduced their concentration, which condition they preferred, and which condition was the most annoying. At the end of the experiment, participants answered further questions about which music condition was easiest to work with and which they most enjoyed. The experiment ran for around 4 h.

Statistical analysis was performed with STATISTICA™ v6.1 (Statsoft, Inc., Tulsa, OK, USA). Data for monitoring accuracy were analysed with an Analysis of Variance (ANOVA) with the between-subject factor of musicality (musical, non-musical) and within-subject factors of music type (no music, classical, rock) and vital sign (heart rate, S_pO_2, respiratory rate, tidal volume and $F_{\acute{E}}CO_2$). Further tests used the Pearson Product-Moment correlation coefficient and the Chi-squared test. Data were tested for significance in two-way tests with $\alpha = 0.05$.

Results

Monitoring accuracy was considerably better than chance given the number of answer alternatives (Figs 1 and 2). The mean accuracy of abnormality judgements across the vital signs matched almost exactly the accuracy of anaesthetists in a similar task reported by Watson and Sanderson [10]. The results of the analysis of variance for abnormality judgements indicate a significant effect of vital sign, $F(4.88) = 11.196$, $p < 0.0001$. Accuracy was better for heart rate and

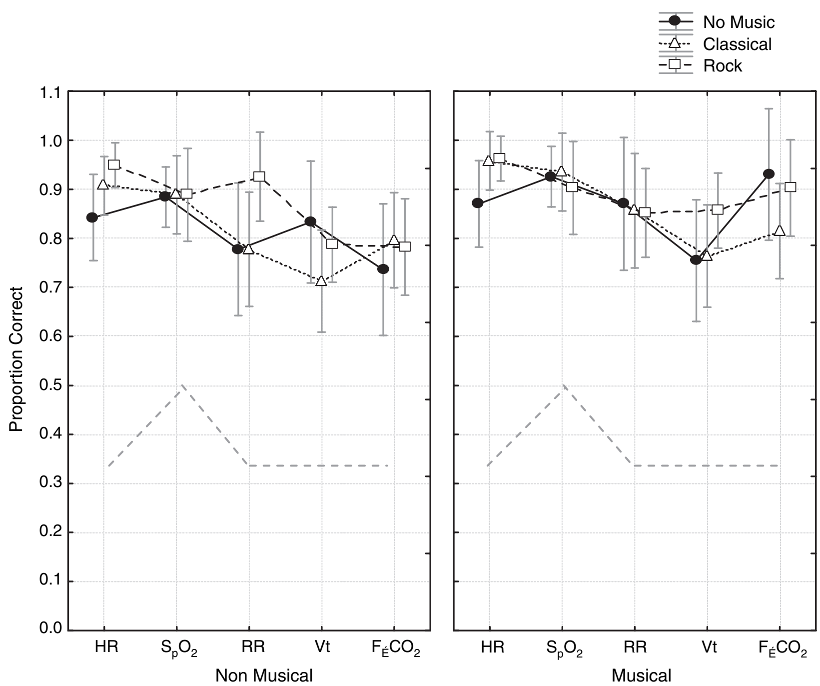

Figure 1 Proportion correct for abnormality judgements. The grey dashed line lower down in the graph represents the probability of correct responses by chance, given the number of answer alternatives. Vertical bars denote 95% confidence intervals. HR, heart rate. S_pO_2, oxygen saturation. Vt, tidal volume. $F_{\acute{E}}CO_2$, end-tidal carbon dioxide.

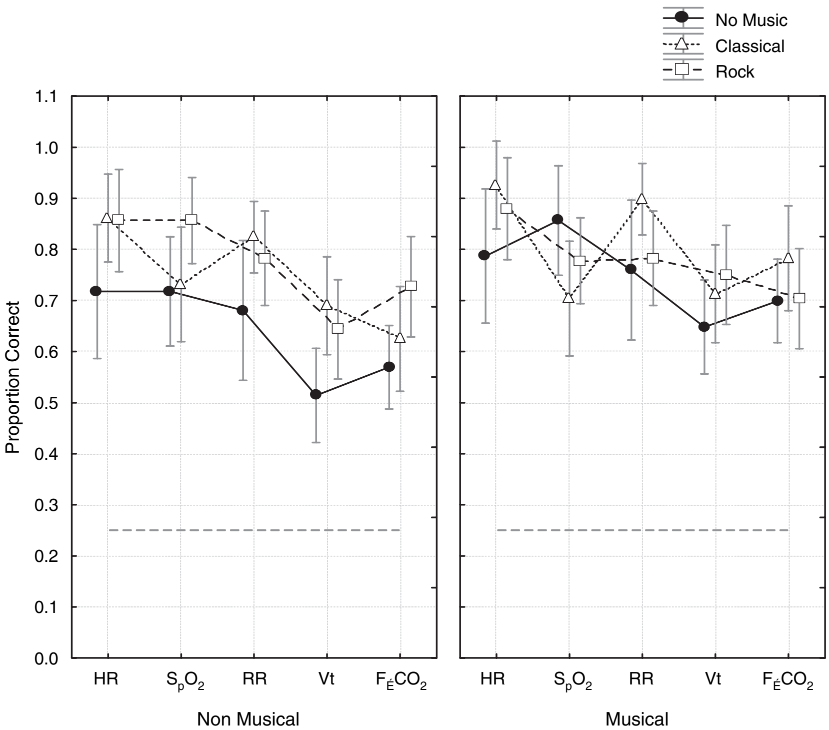

Figure 2 Proportion of correct directional or trend judgements. The grey dashed line lower down in the graph represents probability of correct responses by chance, given the number of answer alternatives. Vertical bars denote 95% confidence intervals. HR, heart rate. S_pO_2, oxygen saturation. Vt, tidal volume. $F_{\acute{E}}CO_2$, end-tidal carbon dioxide.

S_pO_2 than for tidal volume and $F_{\acute{E}}CO_2$, but this partly reflects the greater interrelations between tidal volume and $F_{\acute{E}}CO_2$ [9, 10]. No other effects were significant.

The mean accuracy of non-musical participants' directional judgements across vital signs matched almost exactly the accuracy of anaesthetists in a similar task reported by Watson and Sanderson [10]. Results for directional judgements indicate that participants' accuracy at detecting trends is better with classical and rock music than with no music, $F(2,44) = 9.34$, $p = 0.0004$. A Tukey HSD test correcting for Type I error indicated that monitoring accuracy with both rock and classical music was significantly higher than with no music, but there was not a significant difference in monitoring accuracy between rock and classical music. There was a significant effect for musical training, $F(1,22) = 10.05$, $p = 0.004$, with musical participants more accurate than non-musical participants at identifying trends in vital signs. The interaction between music condition and musical training was marginally significant, $F(2,44) = 2.938$, $p = 0.063$, with non-musical participants showing a greater relative benefit of music over no music than did the musical participants. Finally, the results also indicate an effect of vital sign, $F(4,40) = 19.948$, $p < 0.0001$, with heart rate and S_pO_2 more accurate than respiratory rate, tidal volume and $F_{\acute{E}}CO_2$. No other effects were significant.

Table 1 Results from post-scenario questions on 7-point Likert scales for ease of monitoring and the role of auditory displays. Data are mean (SD).

	No music	Classical music	Rock music
Ease of monitoring	4.9 (1.1)	3.6 (1.1)	3.7 (1.3)
Ease of monitoring with auditory displays	4.9 (1.0)	3.8 (1.1)	3.9 (1.2)
Reliance on auditory displays	5.0 (0.9)	4.7 (0.9)	4.6 (1.1)

The results of the Likert scale questionnaires after each scenario indicated that participants found it easiest to monitor the simulated patient with no music, $F(2,44) = 20.27$, $p < 0.00001$, they found it easiest to use the auditory display when there was no music, $F(2,44) = 16.34$, $p < 0.00001$, and they were most likely to rely on the auditory display when there was no music $F(2,44) = 4.667$, $p < 0.014$ (Table 1). At the end of each cluster of three scenarios, between 65% and 74% of participants reported that it was easiest to monitor with no music, and between 70% and 75% of participants reported that music reduced their concentration (Table 2). At the end of the experiment, 67% of participants reported that they preferred to work with no music but only 29% reported that working with no music was most enjoyable (Table 3), which was significant in a Chi-squared test, $p = 0.026$.

Table 2 Summary of participants' subjective responses at the end of each cluster of three scenarios.

	Cluster 1			Cluster 2			Cluster 3		
	No music	Classical music	Rock music	No music	Classical music	Rock music	No music	Classical music	Rock music
Easiest condition to work with	17	4	2	15	6	2	16	4	3
	Improve	Worsen	Neither	Improve	Worsen	Neither	Improve	Worsen	Neither
Effect of music on concentration	2	17	5	4	16	3	4	18	2

One participant failed to answer the question about the easiest condition for Cluster 1, leaving a total of 23 participants for that question.

Table 3 Summary of participants' subjective responses at the end of the experiment.

	No music	Classical music	Rock music
Easiest condition	16	6	2
Most enjoyable	7	10	7

Discussion

This study is one in a series on the effects on operating theatre noise on participants' ability to monitor patients with visual and auditory displays. It is the first study to test the effect of ambient music on simulated patient monitoring, so extending prior results for anaesthetists performing laboratory tasks [5] and for surgeons using laparoscopy simulators [7, 8]. It is also the first study to find that music can improve the accuracy of simulated anaesthesia monitoring, even though benefits of music have previously been found in non-anaesthesia research [6, 7]. Hawksworth *et al.* [5] tested the effect of music on performance of a perceptual-motor task (rather than on patient monitoring) and found that music had no effect. We find no effect of music on abnormality judgements but strong improvements with music for trend judgements. Finally, the present study is the first to find better performance with experimenter-selected music. Such results were previously found only with participant-selected music; Allen & Blascovitch [7] showed improved performance with participant-selected classical music alone.

An important concern is that results from our non-anaesthetist participants may not generalise to anaesthetists. However, in the 'no music' condition of the present experiment, the non-anaesthetist participants showed average levels and patterns of accuracy in abnormality and trend judgements that were similar to those of anaesthetists in a prior study with no music [10]. Therefore, for the relatively low-level task of identifying abnormality and trends in vital signs with no ambient music, there appears to be little difference between the performance of trained non-anaesthetists and anaesthetists. It is still possible that anaesthetists might not react to ambient music as did our non-anaesthetists.

The inconsistent effects of music in the literature cited may have partly been due to the different tasks used. In the present study, when participants reported whether vital signs were normal or abnormal, music had no effect on their accuracy. However, when participants reported trends, music enhanced their performance, especially if they were not musically trained. Music may have a generally arousing effect in a relatively low workload situation, but it may also provide a rhythm and pitch standard against which dynamic changes in auditory displays can be judged. Only tasks aided by temporal comparisons might show an effect of music.

Even though music helped participants identify trends in vital signs, participants reported that working with no music was easier and generally preferable. Hawksworth *et al.* reported that 51% of anaesthetists found music distracting, especially in times of anaesthetic crisis, and 26% preferred to work in silence [3]. Even under low workload conditions, the majority of our participants preferred to work without ambient music.

Musical training may not affect abnormality judgements because all participants may be equally good at inspecting the visual monitor and storing the current vital signs in working memory for possible later report. However, musical training may affect directional judgements because integration of information over time is needed, which is hard to achieve through successive inspections of a visual monitor. First, musically trained participants may have better memory for sequences [13], which is required to make directional judgements. Second, musical participants may have taken better advantage of the auditory support provided by the pulse oximetry and the respiratory auditory display to maintain an auditory memory of the patient's state over the previous 30 s or so.

This study has limitations that we are addressing in current work. First, as noted, anaesthetists may react differently to music than do non-anaesthetists, especially if called upon to make a medical evaluation of a patient's status rather than simply report vital signs. In addition, anaesthetists' patterns of attention may differ from those of non-anaesthetists, possibly leading to different results with ambient music. Second, we need to compare the effect of music on the accuracy of abnormality and trend judgements with visual displays only vs. with auditory displays only in order to pinpoint the source of its effect. If music has a generally arousing effect, then it should affect monitoring with either display, whereas if the effects of music are acoustic only, then music should affect monitoring with auditory displays only. Third, the present results are specific to monitoring under low levels of workload. In other research, we have found that music can worsen participants' accuracy at detecting trends if participants have to perform high-workload tasks at the same time [14, 15]. Fourth, the music in this study was played at a moderate intensity only. If the music were louder, the benefit of music for detecting trends might disappear. A study addressing all the above concerns is under way.

Although our data reflect the performance of participants without anaesthesia training, they support the impression that under relatively low workload conditions, ambient music at moderate sound pressure levels can improve the detection of trends in vital signs even though participants express a preference for working with no music.

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