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ORIGINAL SCIENTIFIC REPORT

Noise in the Operating Room Distracts Members of the Surgical Team. An Observational Study

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Abstract

Background Noise pollution in operation rooms may distract the surgical team members. In particular during phases of high task complexity, noise can jeopardize concentration. Phases of high complexity are related to task specificities and may thus be different for different members of the surgical team.

Study design Noise exposure was measured during 110 open abdominal surgeries. Distinguishing three phases (opening, main phase, and closing), noise was related to self-report of distraction levels by main and secondary surgeons, scrub nurses and anesthetists.

Results Noise pollution was higher than recommended levels for concentrated work. Adjusted for duration, surgical type, and difficulty of the surgery, results showed that second surgeons are more likely distracted when noise pollution was high in the main phase; and anesthetists are more likely distracted when noise pollution was high during the closing phase. Main surgeons' and scrub nurses' concentration was not impaired by measured noise levels.

Conclusions In phases with higher concentration demands, noise pollution was particularly distracting for second surgeons and anesthetist, corresponding to their specific task demands (anesthetists) and experience (second surgeons). Reducing noise levels particularly in the main and closing phase of the surgery may reduce concentration impairments.

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Introduction

Operating rooms (OR) are noisy environments [1] with noise pollution levels that regularly exceed the maximum of 55 dB(A) noise limit for task requiring high mental concentration [2–7]. High noise levels in the OR have various sources, from handling equipment to loud conversations [2, 8, 9], so many of the noise sources are controllable, to at least some extent [6].

Surgeons, anesthetists and OR nurses regularly report being disturbed by noise during surgeries [10]. Exposure to noise, defined as unwanted sound, has many negative effects: It can lead to exhaustion [11], elicit stress responses [12, 13], impair sensori-motor performance [14], interfere with communication [15], and impair cognitive performance [16]. There is evidence that noise negatively affects surgical performance. Noise pollution has been found to be associated with higher levels of patient complications [17–19] and higher error rates [20]. Higher noise levels also led to more irritation [21], impaired auditory performance [22] and impaired communication among members of the surgical team [23]. Nevertheless, experimental studies did not show performance impairments for manual tasks for surgeons exposed to different types and levels of noise [24, 25]. For anesthetists, negative effects of noise have also been found: Noise exposure impaired anesthetist's mental efficiency and short-term memory [26] and decreased their speed of response to patient changes [27].

Most of the empirical findings relating noise to surgical performance are based on short-term experimental research. However, effects of noise may be different if performance has to be maintained over a long period of time under elevated noise levels [28], but also if additional stressors [20] [22] are present or if task complexity is high [29]. During surgeries, task complexity varies across the opening phase, the main phase and the closure phase [10, 30]. For surgeons, the main phase of the surgery is the most complex phase and generates the highest cognitive workload [31], whereas for anesthetists, the closure phase is particularly demanding, because patient emergence is induced during this phase [31–33]. For OR nurses, attention-demanding phases seem more fluctuant over the course of a surgery [34].

Aim of the study was to identify whether elevated noise levels in the OR in different phases of the surgical procedure were related to self-reported distraction of surgeons, anesthetists and scrub nurses.

Materials and methods

This prospective observational study took place in the visceral surgical department of a middle-sized European University Hospital. It relates noise exposure measurements during surgeries with self-report of surgeons, anesthetists and scrub nurses obtained before leaving the OR.

Inclusion criteria were elective surgeries planned as open abdominal procedures with an expected duration of at least 60 min up to 7 h (the limit of the sound meter recording capacity was 8 h) and the availability of observers. Data were collected for 119 surgeries; nine surgeries were excluded because of technical problems with the sound meter (i.e., too long surgery), and the final sample is 110 surgeries or a total sound measurement time of 367 h. The local ethical board approved the study.

Noise (sound pressure levels) was measured with a digital sound level meter (TES-1352H; ©, TES Electrical Electronic Corp., Taipei, Taiwan, R.O.C.). A weighted sound pressure levels (SPL) were recorded each second between incision and closure of the operative procedure. The sound meter was placed on the main operative lamp above the surgical team. Noise levels were calculated for each phase of the surgery.

Although measuring sound pressure level is relatively easy, it is more difficult to assess noise levels, because they fluctuate over time. A common measure of noise background for a given exposure time is the median noise level (L_{50}), which is the level of noise that is exceeded during 50 percent of exposure time. This measure has been used in previous OR related studies [9, 10]. We thus chose L_{50} to describe noise exposure, measuring noise levels exceeded in 50% of the duration of the respective phase for each surgery. In contrast to other noise levels, for example the Leq (energetic average sound pressure level), the L_{50} metric has the advantage to be relatively insensitive to suddenly occurring high-level noises that are not representative for the measurement period.

Phases of the surgery were distinguished based on the presence of the main surgeon [35], as his or her presence likely indicated a high complexity period. In the surgical department where the study took place, second surgeons (holding a general surgery degree and working toward a specialty degree) were the responsible surgeons for less complex periods. They often started the surgery until the target organs were ready for resection (*phase 1*). The main phase (*phase 2)* started when the main surgeon joined the team. Unless there were special events or requirements, the main surgeon left before closing; if this happened, the third, and final phase started *(phase 3)*. In cases in which the main surgeon was present throughout the procedure, the whole surgery was considered to be phase 2. If the main surgeon was present from the beginning but left before closure, we coded no phase 1 for those surgeries. If the main surgeon joined for phase two and stayed to the end of the surgery, we coded no phase 3. Observers recorded the time of arrival and departure of the main surgeons.

Difficulty of surgery was assessed with one question, asking "How difficult was this surgery for you?" using a 1 to 7 scale with two opposite poles "*easy, routine"(1)* to *"very difficult"(7).*

Feeling distracted was the main outcome variable and was measured as the subjective self-reported distraction during the surgery. This was assessed with one question, using a 1 to 7 scale with two opposite poles: During this surgery, "I could work in a very *concentrated way" (1)* to "…I felt *very distracted" (7)* and a midpoint descriptor of "medium".

Observers present during the surgery handed the questionnaire to surgeons, anesthetists and nurses at the end of the surgery, or before they left the OR. Respondents were classified as distracted if they indicated a level of distraction of four (middle) or higher; they were classified as concentrated, if they indicated a level of distraction of three or less.

Statistical analyses were performed using SPSS® for Windows ® version 24 (IBM, Armonk, New York, USA), $P < 0.05$ (two-tailed) was considered statistically significant; 95% confidence intervals are reported. The difference in noise levels across phases was tested with repeated measurement analysis of variance; pairwise comparisons were based on the Least Square Difference method. Influences of noise levels on self-reported distraction were assessed using univariate logistic regression for univariate effects and adjusted logistic regression for effects adjusted for difficulty, type of surgery as well as for duration of the phases.

Results

Sample characteristics

The sample consisted of 110 surgeries (53 hepatobiliary surgeries, 19 upper gastro-intestinal tract surgeries, 26 lower gastro-intestinal tract surgeries, 12 other visceral surgeries; one surgery was not finished as planned, because it was terminated after a diagnostic laparoscopic procedure). Mean duration from incision to closure was 4.34 h (SD = 1.65 h); median = 4.27 h; duration ranged between 1.2 and 7.3 h.

Response rate for the distraction self-report was 91.8% for the main surgeons; 76.4% for the second surgeon; 95.5% for the anesthetists, and 96.4% for the scrub nurses. According to the cut-off criteria (at least 4/7), 38.6% of the main surgeons, 42.9% of the second surgeons, 16.2% of the anesthetists, and 11.3% of the scrub nurses felt distracted during the surgery (see Table 1).

In 91 of the 110 surgeries, the main surgeon joined the team only for the main phase. In 4 surgeries, the main surgeon was present throughout the surgery, in 13 surgeries, the main surgeon was present from the beginning, but left after the main phase; in 2 surgeries, the main surgeon joined for the main phase and stayed until the end of the surgery. Duration of the different phases and noise levels are reported in Table 2.

Noise level in different phases and types of surgery

Noise levels (L_{50}) were significantly higher in the main phase as compared to the first phase ($t = -9.42$, df 92. $P < .001$), and significantly higher in the closing phase as compared to the first phase ($t = -7.990$, df 86. $P < .001$), noise levels were not significantly different between the

Table 1 Descriptive statistics for self-reported feeling of being distracted and difficulty of surgery for main and second surgeons, scrub nurses and anesthetists

	n	Mean	Standard Deviation	Range (min, max)	
Feeling distracted					% distracted (≥ 4)
Main surgeon	101	3.12	1.47	1,6	35.5%
Second surgeon	84	2.79	1.45	1,6	32.7%
Anesthetists	106	2.11	1.01	1,7	16.2%
Scrub nurses	105	2.40	1.01	1,7	11.3%
Perceived difficulty of surgery					% difficult (≥ 4)
Main surgeon	101	4.54	4.48	1,7	71.8%
Second surgeon	84	4.49	4.52	1,7	57.3%
Anesthetists	106	3.98	1.40	1,7	67.6%
Scrub nurses	105	3.39	4.69	1,7	42.7%

Feeling distracted and difficulty are reported on a scale from 1 to 7

Table 2 Duration and noise levels (L50) for different phases of surgeries

	N	Mean duration (h)	SD duration (h)	95% CI		L50 [db(A)]	SD [db(A)]	95% CI	
				Lower	Higher			Lower	Higher
Phase 1: Preparation	93	1.17	0.776	1.01	1.32	54.52	1.55	54.21	54.84
Main phase	110	2.45	1.49	2.38	2.94	55.84	1.73	55.51	56.16
Phase 3: Finishing and closing	104	0.81	0.69	0.68	0.95	56.34	1.93	55.96	56.34

main phase and the closing phase ($t = -1.899$, df = 97. P = .060) (Table 2).

Noise levels between surgery types were not significantly different (Table 3), with one exception: In the main phase, hepatobiliary surgeries were significantly louder than lower GI tract surgeries (P = .008).

Noise and reported distraction

Table 4 reports noise levels for "concentrated" vs "distracted" main surgeons, second surgeons, anesthetists, and scrub nurses across phases. Table 5 contains univariate results and results adjusted for duration of phase, surgery type (hepatobiliary vs other surgeries), and perceived difficulty of surgery for all phases, based on logistic regression analyses. The results show that noise levels did not affect self-reported distraction for main surgeons nor for scrub nurses in any phase of the surgery. For second surgeons, reported distraction was significantly related to higher noise levels, but only in the main phase, not in the first or the closing phase. Adjusting for phase duration, surgery type and perceived difficulty of surgery did not change these results. For anesthetists, reported distraction was significantly related to higher noise levels only in the closing phase of the surgery, but not in the first and main phase. Adjusting for phase duration type of surgery, and difficulty did not change this result. Figure 1 illustrates noise levels (a) for second surgeons reporting concentration versus distraction in the main phase and (b) for anesthetists reporting concentration versus distraction in the closing phase.

Discussion

This study confirmed that noise pollution in the OR is a real concern. First, the recommendations for maximum noise levels of 55 dB(A) [5, 6] were exceeded in at least 50% of the time in the main and the closing phase. Other studies

Table 3 Type of surgery and mean noise level (L_{50}) in different phases

Surgery type	Upper GI tract		Hepatobiliary		Lower GI tract		Other	
	M	95% CI	M	95% CI	M	95% CI	M	95% CI
Phase 1 noise level [dB(A)]	54.49	(53.76–55.23)	54.88	(54.44–55.32)	53.79	(53.1–54.49)	54.39	(53.24–55.54)
Main phase noise level [dB(A)]	56.00	(55.25–56.75)	56.30	(55.83–56.76)	55.21	(54.56–55.86)	55.44	(54.45–56.42)
Phase 3 noise level [dB(A)]	56.69	(55.8–57.59)	56.22	(55.67–56.77)	56.38	(55.56–57.21)	56.85	(55.59–58.11)

Noise level is expressed in L50 for each phase, M refers to the arithmetic mean of the L50 values

Table 4 Noise level across phases for main and second surgeons, anesthetists, and scrub nurses reporting low versus high distraction levels

Target	Main surgeons		Second surgeons		Anesthetists		Scrub nurses	
	Concentrated	Distracted	Concentrated	Distracted	Concentrated	Distracted	Concentrated	Distracted
Phase 1 L_{50} noise level [dB(A)]	–[a]	–[a]	54.05 (1.63)	54.47 (1.13)	54.51 (1.40)	54.27 (1.72)	54.59 (1.41)	54.31 (1.79)
Main phase L_{50} noise level	55.88 (1.62)	55.85 (1.86)	55.34 (1.64)	56.20 (1.42)	55.82 (1.74)	56.09 (1.52)	55.86 (1.68)	55.71 (1.91)
Phase 3 L_{50} noise level	–[a]	–[a]	56.20 (1.83)	56.38 (2.00)	56.14 (1.85)	57.20 (1.90)	56.36 (1.93)	56.05 (1.41)

Distracted: ≥4 on a scale from 1 to 7. Numbers in brackets are standard deviations

[a]Main surgeon is not present in this phase

Table 5 Relationship of noise level and reported distraction; univariate and adjusted for type of surgery, duration of surgery and self-reported difficulty

	Main surgeons		Second surgeons		Anesthetists		Scrub nurses	
	Univariate OR; 95% CI; *P*	Adjusted OR; 95% CI; *P*	Univariate OR; 95% CI; *P*	Adjusted OR; 95% CI; *P*	Univariate OR; 95% CI; *P*	Adjusted OR; 95% CI; *P*	Univariate OR; 95% CI; *P*	Adjusted OR; 95% CI; *P*
Phase 1 distracted	–[a]	–[a]	1.26 (0.915–1.77); 0.169	1.29 (0.90–1.86); 0.582	0.90 (0.610–1.339); 0.616	0.73 (0.16–1.15); 0.220	0.93 (0.59–1.46); 0.745	0.96 (0.57–1.61); 0.875
Main phase distracted	0.989 (0.78–1.25); 0.924	0.927 (0.71–1.21); 0.537	1.476 (1.07–2.03); 0.017*	1.46 (1.06–2.01); 0.020*	1.108 (0.81–1.52); 0.522	0.986 (0.70–1.39); 0.933	0.951 (0.67–1.35); 0.782	0.911 (0.63–1.31); 0.616
Phase 3 distracted	–[a]	–[a]	1.068 (0.84–1.36); 0.588	1.082 (0.85–1.38); 0.528	1.367 (1.02–1.83); 0.036*	1.39 (1.01–1.92); 0.045*	0.922 (0.66–1.29); 0.638	0.772 (0.52–1.14); 0.194

OR odds ratio

$^*P < 0.05$; 95% CI 95% Confidence interval

[a]Main surgeons were not present in this phase

reported similar [10], or even higher noise pollution [4, 36] in the OR.

Second, noise levels were not stable across the different phases of the surgery, with the main and closing phases being noisier than the opening phase. This result corresponds to several previous studies that reported increasing noise levels during surgeries or a particularly high noise pollution in the last phase of a surgery [10, 17, 32, 33, 37]. This implies that noise pollution is highest in the phases of high mental workload for surgeons (main phase) and well as for anesthetists (in the closing phase) [30]. Surgeons, anesthetists and nurses reported distraction at the end of their presence in the OR. It is possible that they subjectively "averaged" distraction levels over the whole time they were present; it seems more likely, though, that their judgements were most strongly influenced by moments of especially high distraction. The results show that only noise in the main phase influenced second surgeons' reported distraction, and only noise in the last phase influenced anesthetists' reported distraction. This indicates that noise pollution in high mental workload phases led to particularly high distraction.

In university hospitals, the main phase of the surgery may be particularly straining for second surgeons because they are in a training situation. This implies that they either learn how to perform the surgery by assisting the main surgeon, or, if already well trained, perform the surgery under close supervision. These factors can be additional stressors in the main phase. For anesthetists, emergence is one of the most complex tasks. For the rest of the surgical team, the last phase is often a routine phase and the team starts relaxing [38, 39]. To allow for concentrated work for the anesthetists during this phase, the suggestion of a "sterile cockpit" period—a period that is explicitly declared as high workload during which distractions should be limited—has already been discussed [30, 32, 33, 40]. Anesthetists have to react to patient changes rapidly and rely on auditory sources (such as pitch changes in surveillance sounds, as well as auditory alarms) [27]. Therefore, anesthetists cannot use a strategy of blocking out noises to protect themselves from noise pollution.

Neither the assessment of distractions of scrub nurses nor of main surgeons were related to noise levels. A study in cardiac surgery has shown that for scrub nurses, none of the three intraoperative phases was characterized by very high mental workload, if no extraordinary events occurred—the highest mental workload of scrub nurses was during the preparation of the surgery [30]. This could also be the case for general surgery, as scrub nurses reported the lowest level of difficulty among all members of the surgical team.

Main surgeons reported over 70% of surgeries as being difficult, confirming high difficulty in the main phase.

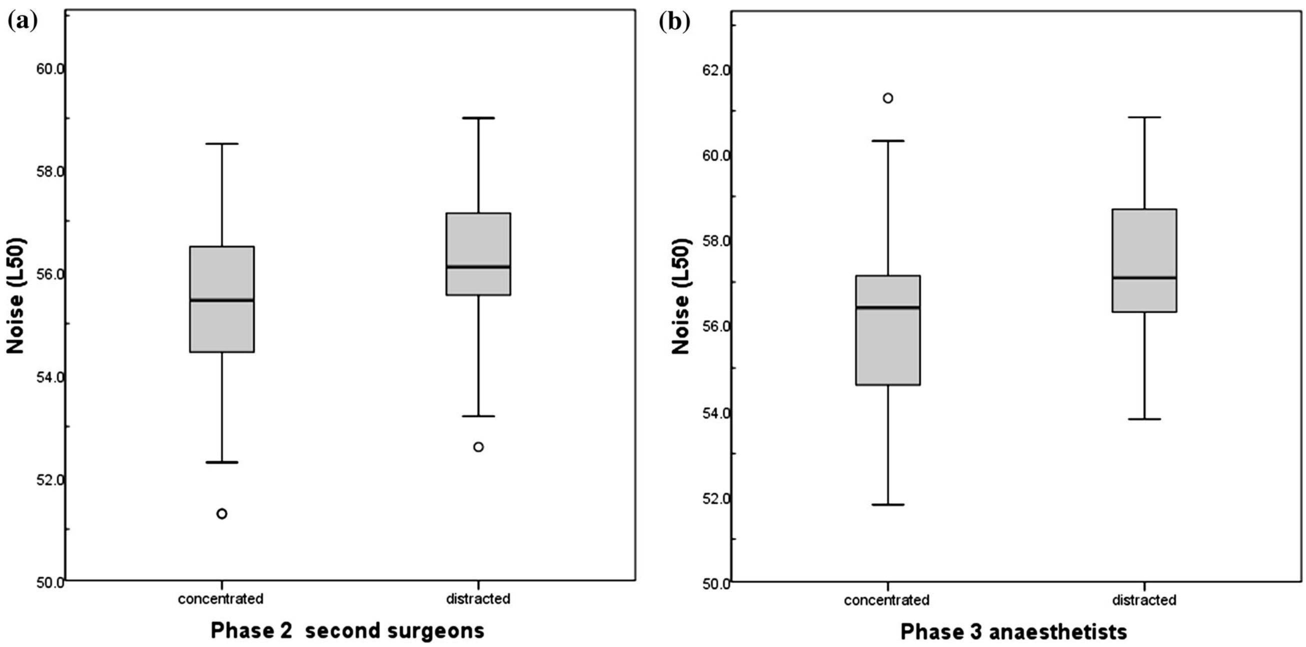

Fig. 1 **a** Boxplot illustration of noise level for second surgeons reporting being able to work concentrated or being distracted in phase 2. **b** Boxplot illustration of noise level for anesthetists reporting being able to work concentrated or being distracted in phase 3

Despite the high mental workload, main surgeons may not report higher levels of distractions because of their high experience. Previous studies found indeed that experienced, but not inexperienced, surgeons are able to block out distractors [24], and studies investigating the effect of distractors other than noise revealed that experienced surgeons showed no or few performance impairments under distracting conditions [25, 41]

However, this does not mean that surgeons are totally oblivious to noise distractions—in another study, almost 60% of surgeons reported that loud noises disturb them [10]. In the present study, main surgeons were not exposed to OR noise as long as second surgeons and we also cannot exclude that they may not suffer cumulative effects of noise over time.

A strength of this study is that noise measures and feelings of being distracted were assessed in the same surgery and thus could be directly related to each other. Previous studies assessed subjective noise annoyance or objective noise measures, but did not combine them. Note that we did not ask whether participants were distracted by noise, but asked about a general feeling of being distracted. Thus, the answers are most likely not biased by the knowledge that noise influences concentration.

A limitation of the study is that only duration, surgery type and difficulty of the surgery were included as potentially confounding variables. It cannot be excluded that noise as well as reported distraction were influenced by third, unmeasured variables. It was also not possible to assess the sources of noise and thus to be able to distinguish between distractions related to the task, and off-task distractions [42]—these might have different impacts on concentration. We also could not measure surgical performance in this study. A limitation is also that we measured concentration—distraction with a single item, which does not allow to capture the concept in a fine-grained way. Finally, the definition of phases on the basis of the main surgeon being present may not fully correspond to the complexity of tasks demands; for instance, the main surgeon might stay during periods of lower complexity for reasons of teaching. However, other definitions of phases (e.g., based on time) would entail similar problems, and a definition based directly on complexity was beyond the expertise of the observers. Note, however, that the presence of the main surgeon during less complex periods would lead to an underestimation of the effects of complexity, and therefore is not likely to invalidate our results.

Many noises in the OR stem from technical devices used [10, 37], suggesting that the design of OR material may contribute to prevent noise pollution. Another source of noise is behavior. Note, however, that general "rules of silences" are not very likely to be successful for reducing noise during long surgeries; rather, periods of "silence" should alternate with well-timed periods of relaxing and chatting, which may help energize the team and maintain a good climate and high morale.

Noise reduction is one of the key safety design principles recommended in healthcare [43]. Noise reduction programs in hospitals in general [44], and in ORs [6], showed that mean reductions of 3–5 decibel (dB) can be achieved. Note that an increase of 3 dB represents doubling the acoustic energy, and an increase of 6 dB is perceived as 50% increase in volume [45], so noise reductions of a even few dB are already worthwhile.

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Compliance with ethical standards

Conflict of interest None of the authors declares a conflict of interest

References

1. Katz JD (2014) Noise in the operating room. Surv Anesthesiol 121:894–898
2. Shankar N, Malhotra K, Ahuja S et al (2001) Noise pollution: a study of noise levels in the operation theatres of a general hospital during various surgical procedures. J Indian Med Assoc 99:244–247
3. Kam P, Kam A, Thompson J (1994) Noise pollution in the anaesthetic and intensive care environment. Anaesthesia 49:982–986
4. Healey AN, Primus CP, Koutantji M (2007) Quantifying distraction and interruption in urological surgery. Qual Saf Health Care 16:135–139
5. Berger EH, Royster LH, Royster JD et al (2003) The noise manual. American Industrial Hygiene Association, Fairfax
6. Engelmann CR, Neis JP, Kirschbaum C et al (2014) A noise-reduction program in a pediatric operation theatre is associated with surgeon's benefits and a reduced rate of complications: a prospective controlled clinical trial. Ann Surg 259:1025–1033
7. Alshammari D, Sica M, Osailan S et al (2017) Noise in a university operating theatre during the cours of pediatric surgical procedures. Curr Pediatr Res 21:572–576
8. Hasfeldt D, Laerkner E, Birkelund R (2010) Noise in the operating room–what do we know? A review of the literature. J Perianesth Nurs 25:380–386
9. Hodge B, Thompson JF (1990) Noise pollution in the operating theatre. Lancet 335:891–894
10. Tsiou C, Efthymiatos G, Katostaras T (2008) Noise in the operating rooms of Greek hospitals. J Acoust Soc Am 123:757–765
11. Witterseh T, Wyon DP, Clausen G (2004) The effects of moderate heat stress and open-plan office noise distraction on SBS symptoms and on the performance of office work. Indoor Air 14:30–40
12. Basner M, Babisch W, Davis A et al (2014) Auditory and non-auditory effects of noise on health. Lancet 383:1325–1332
13. Rylander R (2004) Physiological aspects of noise-induced stress and annoyance. J Sound Vib 277:471–478
14. Szalma JL, Hancock PA (2011) Noise effects on human performance: a meta-analytic synthesis. Psychol Bull 137:682–707
15. Stansfeld SA, Matheson MP (2003) Noise pollution: non-auditory effects on health. Br Med Bull 68:243–257
16. Baker MA, Holding DH (1993) The effects of noise and speech on cognitive task performance. J Gen Psychol 120:339–355
17. Kurmann A, Peter M, Tschan F et al (2011) Adverse effect of noise in the operating theatre on surgical-site infection. Br J Surg 98:1021–1025
18. Grayson D, Boxerman S, Potter P, et al (2005) Do transient working conditions trigger medical errors?, DTIC Document
19. Dholakia S, Jeans JP, Khalid U et al (2015) The association of noise and surgical-site infection in day-case hernia repairs. Surgery 157:1153–1156
20. Moorthy K, Munz Y, Dosis A et al (2003) The effect of stress-inducing conditions on the performance of a laparoscopic task. Surg Endosc 17:1481–1484
21. Pluyter JR, Buzink SN, Rutkowski A-F et al (2010) Do absorption and realistic distraction influence performance of component task surgical procedure? Surg Endosc 24:902–907
22. Way TJ, Long A, Weihing J et al (2013) Effect of noise on auditory processing in the operating room. J Am Coll Surg 216:933–938
23. Keller S, Tschan F, Beldi G et al (2016) Noise peaks influence communication in the operating room. Observ Study Ergon 59:1541–1552
24. Moorthy K, Munz Y, Undre S et al (2004) Objective evaluation of the effect of noise on the performance of a complex laparoscopic task. Surgery 136:25–30
25. Suh IH, Chien JH, Mukherjee M et al (2010) The negative effect of distraction on performance of robot-assisted surgical skills in medical students and residents. Int J Med Robot Comput Assist Surg 6:377–381
26. Murthy VS, Malhotra SK, Bala I et al (1995) Detrimental effects of noise on anaesthesists. Can J Anaesth 42:608–611
27. Stevenson RA, Schlesinger JJ, Wallace MT (2013) Effects of divided attention and operating room noise on perception of pulse oximeter pitch changes: a laboratory study. Anesthesiology 118:376–381
28. Clark C, Sörqvist P (2012) A 3 year update on the influence of noise on performance and behavior. Noise Health 14:292–296
29. Loewen LJ, Suedfeld P (1992) Cognitive and arousal effects of masking office noise. Environ Behav 24:381–395
30. Wadhera RK, Parker SH, Burkhart HM et al (2010) Is the "sterile cockpit" concept applicable to cardiovascular surgery critical intervals or critical events? The impact of protocol-driven communication during cardiopulmonary bypass. J Thorac Cardiovasc Surg 139:312–319
31. Parker SH, Flin R, McKinley A et al (2014) Factors influencing surgeons' intraoperative leadership: video analysis of unanticipated events in the operating room. World J Surg 38:4–10. https://doi.org/10.1007/s00268-013-2241-0
32. Broom MA, Capek AL, Carachi P et al (2011) Critical phase distractions in anaesthesia and the sterile cockpit concept. Anaesthesia 66:175–179
33. Jenkins A, Wilkinson JV, Akeroyd MA et al (2015) Distractions during critical phases of anaesthesia for caesarean section: an observational study. Anaesthesia 70:543–548
34. Wadhera RK, Parker SH, Burkhart HM et al (2010) Is the "sterile cockpit" concept applicable to cardiovascular surgery critical intervals or critical events? The impact of protocol-driven communication during cardiopulmonary bypass. J Thorac Cardiovasc Surg 139:312–319

35. Kurmann A, Keller S, Tschan-Semmer F et al (2014) Impact of team familiarity in the operating room on surgical complications. World J Surg 38:3047–3052. https://doi.org/10.1007/s00268-014-2680-2
36. Ryherd EE, Okcu S, Ackerman J et al (2012) Noise pollution in hospitals: impacts on staff. JCOM 19:491–500
37. Ginsberg SH, Pantin E, Kraidin J et al (2013) Noise levels in modern operating rooms during surgery. J Cardiothorac Vasc Anesth 27:528–530
38. Tschan F, Seelandt JC, Keller S et al (2015) Impact of case-relevant and case-irrelevant communication within the surgical team on surgical-site infection. Br J Surg 102:1718–1725
39. Katz P (1981) Ritual in the operating-room. Ethnology 20:335–350
40. Wahr JA, Prager RL, Abernathy JH 3rd et al (2013) Patient safety in the cardiac operating room: human factors and teamwork: a scientific statement from the American Heart Association. Circulation 128:1139–1169
41. Hsu KE, Man FY, Gizicki RA et al (2008) Experienced surgeons can do more than one thing at a time: effect of distraction on performance of a simple laparoscopic and cognitive task by experienced and novice surgeons. Surg Endosc 22:196–201
42. Galvan C, Bacha EA, Mohr J et al (2005) A human factors approach to understanding patient safety during pediatric cardiac surgery. Prog Pediatr Cardiol 20:13–20
43. Reiling J (2006) Safe design of healthcare facilities. Qual Saf Health Care 15(Suppl 1):i34–i40
44. MacLeod M, Dunn J, Busch-Vishniac IJ et al (2007) Quieting Weinberg 5C: a case study in hospital noise control. J Acoust Soc Am 121:3501–3508
45. South T (2004) Managing noise and vibration at work: a practical guide to assessment, measurement and control. Elsevier, Butterworth-Heinemann, Oxford