The effect of music on monitoring a simulated anaesthetised patient with sonification

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Abstract

The idea of sonifying anaesthetised patients' vital signs is gaining acceptance, but some anaesthetists are concerned about additional noise in the operating theatre. We tested the effect of ambient music (jazz, classical and rock) on participants' ability to monitor a simulated anaesthetised patient with sonification and visual monitors. Participants liked working with ambient music when workload was low. Participants preferred rock music, but reported working better with classical. Ambient music has less effect on participants' ability to monitor the simulated patient than a distractor task does. We discuss practical implications of these findings.

Keywords:

sonification, auditory displays, music, musicality, anaesthesia, timeshared tasks, noise

INTRODUCTION

Over the last ten years researchers have sought better ways to keep anaesthetists continuously informed about the status of their patients. Field observations and cognitive task analyses indicate that anaesthetists might benefit from auditory displays (Watson et al., 2004) Auditory displays may be *sonifications* that represent continuous data relations via auditory relations, or *earcons* that represent discrete forms of information in a short abstract auditory code (Kramer, 1994). Because auditory displays can be continuously heard from a variety of locations, they could give the anaesthetist a background awareness of the patient's state while he or she carries out visually-intensive perceptual motor tasks. The existing pulse oximetry system (the beeping heart monitor) is a sonification that exploits this principle that has proven to be an invaluable display (Weinger and Englund, 1990).

Several studies have presented ways of extending the idea behind the pulse oximetry system to sonifying not only a patient's heart rate (HR) and oxygenation (O2), but also their blood pressure (BP), respiration rate (RR), tidal volume (Vt) and end-tidal carbon dioxide (ETCO2). Watson and Sanderson (2004) found that anaesthetists could monitor a patient as accurately with a sonification as with a visual display, but with a sonification anaesthetists could perform timeshared tasks significantly better than with a visual display. Other researchers have found that sonification leads to faster identification of abnormalities (Loeb and Fitch, 2002). Although these findings are promising, many anaesthetists comment that with its sterile reflecting surfaces, the operating theatre (OT) is already a noisy place and further sound may be problematic. The typical average OT noise level is between 60-65dB(A), but can reach 90 dB(A) (Weinger and Englund, 1990). Sources include suctioning, diathermy, pagers, opening of packages, and background music. Sonified patient data may be masked by such noise. In addition, sonified patient data may annoy clinicians who have low tolerance for further noise. These factors need further investigation because they might severely restrict the usefulness of sonification in the OT.

Music is often played in the OT and it is the sound source most likely to compete with sonification. There have already been some studies of the effect of music on clinicians' performance. In a UK survey, 72% of respondents reported that music is regularly played in the OT although 26% of respondents preferred to work in silence (Hawksworth et al., 1997). The effect that music has on anaesthetists' performance depends on whether a vocal track is present, on the listener's preference for the style of music and on the listener's familiarity with the piece being played. Hawksworth et al. report that anaesthetists find pop and reggae the most distracting music in the OT. Hawksworth et al. (1998) report that rock, jazz and classical are the most popular musical styles for the OT.

In an empirical study, Hawksworth et al. (1998) investigated the effect of music on anaesthetists' ability to perform a general manual control task but found no effect. Radocy and Boyle (1979) found that ambient music increases anaesthetists' arousal and attention during vigilance tasks. Consistently with findings that familiar music increased arousal and task performance (Fontaine and Schwalm, 1979), Allen and Blascovich (1994) found that surgeons performed cognitive tasks faster and more accurately with familiar-self-selected music than with experimenter-selected music or no music. However, 46 of the 50 pieces the surgeons selected were classical music, so better performance may have been due to musical style rather than to familiarity.

In summary, anaesthetists differ in their preference for music in the OT, but studies suggest that familiar classical music can benefit performance of laboratory tasks. Empirical studies of the effects of music on anaesthetists' performance have only used simple laboratory tasks, restricting the generality of the findings. We report a preliminary investigation of the effect of music on people's ability to monitor a simulated anaesthetised patient using sonification. We compare the effect of music on performance with the effect of two different kinds of distractor task on performance. We also manipulate musical style, comparing jazz, classical and rock music.

METHOD

Participants. Participants were 24 advanced undergraduate students from The University of Queensland. None had training in physiology or health sciences. All answered a preliminary questionnaire about their level of musical training and whether they currently played an instrument.

Apparatus. The anaesthesia simulation was Arbiter, which is based on the Body Anaesthesia Simulator™. Nine 9-minute anaesthesia scenarios were created within Arbiter that are based on actually observed incidents. Arbiter presented a visual display of patient data as well as a sonification of HR, O2, RR, Vt, and ETCO2. HR and O2 were presented as the normal pulse oximetry sound. In a second sound stream, inhalation was represented as a tone at one musical pitch and exhalation as a tone one musical minor third below the inhalation pitch. RR was mapped to breath cycle length, Vt to sound pressure level, and ETCO2 to the relative pitch of the inhalation:exhalation pair (see Watson and Sanderson, 2004, for details). An arithmetic distractor task ran on a second computer that presented participants with a series of simple arithmetic expressions for a true-false judgment with a keypress, and presented participants with a graph showing their cumulative speed and accuracy on the task. A manual distractor task required participants to transfer adhesive labels from a peel-off sheet onto a designated box on a paper sheet. The labels and the box were numbered and the participant had to check their numbers were the same—if not, the participants oriented the label slightly differently within the box to mark the mismatch. Participants faced the distractor task, with the patient monitoring screen directly behind them.

The jazz was Charlie Parker, the rock Bryan Adams, and the classical music J.S. Bach concertos in D minor. All were chosen to have a relatively even dynamic range throughout the piece. Any extremes of volume, for example during musical transitions, were digitally corrected with Sonic Foundry Sound Forge Studio™ before use (see Shek, 2003, for further details). The sound pressure level for the sonification was set at 73dB(A) which was approximately 8dB(A) more than the background music at 65dB(A). An experienced anaesthetist consultant set this sound level difference as representative of how music was heard in the OT.

Design. The experiment had two independent variables: music/distractor Condition and Distractor task. In the Music/No Distractor (MnD) condition, participants monitored the simulated patient while listening to jazz, classical or rock music. In the No Music/Distractor condition (nMD) participants monitored the simulated patient while performing the manual or arithmetic distractor task. In the Music/Distractor (MD) condition, participants monitored the simulated patient while listening to the music and performing the manual or arithmetic distractor task. The conditions MnD, nMD and MD were counterbalanced within subjects. The manual or arithmetic distractor task was manipulated between subjects, with 12 participants doing each task. Participants performed a block of three anaesthesia scenarios under one condition of the experiment before moving to the next block and next condition. The order in which participants experienced the three experimental conditions was counterbalanced, as was the allocation of scenarios to conditions, to avoid a conflation of conditions with practice, or conditions with scenarios. Musical style (jazz, classical or rock) was manipulated within each block of three anaesthesia scenarios. The order of presentation of musical style within each block was counterbalanced to avoid a conflation of musical style with scenarios or with serial position within block.

Procedure. The experiment ran for four hours. After completing a questionnaire covering demographic details and musical training and practice, participants trained on the sonification for about an hour until they reached basic competence. Then the first block of the experiment started. After the first, second, and third part of each scenario, participants reported on the status of the patient's five vital signs and assessed overall patient well-being. After each block in the MnD and MD conditions, participants answered questions about the three musical styles they had just experienced. After all three blocks, participants again answered questions about the three musical styles but also compared the three Conditions they had experienced. Participants were told they could look around at the simulated patient monitoring screen whenever they liked, except when answering probes, but that they had to stay positioned facing away from the screen as often happens in the OT.

RESULTS

Participants were divided post-hoc into a musical vs non-musical group, based on their answers to the initial questionnaire. Participants were considered musical if they had at least two years of formal musical training or played a musical instrument at least once a week. In this way the manual vs arithmetic participant groups were each divided approximately equally into musical and non-musical subgroups.

Conditions. The first ANOVA was a between-within ANOVA, with between-subjects factors Distractor Task and Musicality (Musical, Non-Musical), and the within-subjects factors Parameter (HR, O2, RR, Vt, ETCO2) and Condition (nMD, MnD, MD). The dependent variable was percentage of correct judgments about the status of the patient's five vital signs (parameters). The kind of Distractor Task and the Musicality of the participant did not affect judgment accuracy. However, there was a significant effect of Condition, with MnD showing better performance than nMD and MD, $F(2, 40)=3.235$, $p=0.049$ (see Figure 1). There was also an effect of Parameter, with HR and O2 reported more accurately than RR, Vt and ETCO2, $F(4, 80)=57.368$, $p<0.001$, as tends to happen with non-anaesthetist participants. There was a three-way interaction of Condition, Distractor Task and Musicality, $F(2, 40)=6.141$, $p=0.0047$, and a four-way interaction of Condition, Distractor Task, Musicality and Parameter, $F(8,160)=2.443$, $p=0.016$, indicating that the effect of Condition on participants' ability to report RR, Vt and ETCO2 depended on their Musicality and on the Distractor Task they were performing.

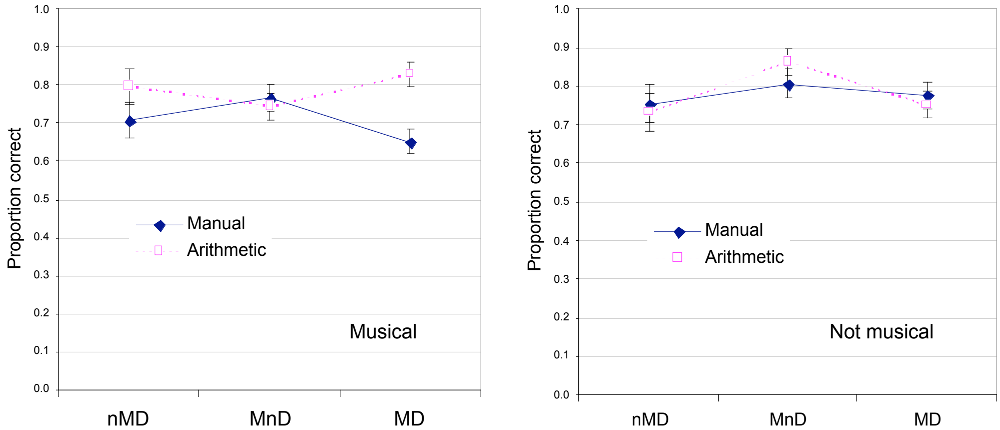

Figure 1: Graphed results for Conditions, Musicality, and Distractor Task. Error bars are SE_M.

Musical Style. The second ANOVA was performed on the MnD and MD conditions alone to extract the effect of Musical Style, and included the between-subjects factors Distractor Task and Musicality, and the within-subjects factors Parameter, Condition, and Musical Style. There was no effect of Distractor Task on the accuracy of participants' judgments about the patient's state, but a trend for Musicality, $F(1, 20)=3.225$, $p=0.088$, suggesting worse accuracy for musical participants. There was also a trend for Musical Style, $F(2, 40)=2.549$, $p=0.09$, with slightly better performance with Classical music. Condition was again significant, $F(1, 20)=4.464$, $p=0.047$, with judgments less accurate in the MD condition. Again there was a strong effect for Parameter, $F(4,40)=44.525$, $p<0.001$, with HR and O2 reported more accurately than RR, Vt and ETCO2. The three-way interaction of Condition, Distractor Task and Musicality, $F(1, 20)=12.186$, $p=0.0023$,and four-way interaction of Condition, Distractor Task, Musicality and Parameter emerged strongly again, $F(4, 80)=4.881$, $p=0.0014$.

	Condition Prefs			Music Pref			Music Preference after MnD						Music Preferences after MD					
				Start Experiment			General			For Work			General			For Work		
	MnD	nMD	MD	J	C	R	J	C	R	J	C	R	J	C	R	J	C	R
1st	**18**	5	1	4	4	**16**	7	6	**11**	8	**14**	2	4	**10**	**10**	7	**14**	3
2nd	3	**16**	3	8	10	6	8	10	6	7	8	9	10	9	5	10	9	5
3rd	3	1	**18**	12	10	1	9	8	7	9	2	**13**	10	5	9	7	1	**16**

Table 1: Summary of subjective preference data across the experiment

Preferences. At the start of the experiment, 16 of the 24 participants expressed a general preference for rock music, with second and third preferences evenly divided between jazz and classical music (see Music Pref in Table 1). After the MnD condition 11 participants generally preferred rock but 14 preferred to work with classical and rock was the least preferred for work. After the MD condition, the general preference was split between rock and classical, but 14 participants still preferred to work with classical, and 16 participants ranked rock as least preferred. When comparing the three conditions at the end, 18 participants felt that the MnD condition was the easiest condition to handle, 16 felt nMD was second easiest, and 18 that MD was the hardest.

DISCUSSION

Participants report that it is easier to monitor a patient when there is ambient music than when they have to perform a distractor task at the same time. This pattern is also evident in their monitoring accuracy. Although adding ambient music increases the reported difficulty of monitoring the patient while carrying out a distractor task, monitoring accuracy under the two conditions is indistinguishable. Therefore, the presence or absence of a distractor task, rather than of ambient music, appears to account for monitoring performance. Being aware of the music does not absorb cognitive capacity, whereas performing the distractor task does (Smith and Jones, 1992). Under the conditions we have tested, then, music appears to have a stronger affective effect than cognitive effect.

Further analysis is needed to fully understand the impact of music. For example, when there is ambient music participants may depend more on visual scanning than on sonification to monitor the patient's state. This would mean that the MnD condition was considered the easiest and led to best performance because participants used the visual display rather than the sonification. We are part way through a video analysis of how often and for how long participants turned their heads to look at the patient monitoring screen that will help to resolve this issue. Headturning appears to be a sensitive measure of the demands of visual vs auditory attention (Sanderson et al., 2004). Similarly, the impact of conditions on timeshared tasks must be explored.

Our results also suggest that musical style may affect performance. Although most participants had an initial preference for rock music, most reported that they preferred to do the patient monitoring task with ambient classical music than with rock music. This preference is reflected in patient monitoring performance, where monitoring is marginally more accurate with ambient classical music than with jazz or rock. This is probably because of the vocal element in the rock music. The effect of musical style may have been stronger if we had included pop or reggae music, neither of which is favoured in the OT (Hawksworth et al., 1997).

Future work. At present we are running further participants to increase the statistical power of the study. This will resolve the currently marginal main effects of musicality and musical style on monitoring accuracy, and will also clarify some of the higher-way interactions with musicality. We are also starting to run a version of the study with anaesthetists. In future work we will add a condition (impractical for the first study) with patient monitoring alone, which will let us assess how much music by itself affects the participant's ability to monitor the patient. The effect of familiarity and self-selection of music needs to be studied in future work, as well as the effect of different sound pressure levels for the sonification and the music.

REFERENCES

Allen, K. and Blascovich, J. (1994) Effects of music on cardiovascular reactivity among surgeons, *Journal of the American Medical Association,* **272,** 882-884.

Fontaine, C. W. and Schwalm, N. D. (1979) Effects of familiarity of music on vigilant performance, *Perception and Motor Skills,* **49,** 71-74.

Hawksworth, C., Asbury, A. J. and Millar, K. (1997) Music in theatre: not so harmonious: A survey of attitudes to music played in the operating theatre, *Anaesthesia,* **52,** 79-83.

Hawksworth, C., Sivalingam, P. and Asbury, A. J. (1998) The effect of music on anaesthetists' psychomotor performance, *Anaesthesia,* **53,** 195-197.

Kramer, G. (1994) In *Auditory display: Sonification, audification, and auditory interfaces.*(Ed, Kramer, G.) Addison-Wesley, New York.

Loeb, R. G. and Fitch, W. T. (2002) A laboratory evaluation of an auditory display designed to enhance intraoperative monitoring, *Anesthesia and Analgesia,* **94,** 362-368.

Radocy, R. E. and Boyle, J. D. (1979) *Psychological foundations of musical behaviour,* Charles C. Thomas, Springfield, IL.

Sanderson, P., Crawford, J., Savill, A., Watson, M. and Russell, W. J. (2004) Visual and auditory attention in patient monitoring: A formative analysis, *Cognition, Technology, and Work,* **16**, 172-185.

Shek, V. (2003). Effect of noise on anesthesia monitoring. Unpublished Bachelor of Information Technology thesis. School of ITEE, The University of Queensland, St Lucia, Qld.

Smith, A. P. and Jones, D. M. (1992) In *Handbook of human performance*(Eds, Jones, D. M. and Smith, A. P.) Academic Press, London.

Watson, M. and Sanderson, P. (2004) Sonification helps eyes-free respiratory monitoring and task timesharing, *Human Factors,* **46**,

Watson, M., Sanderson, P. and Russell, W. J. (2004) Tailoring reveals information requirements: The case of anaesthesia alarms, *Interacting with Computers,* **16,** 271-293.

Weinger, M. B. and Englund, C. E. (1990) Ergonomic and Human-Factors Affecting Anesthetic Vigilance and Monitoring Performance in the Operating-Room Environment, *Anesthesiology,* **73,** 995-1021.