Effects of noise on communication and concentration during surgeries: the moderating role of experience and task

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ABSTRACT

Performing surgery requires excellent coordination and communication at the team level and high levels of concentration at the individual level. We present two studies investigating the effects of noise on (1) communication and (2) self-assessed concentration during 109 long abdominal surgeries.

Analyses of 5-min intervals of surgical procedures showed that noise peaks (>70 dB(A)) were associated with a decrease of case-relevant, but not of case-irrelevant communication – however, only when the surgery was led by the less experienced surgeon. Concentration impairment under higher noise levels varied as a function of the experience of the leading surgeon and the phase of the surgery. Less experienced surgeons reported concentration impairment under higher noise during the complex phase of the surgery. Furthermore, anesthesiologist's concentration was impaired by higher noise levels towards the end of the surgery, the most complex phase for their specific tasks.

Thus, noise affects case-relevant communication during surgeries, and distracts surgeons and anesthetists, but these effects depend on experience and on the complexity of the task.

INTRODUCTION

More than 30 years ago, researchers were alarmed by high noise in hospitals, including operating rooms (OR) [1,2]. They measured noise levels higher than acceptable, and pointed to the associated risks for physiological reactions, safe communication, staff irritability and thus patient safety[1]. Results from more recent studies still point to noise levels higher than acceptable [3]. Interestingly, the same noise sources did not disappear across the past decades; unwrapping of instrument is a good example, with noise levels ranging constantly between 70 and 80 dB(A) [1,3,4].

In the medical domain, where stakes are especially high, impaired performance due to high noise levels can have serious consequences. We focus on two important aspects of surgeries that are especially sensitive to distractors and noise effects [5] communication and concentration.

Surgery is teamwork, and optimal ***communication*** within the surgical team is recognized as a key teamwork skill [6], and as a factor that influences patient outcomes [78]. Communication supports situation awareness (i.e. keeping track of the situation of the surgery and its evolution) [6] and is the basis for team coordination [9]. Communication failures were contributing to almost half of surgical errors, according to a study where surgeons reported their errors themselves [10]. An observational study also revealed that communication failures are frequent: About thirty percent of communication events during surgeries were classified as failures. Although many communication failures did not directly lead to medical errors, they can result in other, less visible, disadvantages for patient, such as delays and longer operative times [11].

Noise has an important influence on communication. In one study, participants exposed to aircraft noise were likely to stop their conversation or, if they continued talking, a majority of participants increased their vocal effort [12]. This study suggests that communication under higher noise levels costs vocal efforts, known as the Lombard reflex. The so called Lombard reflex applies when participants speak louder to maintain the intelligibility of their message [13]. More specifically, the Lombard reflex triggers louder speech and hyperarticulation [14]. Thus, if the speaker is not ready to invest efforts in communicating louder, noise levels are likely to be associated with interruptions in verbal exchanges of information.

Concentration is another key factor in surgery. Performing surgery requires not only manual skills but also cognitive skills and decision making [15,16]. Performance of all these aspects can suffer if concentration is impaired [17-20]. This is true for surgeons, but similarly, for anaesthesiologists, previous studies showed that distractors impairing concentration impacted their tasks [21,22]. Thus, not being able to concentrate can threaten the efficient work of different team members in surgeries.

Noise is a powerful distractor. Research found that noise impairs information processing, attentional processing and memory processes [23]. For example, in one study, participants had more difficulty concentrating when exposed to 55 dB(A) than when exposed to 35 dB(A) [24]. Because noise can also act as an environmental stressor [23,25], the pressure experienced by employees working in a noisy environment [26] may also contribute to decrease concentration.

Theoretical models on the distracting effects of noise postulate that aspects of the task and the person exposed to the noise are key factors to consider when investigating effects of noise on employees [27,28]. They imply that the same noise or noise level may affect different people exposed to this noise differently. Similarly, a person may react differently to noise levels depending on the task he or she is performing.

We will first present theory and past research showing which person characteristics moderate noise effects on performance, and secondly present how different tasks moderate the effect of noise on performance. We then report two field studies where we investigated moderator effects of a person variable (experience level) and of a task variable (phases of different complexity during surgeries) on the effect of noise on key performance aspects in surgery. In the first study, we focused on communication and in the second study on concentration, thus covering both personal and team performance predictors.

Experience moderates effects of noise on performance

The same noise level is likely to show different effects on different people. Past laboratory research showed that demographical and personality aspects moderate noise effects. For example, one study found that male subjects' performance under certain noise conditions was affected, whereas female's performance was not; the reverse pattern applied to other types of noise [27]. Similarly, an experimental study suggests that memory processes of older adults are more impaired by higher noise levels compared to younger adults [29]. Personality also moderates the effects of noise on individuals, with introverts being more sensitive to noise compared to extroverts [30].

Although seldom investigated in laboratory experiments, the role of experience emerged as an important moderator of distractor – and thus most likely also noise - effects in field studies, for example in surgery. In one study that was conducted using a laparoscopic simulator (i.e. high reality virtual mini-invasive surgery), double tasking (where the two tasks distract from each other) reduced surgical performance of medical students, but did not impair performance of experienced surgeons [31]. A similar study, conducted with another type of operating technology, robotic surgery, also found that more experienced surgeons were better at performing a secondary task compared to inexperienced students [32]. These results suggest that experience is associated with an increase of resilience towards the distractions inherent in double tasking. This effect may extend to other types of distractors, for example higher noise levels. Indeed, most studies that found effects of (noise) distractions on performance involved participants with rather low level of expertise on the task [33-35]. Interestingly, the one study that found no effect of noise on surgical performance recruited surgeons with various levels of experience, but did not control for experience levels [36]. This suggests again that higher experience may go in pair with an increased resistance towards distractors and the capacity to "block out" noises [36].

One mechanism that explains experience effects is based on theories that focus on the limitation of attentional resources [37]. Attentional resources are limited, and noise consumes such resources. To conduct the same task, novices need more attentional resources than experts. Experts can rely on automatic processes that they previously developed whereas novices have to invest a lot of attention in the task completion, because they lack these automatisms [38]. Consequently, when exposed to higher noise levels that draw on attentional resources, the attentional resources left may still be sufficient for experts to conduct the task efficiently, but not for novices.

To our knowledge, there is no study examining effects of noise levels on aspects of surgical performance including different levels of surgical expertise. Study one contributes to fill this gap. We hypothesized that the communication of second (less experienced) surgeons is more impacted by noise as compared to the communication of main surgeons. We report results of a study investigating these aspects [39].

Task characteristics moderate effects of noise on performance

Similarly to the fact that novices need more attentional resources than experts for a similar task, different tasks require different amounts of attentional resources. In general, more complex and more difficult tasks require more attentional resources, but also simple tasks where small attentional slips can have grave consequences (for example counting errors in medication), require high attentional resources. Distractions will thus particularly harm such tasks. Threats of distractions during high task complexity are well known in aviation, and this has led to the "sterile cockpit rule": During critical phases of the flight, distractions of the pilots are prevented by the rule that stipulates a ban on distracting pilots during critical task phases, such as departure and landing [40]. Similarly, in hospitals the emergence of "no interruption zones" (often explicitly written on the floor) translates the idea that some tasks are more vulnerable to distractions [41]. Typically, preparation of medicine is such a high attention demanding task where no interruption zones are implemented [42].

In surgery, researchers sought to identify phases of the task that are particularly attention demanding, similarly to take-off and landing in aviation. During such attention demanding phases, it has been argued that a rule similar than the concept of "sterile cockpit" could apply to protect the team from distractions [22,43]. Several studies have indeed identified phases of different workload and concentration demands in surgery. Very generally spoken, surgeries have an opening, repair and a closure phase [44]. The main (repair) phase of the surgery (e.g. resection of an organ or part of it and the following reconstruction in cancer surgery) has been found to be the most complex phase with the highest workload for surgeons [43,45]. Although this main phase is the most attention demanding phase for surgeons, this does not apply to all other members of the surgical team. For anaesthetists, task complexity is generally lower during the main phase of the surgery, but is very high during the induction phase prior to opening, and increases again towards the end of the surgery, during and after closure [21,22,43,46]. In addition, for surgeons and anaesthetists, high workload increases when the patients are instable (i.e. in a worse medical condition) [47]. Thus, there are considerable barriers in applying the sterile cockpit concept in the operating room [43], because different teams (surgeons and anaesthetists) share the same work place and are thus exposed to the same noise levels at the same times, whereas the high workload phases do not overlap across the different professions [43].

Evidence that complex tasks are particularly vulnerable to suffer from noise distractors comes from other fields, but also from surgical research. One non-surgical related study showed that noise decreased the performance of participants for complex cognitive tasks, but not simpler tasks [48]. A study in surgery showed that surgeons were more impaired by noise only if they had at the same time to perform a manual task [49], or if another stressor than noise was present [36]. These results suggest that the conjunction of both high workload phases and (noise) distractions is particularly detrimental for surgical performance and in turn for patient outcome. Indeed, prior research supports the link between attentional demands, noise or other distractions and impaired performance. Higher noise levels are associated with worse patient outcome in several field studies [50-52] and are negatively related to surgical performance in experimental studies [34]. Thus, when considering noise effects, task demands should be considered. During different phases of the surgery, noise may show different effects.

Study 2 investigates effects of noise levels on the subjective feeling of distraction by surgeons and anaesthetists.

STUDY 1: EFFECTS OF NOISE ON COMMUNICATION

The aim of this study was to investigate effects of noise on communication within the surgical team in relationship to different experience levels of surgeons, an extended version is published elsewhere (Keller et al., 2016).

Results are based on data of 109 long open abdominal surgeries which took place in a university hospital in Western Europe. We measured noise during the surgery with a noise recording device (TES-1352H (©, TES Electrical Electronic Corp., Taipei, Taiwan, R.O.C.)), that was attached at the main operative lamp above the surgical field. The noise device recorded one measure of noise every second, between 50 and 90 dB(A).

Noise data were then combined with observational data: Between incision and closure, trained observers were observing communication within the surgical team using validated observational system [53]. The observers noted and time-stamped each communication event. They distinguished between two main types of communication, case-relevant and case-irrelevant communication. Case-relevant communication was defined as communication about the patient or the procedure. This included explaining own actions, planning the next steps, and all other communication relevant to the patient or surgery at hand. Case-irrelevant communication included communication that was not related to the patient or the surgery (e.g. small talk, communication about another patient or private communications).

To relate noise to communication, we combined noise and communication data for each five-minute interval for each of the surgeries. This allows analyses of micro-phases of the surgery, because noise has an immediate effect on communication. For each five-minute interval, we identified the number of noise peaks above 70 dB(A), and counted the number of case-relevant and case-irrelevant communication that were observed during this period.

Each five-minute interval was also located within phases of the surgery with different complexity levels. The opening as well as the closing phase were normally performed under the responsibility of the second surgeon. Second surgeons have several years of experience, but are still in training towards their specialty degree and clearly have less expertise than primary surgeons. The main phase of the surgery started when the experienced primary surgeon joined the group and was taking the lead. Primary surgeons have more than 10 years of experience in their specialty.

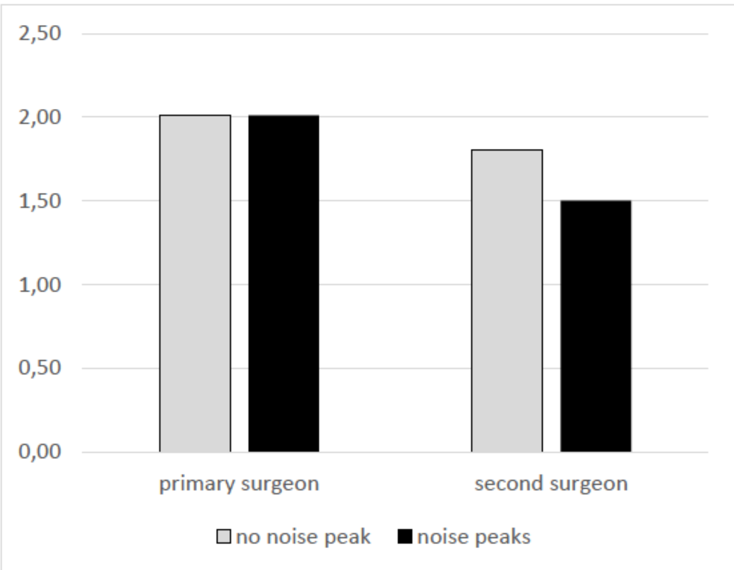
A first result showed that noise peaks above 70 dB(A) were more frequent during the phase of the surgery under the lead of the second surgeon (mean of 43.48 noise peaks per hour, SD=37.59) than in the main phase under the responsibility of the primary (mean of 31.35 peaks per hour, SD=25.38) [39]. This indicates that noise peaks were less likely during the main phase (p = .003).

To test to what extent noise peaks were associated with case-relevant communication, we ran multilevel models with the five-minute interval at the level 1 and surgery characteristics at the level 2; this method allowed to control for the interdependence of five-minute intervals nested in a same surgery. The dependent variable was the communication in the five-minute interval and the independent variable the noise peaks per five-minute interval. We controlled for the duration of the surgery, for noise in the previous five-minute interval and for responsibility of the primary vs second surgeon. We also assessed the effect of the interaction of noise peaks and phases to investigate whether noise peaks had a different influence during the phases with primary or second surgeon responsibility.

The results showed that noise peaks were associated with a decrease in case-relevant communication: noise peaks impaired case-relevant communication. This was however only the case when the second surgeon was leading the surgery, but not when the more experienced primary surgeon was operating. The results are depicted in Figure 1. It is interesting to note that communication in the main phase that is more complex and more attention-demanding was not impaired by noise peaks. This indicates that the experience of the primary surgeon compensates even for complex task phases.

We also tested the impact of noise on case-irrelevant communication. The aim of this analysis was to investigate if noise impacted communication in general (thus impaired all verbal exchanges, case-relevant and case-irrelevant), or if noise mainly impaired task-related communication. Interestingly, we found not only that noise peaks did not predict a decrease in case-irrelevant communication, there was a tendency that in five-minute intervals with more noise-peaks, more case-irrelevant communication occurred. This shows that during surgeries, noise peaks did not impair communication through the pathway of noise obstructing communication. It is rather that noise was consuming necessary attentional resources: Understanding and processing task-relevant communication requires more attention than understanding small-talk, and noise impaired only the first type of communication.

Figure 1: Mean count of case-relevant communication per five-minute intervals as a function of level of experience of surgeon in charge of surgery and noise peaks during the five-minute interval



Note. Because 42.2 % of the five-minute intervals did not contain noise peaks, we median split the 5-min intervals as having none (no noise peak condition) vs one or more noise peaks (noise peaks condition)

To sum up, in this first study, we showed that noise peaks impacted communication during surgeries, with more noise peaks associated with less case-relevant communication, if a less experienced surgeon is leading the surgery. This is in accordance with other results suggesting that experience is a protecting factor against noise effects on communication. Because noise peaks are more frequent during the phase of the surgery under the lead of the second surgeons, these phases contain a double risk – more noise and a higher vulnerability towards this noise.

STUDY 2: EFFECTS OF NOISE ON CONCENTRATION

In a second study, we investigated the effects of noise during different phases of the surgery on self-assessed concentration of surgeons, anaesthetists and scrub nurses. The aim was to identify if phases of the surgery traditionally associated with higher attentional demands are also phases where higher noise particularly impairs concentration. An extended version of this research is ready to submit [54].

Study 2 analysed the same 110 surgeries as study one. For this study, we combined background noise during phases of surgery with self-reported distraction by surgeons and anaesthetists [455]. *Noise background levels* was measured as L_{50}, which is the nose level exceeded in 50% of each phase. This metric is well suited to assess constant background noises, because it is not sensible to high noise peaks. Distraction was self-reported by surgeons and anesthetists using a post-surgery questionnaire. The phases of the surgery were defined as in study one. Note that less complex task phases for surgeons (the opening and closing phase) were performed under the responsibility of the second surgeon, whereas for the main, most complex phase, the primary surgeon was responsible. Note too that for anesthesiologists, the last phase of the surgery was the most complex one.

Controlling for duration of the surgery, results showed that noise in the main phase did not predict distractions for primary surgeons (note that the primary surgeons were only present during the main phase. However, higher average noise in the main phase was related to higher self-reported distractions for the second surgeon; and higher average noise in the closing phase ware related to higher self-reported distractions for the anaesthetists.

These results support the hypothesis that noise impairs concentration in high-workload phases: The main phase of the surgery is the phase with the highest workload for surgeons, and the closing phase is the phase with the highest workload for anaesthetists. The results also indicate that, again, expertise seems to protect from distractions of noise – primary surgeons did not report higher distractions in the main phase. Note that we did not control for expertise levels of anaesthetists, nor do we have noise data for the induction phase of anaesthesia.

OVERALL DISCUSSION

We investigated noise and communication and concentration during 110 surgeries. The result of both studies showed that the effect of noise on performance is moderated by the degree of attentional demands required by the task or the lack of expertise. In the first study, higher surgical expertise seems to protect primary surgeons against the disturbing effects of noise peaks on communication, the second study showed that higher background noise did not impair self-reported concentration of primary surgeons. These results are in line with research that showed that experienced surgeons can successfully “block out” noise and other distractions [36]. Another effect could, however, play a role: In the operating room, the primary surgeon also holds the highest hierarchical status, and thus has the authority to control noise levels. Controllability is a factor that contributes to reduce the impact of noise, these aspects could be an additional explanation why primary surgeons are less affected by noise.

Second surgeons, although less experienced, are responsible for the opening and the closing phase. Results of study one showed that during those phases, noise peaks negatively affected the occurrence of case-relevant communication – communication that is particularly important for high surgical performance [78]. In addition, second surgeons’ concentration suffered, if in the most complex phase, noise levels were high. These results can be explained on the one hand by the lower experience second surgeons have – they are not (yet) able to block out noises. On the other hand, the results indicate that concentration impairments are particularly important in high workload phases of the surgery.

Similarly, anaesthetists’ concentration levels were only impaired by high noise levels during the closing phase of the surgery which is also the phase of highest workload for the anaesthetists during the surgery, because they prepare for the patient to wake up. Again, this indicates that concentration in high workload phases is particularly likely to be impaired by noise.

Although the studies are not without limitations, they help to further shed light on the complex relationship between noise and performance. The micro-analyses based on five-minute intervals are unique in this field and are particularly useful to specifically assess the link between noise disturbances and communication; the analyses of the different phases of task complexity show that in interdisciplinary groups, noise at different moments may impact different people. The two field studies that are based on several hundred hours of noise measures and behavioural observations confirm that noise is still an important concern in surgery: We found not only that noise peaks affect important team processes because it impairs optimal case-relevant communication, but also that background noise impairs concentration, at least in phases of high task complexity.

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