A systematic review of the effect of distraction on surgeon performance: directions for operating room policy and surgical training

Helena Mentis, Amine Chellali, Kelly Manser, Caroline G. L. Cao, Steven D. Schwaitzberg

▶ **To cite this version:**

Helena Mentis, Amine Chellali, Kelly Manser, Caroline G. L. Cao, Steven D. Schwaitzberg. A systematic review of the effect of distraction on surgeon performance: directions for operating room policy and surgical training. Surgical Endoscopy, Springer Verlag (Germany), 2016, 30 (5), pp.1713–1724. <10.1007/s00464-015-4443-z>. <hal-01187233>

HAL Id: hal-01187233

https://hal.archives-ouvertes.fr/hal-01187233

Submitted on 26 Aug 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

A Systematic Review of the Effect of Distraction on Surgeon Performance: Directions for Operating Room Policy and Surgical Training

Helena M. Mentis, PhD, Department of Information Systems, University of Maryland, Baltimore County

Amine Chellali, PhD, Department of Computer Engineering, University of Evry

Kelly Manser, BA, Department of Surgery, Cambridge Health Alliance

Caroline G.L. Cao, PhD, Department of Biomedical, Industrial, & Human Factors Engineering, Wright State University

Steven D. Schwaitzberg, MD, FACS, Department of Surgery, Cambridge Health Alliance

Supported by grants from the National Institute of Medicine: NIH NIBIB 2R01 EB005807-05A1, 1R01 EB010037-01, 1R01 EB009362-01A2, 1R01 EB014305-01A1.

Corresponding Author:

Helena Mentis, PhD

Department of Information Systems

University of Maryland, Baltimore County

1000 Hilltop Rd, Baltimore, MD 21250

E-mail: mentis@umbc.edu

Phone: (410) 455-3206

Fax: (410) 455-1073

Abstract

Background. Distractions during surgical procedures have been linked to medical error and team inefficiency. This systematic review identifies the most common and most significant forms of distraction in order to devise guidelines for mitigating the effects of distractions in the OR.

Methods. In January 2015, a PubMed and Google Scholar search yielded 963 articles, of which 17 (2 %) either directly observed the occurrence of distractions in operating rooms or conducted a laboratory experiment to determine the effect of distraction on surgical performance.

Results. Observational studies indicated that movement and case-irrelevant conversation were the most frequently occurring distractions, but equipment and procedural distractions were the most severe. Laboratory studies indicated that (1) auditory and mental distractions can significantly impact surgical performance, but visual distractions do not incur the same level of effects; (2) task difficulty has an interaction effect with distractions; and (3) inexperienced subjects reduce their speed when faced with distractions, while experienced subjects did not.

Conclusion. This systematic review suggests that operating room protocols should ensure that distractions from intermittent auditory and mental distractions are significantly reduced. In addition, surgical residents would benefit from training for intermittent auditory and mental distractions in order to develop automaticity and high skill performance during distractions, particularly during more difficult surgical tasks. It is unclear as to whether training should be done in the presence of distractions or distractions should only be used for post-training testing of levels of automaticity.

Keywords

Distraction, surgery, safety, performance.

Introduction

The complex task of surgery requires a high level of concentration and fine-motor skills in order to attain precision and coordination of hand movements to maneuver instruments. Unfortunately, the reality of the OR is that it is full of distractions such as calls from the ward, beeper pages, and conversations not pertinent to the surgical procedure [1, 2]. Distractions can have a deleterious effect on surgical performance, as a lapse of attention can lead to complications such as visceral injury or hemorrhage [3]. When asked, surgeons regard 'full focus' and 'distraction control' to be important factors in successful surgical outcomes [4]. Recent studies point to distraction in the OR as one of the most important contributing factors in up to 50 % of hospital errors [5]. Distractions may occur as often as once every 3 min and on average 13.5 times per case [3, 6].

Since distractions are so prevalent in the OR, policies to reduce or remove distractions from the OR are a very important first step. In order to instill such policies, one can attempt to address all forms of distraction or through best guesses which distractions are most significant. A systematic review of the literature, though, can reveal the most significant distractions on performance as well as the most commonly occurring distractions in the OR.

In addition, while steps can and should be taken to minimize error-associated distractions in the OR, policy changes alone cannot eliminate all distractions from occurring. Little can be done to prevent a tray of tools from being dropped by accident or a policy-ignorant new employee from mistakenly entering the OR. In addition, some factors which could be construed as distractions can also provide benefits. For instance, conversation between surgical team members can help build rapport, while communications regarding other patients under a surgeon's care are often a necessary occurrence [7]. It has been suggested that new surgeons need to learn how to focus their attention on the surgery at hand or learn to engage in a form of multitasking that entails the act of filtering out distractions while maintaining focus and control over the surgical procedures [8].

Repeated practice may be the key to facilitating this multitasking by allowing motor skills to become automatized [9]. More experienced surgeons appear to be less affected by distractions when performing a surgical skill [10]. Typically, in a dual-task situation (or distraction episode), there is a slowing effect over both tasks as a performer's perceptual processes are engaged in, typically, the first encountered task [11–14]. Experience in performing a particular technical skill is thought to lead to automaticity, requiring less conscious effort or cognitive capacity and thus reducing the effect of a distracting event [15].

Until recently, many surgical residents gained physical task automaticity and experience with working under distracting conditions through actual OR task performance. As resident work hours are increasingly limited, primarily due to concerns over fatigue, there has been a renewed interest in other mechanisms toward training residents in order to assuage concerns over surgical proficiency and competency [16]. Specifically, efforts have been made to develop simulator-based training and validated tests of proficiency [17–20]. However, the development of these training simulators has not replicated the environmental variables of a busy and potentially distracting OR. The opportunity for not only training for automaticity, but also training for focused attention during distractions could be met by simulator-based training. This requires simulation system designers to have a deep understanding of the types of distractions faced by surgeons and the ways in which distractions affect surgical performance in order to validate the efficacy of these training systems.

This paper addresses the question of the types of distractions faced by surgeons in the OR through a systematic review of OR observational studies, as well as how distractions affect surgical performance through a systematic review of experimental studies of distraction. The first section of the review includes the findings from five selected publications that have observed the occurrence of distractions in the OR and report on their frequency, level of distraction, or contribution to errors. The second section of the review includes studies from 12 selected publications that have conducted controlled laboratory experiments and reported on the effect of various distractions on surgical performance. This paper summarizes and distills conclusions on key theoretical and methodological issues in service of the ultimate goal of creating effective distraction-minimizing policies as well as effectively training surgeons to mitigate the effects of distraction in surgical practice.

Materials and Methods

Working Definition of Distraction

Healey et al. [3] provided a definition of distraction as an event that causes a break in attention and a concurrent orientation to a secondary task. This working definition is in contrast to an interruption, which is an event where there is a break in task activity in order to attend to a secondary task or, similarly, a disruption, which is a break in the natural progression of a task [21]. Healey et al. [22] further operationalized a distraction by its elucidation of an observed behavior such as momentarily orienting away from a primary task or concurrently attending to a secondary task. As this paper is most concerned with distractions, the papers and discussion included are of measurements and findings on distractions rather than interruptions or disruptions. However, on occasion, research presented did not make a distinction between distraction and interruption. In those cases, we include all data presented.

Paper Selection

An online search of PubMed was conducted in January 2015 by three of the authors (HM, AC, and KM). The authors compared and discussed findings after the first search and made a final agreement as to what papers would be included. The criteria for inclusion were that the paper (1) presented novel empirical results, (2) specified distraction or a distracting event such as noise as at least one of the constructs of interest, and (3) specified their interest in surgeon performance and/or surgery outcomes. No methodological quality exclusion criteria were applied as (1) there were a relatively small number of papers fulfilling our inclusion criteria and (2) we found the methodological variety and quality an interesting finding to present in this paper.

The first search included 'distraction,' 'surgery,' and 'performance' as keywords and limited to articles in English. This yielded a total of 102 empirical papers—eleven (11) papers presented findings from observations of distractions in the operating room or from laboratory studies of the effect of distractions on surgical performance [3, 8, 10, 14, 24–26, 28, 33–35]. A follow-up search replaced 'distraction' with 'noise' which yielded 752 empirical papers for review—in total, five (5) of which were new and topically appropriate [27, 29–32]. Finally, a search on 'safety,' 'distraction,' and 'surgery' yielded 109 papers for review—one (1) new paper was found that was a suitable paper for this review [22]. In total, 17 papers were identified. Selection process is outlined in the flowchart in Fig. 1.

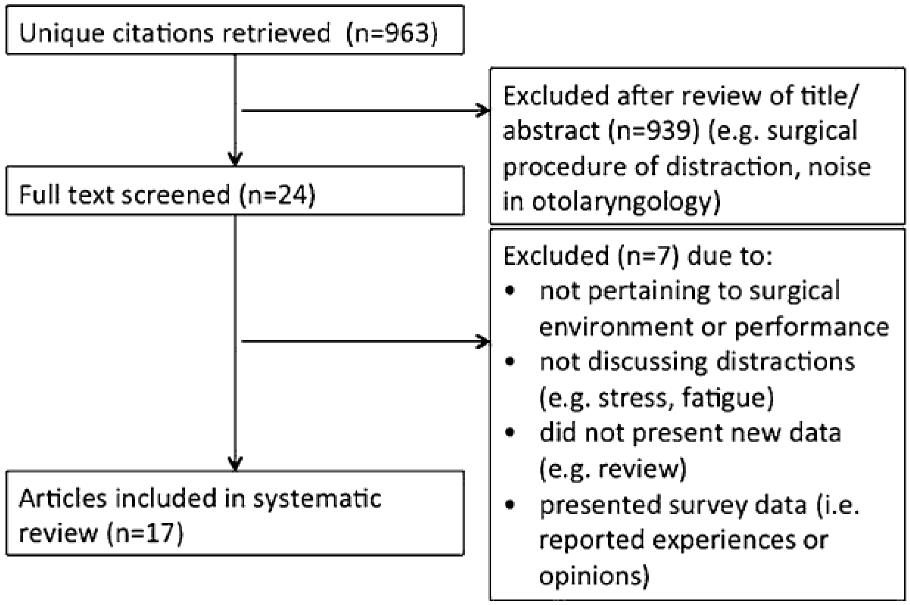

Figure 1. Flowchart of included articles selection process.

An additional search of Google Scholar was conducted to identify any further papers not already discovered through the PubMed search. No further papers were identified.

Finally, we reviewed the reference lists of selected articles to identify additional manuscripts not identified in our primary search. No further papers were identified.

Results

Reports of Distractors in the OR

There has been a wide array of distractions uncovered by observational studies of OR environments. They range from ringing telephones to case-irrelevant communication to doors' opening and closing. The disparity in categorization across the different studies covered in this review provides a challenge in determining actual frequency of each type of identified distractions. In addition, many of these studies rated the severity of the distracting event, but the scales have not been consistent. For the following, we present an aggregate view of the frequency and severity ratings of generalized categories of distractions.

Table 1 shows only the four most frequent and distracting events found in each OR observation study. In Table 2, we aggregated all distracting events found and presented the rankings of most frequent and most severe. We tabulated this by recording all of the forms of distraction and recorded the related counts (for frequency) and ratings (for severity). We then aggregated all of the forms of distraction into six categories: case-irrelevant communication, equipment issues, phone calls/pagers/bleepers, radio, movement, and procedural issues. We summed the counts and ratings in each category, normalized counts by number of cases and ratings on a 9-point scale, and then ordered the categories by most to least for frequency and highest to lowest for severity. Thus, Table 2 includes all of the forms of distraction related in the five observation studies, not only the most frequent or severe as are shown in Table 1.

We can first see that the most frequently occurring distractions included movement, case-irrelevant communication, phones/beepers/bleepers, and radio. These are generally the distractions most people are aware of, as evidenced by Lee et al.'s survey of 523 urologists, which showed that the most common perceived environmental distractors were music, pagers, and loud talking by personnel [23]. However, the severity ratings of the distraction point to equipment issues, procedural issues, case-irrelevant communications, and phones/pagers/bleepers as the most distracting. This misalignment between frequency and severity of observed distractions was pervasive across a number of the studies reviewed.

For instance, in Healey et al.'s study of 50 general surgery procedures, they showed that those disrupting events that received the highest disruption ratings were equipment problems, communication difficulties between the personnel, environment, and procedural issues [3]. Likewise, Persoon et al.'s observations of 78 endourological procedures showed the significant impact of equipment problems, case-related communication, and irrelevant communication on disrupting a surgical team member [24]. In comparison, door movement, radio, telephone, and the pager—although frequently occurring or typically considered distracting—were deemed to have a relatively minimal effect. However, this misalignment is not always the case; Healey et al.'s follow-up study of 30 urology procedures also showed conversations, and phone calls as being the most frequently occurring as well as some of the most highly rated in terms of severity of disruption [22].

It is apparent that case-irrelevant communication is both a frequent and significant distracting event. Sevdalis, et al.'s observation of 48 general surgery procedures showed that surgeons are the most frequent instigators of case-irrelevant communication (35.8 % of the time) and it is usually directed toward another surgeon (93.1 % of the time) [25]. However, these case-irrelevant communications were significantly less distracting than those introduced by an initiator external to the surgical team, such as a momentarily visiting nurse.

More recently, Sevdalis et al. [26] corroborated the apparent link between case-irrelevant communication and impact on surgical outcomes by relating them to performance of OR safety checks. In an observational study of 24 urologic procedures, external queries from OR nurses regarding other patients were both the most common and most severe communication distractor, and frequency and severity of communication-based distractions correlated negatively with the completion of patient-related safety checks during the intraoperative period (number of distractions: $r_s = -.56$, $p < .05$; average severity of distractions: $r_s = -.55$, $p < .05$).

From this review of observations of distraction events and consequences in the OR, a clear difference between frequency of distraction and consequence of that distraction is evident. Issues that occur frequently have been shown to have a minimal effect (e.g., door movement, person walking past monitor). However, this may be an artifact of learning. A surgeon faced with a frequently ringing phone, for example, may habituate to the sound and so be less inclined to pay it heed. The following section reviews studies that have attempted to ascertain the effects of these frequently occurring distractions. The following section sheds light on the relationship between distractions and errors.

Experimental Assessments of Distraction Events

Measuring Performance

Before one can begin to review the various findings of the controlled laboratory experiments, it is necessary to the different measurements used for assessing the impact on performance of surgical tasks. The noticeable lack of consistency in measures across these studies created a significant problem for summarizing and comparing results in order to provide a fundamental understanding of the effect of distraction on surgical performance (see Table 3).

The most common measure used in determining the effect of distraction on surgical performance was speed. Time to task completion or another speed-related variable was used in 11 out of 12 of the experimental studies [8, 10, 14, 27–34]. Measurement of error or accuracy was featured in 9 of the 12 experimental studies [10, 14, 27, 28, 31–35]. The former measure of performance provided a comparable unit of measurement across studies—time is a standardized construct where one can reliably measure an increase or decrease between two groups of subjects although not directly comparable as the time between different types of tasks would be variable. However, measurement of error is not as well defined. In almost all of the studies reviewed, there is no indication as to what entails an 'error' during the task. Furthermore, although Moorthy et al. [31] referred to the accuracy of suturing and quality of knots as a measure of error, in none of the studies reviewed is there an indication of how one computed the severity of the errors.

Related to time to task completion, the related measures of economy of movement [27, 28, 34], total distance traveled [8, 14, 29, 30], and number of movements [31] also were prevalent measures used in assessing the effect of distraction on performance. An increase in any of these measures would invariably amount to an increase in time to completion. However, an increase in time to completion does not necessitate an increase in one of those three measures.

In the following sections, we present trends and individual study findings, but due to the lack of consistency between performance measures, missing experimental or results data, or variance in experimental design, aggregated findings (i.e., a meta-analysis) could not be performed.

Outcomes of Distractions on Performance

When one considers the variety of findings on the effects of distraction on surgical performance, the between-study variation in experimental design is striking. Being able to relate the outcomes and findings of these different studies to type of distraction, surgical task, and subject experience allows for a better understanding of the effects of various distractions on surgical performance.

Effect of Different Types of Distractions

From the experiments reviewed, it is possible to classify distractions through two categorization mechanisms: process needed for attention and timing of distraction.

First, one can categorize a distractor by the perceptual process (i.e., visual, auditory, olfactory) or cognitive process (i.e., perceptual, memory, decision-making) needed for attention (Table 3). Just as the field studies had shown auditory distractions to be much more prevalent and impactful than visual distractions, in experimental studies, the introduction of auditory distractors have been much more common, appearing in 9 of the present studies [8, 27–

33, 35]. For instance, Feuerbacher et al. [35] introduced sounds such as noise from a dropped metal tray, while Moorthy et al. [31], Siu et al. [29], and Suh et al. [8] introduced prerecorded OR noise (at 80–85 dB in the first two studies and 50–90 dB in the latter two studies).

The experimental studies showed auditory distractions to have a significant impact corroborating the observational studies' findings that auditory distractions were quite distracting and associated with errors. Four studies showed the negative impact on error rates or accuracy [27, 28, 33, 35].

Four studies showed the negative impact on speed or time to task completion [27, 29, 32, 33]. Finally, two studies showed the negative impact on economy of motion [27, 29]. However, two studies also showed no impact at all from auditory distractions [8, 31]. In addition, three studies showed that the type of auditory distraction does make a difference in performance. For instance, Siu et al. [30] showed that time to task completion ($p = .001$) and economy of motion ($p = .038$) were enhanced by Jamaican music compared to no music, and Conrad et al. [32] showed that classical music improved time to task completion and accuracy (not significant, data presented as trends). Thus, not all auditory distractions are alike, and some, such as certain types of music, are associated with enhanced surgical performance outcomes.

Visual stimuli have also been introduced in the form of unexpected movement within the subjects' field of view, but to a far lesser extent across the studies [27, 28, 35]. In addition, the outcomes of these studies have indicated that visual distractions do not pose a significant impact on surgical performance. For instance, Szafranski et al. [27] and Feuerbacher et al. [35] have shown visual distractions imposing no impact on error rates, time to task completion, and economy of motion. The only study that has shown an impact on error rates compared to no distraction is Pluyter et al. [28] ($z = -2.255$; $p = .02$), but the visual distractions were paired with auditory distractions, so it is unclear whether the performance degradation was simply due to the auditory distractions. Thus, OR environment movement and motion have not been well-demonstrated as a significant concern for surgical performance.

Still other studies have taken to introducing other forms of distraction that may not be realistic to an OR environment but are convenient for presenting controlled or novel distracting elements [8, 10, 14, 32–34]. For instance, Goodell et al. [34] had participants solve medium difficulty level arithmetic problems throughout the primary task. These mental distractions are meant to be a surrogate for secondary cognitive tasks in the OR, such as teaching or answering a question about another patient. The findings from these studies have been mixed, although overall they have indicated a more negative impact on performance than visual distractors. For instance, three studies have shown an increase in time to task completion [8, 32, 34], two studies have shown a reduction in overall speed [8, 33], two studies have shown a reduction in accuracy [32, 33], and one study has shown a reduction in economy of motion [14]. However, one study has shown no effect on speed and errors due to mental distractions for experts and novices [10], and another study found no impact on time to task completion or errors for experts or novices [14].

The second categorization mechanism to consider is whether the distraction was intermittent, such as a telephone call, or continuous, such as music or a regular machine bleep (Table 3). Although most observations have primarily found intermittent distractions, in laboratory experiments, continuous distractions have been used in 11 out of 12 of the studies reviewed [8, 10, 14, 27–34]. The findings have been mixed, with two studies reporting no effects [10, 31]. Of those that did report effects, five reported a negative impact on speed [8, 29, 32–34], three reported a negative effect on error rates and accuracy [28, 32, 33], and two reported a negative effect on economy of motion [28, 32, 33].

One of the experimental studies that specifically investigated intermittent distractions involved the investigators performing 9 months of OR observations prior to the study, grounding their work with realistic OR experiences [35]. They found that 8 of 18 participants committed a total of 10 surgical errors with intermittent auditory distractions compared to only one participant committing an error in the non-distracted condition ($p = .02$); however, intermittent visual led to no errors. The other study that investigated intermittent distractions, Szafranski et al. [27], had intermittent auditory, visual, and vibratory distraction punctuating a continuous auditory distraction and found intermittent auditory to lead to a statistically significant increase in errors compared to a no-noise environment ($p < .05$), while intermittent visual or vibratory had no significant effect.

Effect of Distractions on Surgical Task Performance

The surgical tasks that the participants were asked to perform in the experimental studies were varied in their difficulty level (see Table 3). One study attempted to replicate actual surgical practice by having experienced residents perform a simulated laparoscopic cholecystectomy with intermittent visual and auditory distractions [35]. This study led to the finding of ten ‘major surgical errors’ due to the distractions committed by 8 out of the 18 participants. This study, along with studies that had participants who perform complex manipulation tasks, such as suturing and mesh alignment, indicated that task difficulty may have an interaction effect with distraction on surgical performance [8, 29, 35]. In particular, Siu et al. showed that there was a greater difference in time to task completion and distance traveled by the tools with an increase in task difficulty (bimanual carrying\suture tying\mesh alignment) with a continuous auditory distractor [29] (increased by 14 % with task difficulty increasing, $p = .035$). However, this finding is in contrast to that of Goodell et al., who showed that there was no difference in performance between their tasks of varying difficulties with continuous mental distractions (acquire-place, withdraw-insert, diathermy, manipulate-diathermy, stitch start, half square knot) [34]. Although it seems that performance on tasks of low difficulty will not be affected by distractions, unfortunately, there is no common set of tasks between these studies, making it difficult to further determine the importance of task difficulty on the effect of distraction.

Effect of Distractions on Experience Level

Although the training of inexperienced surgical residents is a topic of particular interest, the studies reviewed here addressed the impact of distraction on both inexperienced and experienced subjects (see Table 3). Nine of the twelve experimental studies involved medical students and/or surgical residents that were in their first 3 years of residency [8, 10, 14, 27–30, 33–35]. These two populations of subjects had no prior experience with the surgical tools used in the studies. Typically, for this study population, speed or time to task completion was the factor most significantly negatively affected by the distractions (5 out of 9 studies) [8, 27, 29, 33, 34]. Of the six studies that investigated issues of goodness of task performance (i.e., number of errors or accuracy), four studies found increases in the number of errors or accuracy committed by inexperienced residents [27, 28, 33, 35]. Finally, economy of motion was found to be negatively affected by distraction in two studies of inexperienced subjects [14, 27].

In contrast, five of the twelve studies included fourth-/fifth-year surgical residents or fellows/attending surgeons—a population that has had relatively more experience with surgical tools, as well as exposure to actual surgical environments [8, 10, 14, 31, 32]. Findings from three of these studies showed no performance impact from auditory or mental distractions [10, 14, 31]. The other two studies showed a minimal negative impact [8, 32]. One of the negative impact studies, Suh et al. [8], showed an increase in time to task completion with an associated decrease in speed from mental (math: $p = .008$, decisionmaking: $p = .015$, memory: $p = .03$), but not auditory, distractions; however, the study team did not investigate the impact on number of errors committed. Another, Conrad et al. [32], found time to task completion increases with dichotic music (6/8 participants) or mental loading (4/8 participants) and accuracy decreased with mental loading as well (6/8 participants).

In sum, although there is no definitive answer as to the effect of distractions on varying levels of experience, the experimental studies reviewed in this paper indicate that inexperienced subjects have difficulty in attending to their primary task when distracted. In order to compensate, they slow down their actions, leading to a longer time to task completion. With experience in the task of manipulating laparoscopic tools, residents and attending surgeons typically do not slow their speed; however, they do make more errors in an environment full of distractions.

Discussion

The motivation for conducting a systematic review of studies of distraction and performance effects on the surgeon is to guide OR policy for properly mitigating distractions as well as spur a discussion on the need to train surgical residents on distraction handling skills that transfer to an actual OR environment filled with distractions. From this systematic review, one can gain an understanding of the types of distractions faced by surgeons and how distractions affect surgical performance.

Focusing OR Policies on Significant Distractions

According to the observational studies reviewed, intermittent distractions are much more common than continuous distractions and, more importantly, are more distracting than continuous distractions. Thus, ORs could benefit from filtering out intermittent distractions, such as phones ringing and objects moving past the field of view over a policy that prevents continuous distractions such as music or case-irrelevant communication in the background. Unfortunately, the majority of controlled laboratory studies have not investigated the occurrence of intermittent distractions. This is an area of investigation that is ripe for further work.

However, the observational studies also showed that those distractions with high frequency typically are not the ones that lead to errors. The misalignment between frequency of distracting events and severity of distracting events points to the need to focus OR policy on reducing those distracting events that are severe (such as case-irrelevant communication) as opposed to those that are frequent but not severe (such as beepers). In addition, there should be an emphasis on addressing distractions that require more attention (e.g., case-irrelevant communications) or those distractions that do not occur as frequently but are significantly distracting when they do (e.g., equipment and procedural issues).

Measuring gained automaticity in distraction training

In training for distractions, the goal is to instill a level of automaticity where task performance is not significantly affected by distractions. The controlled laboratory experiments reviewed in this paper showed that inexperienced subjects such as medical students and first- and second-year residents reduce their speed on a primary task when faced with distractions. This indicates that their ability to focus on the main task at hand is compromised by the distraction and they slow their actions in order to prevent errors. It is also evident from the laboratory experiments that experienced subjects such as attending surgeons did not significantly slow down their movements in order to compensate for the distracting events; those with experience have gained automaticity that provided for greater spare cognitive capacity. In addition, the controlled laboratory experiments also showed that, although speed did not decrease, experienced subjects' error rates did have a propensity to increase due to the introduction of a distraction. Thus, in the course of gaining automaticity in the performance of surgical tasks, inexperienced learners can be expected to maintain speed while also presenting no increase in errors in reaction to a presented distraction. Learners could be tested on their automaticity of a task by comparing their performance on the task with 'no distractions' to their performance on the same task 'with distractions.'

Further research should address if a subject should be trained on a task with distractions at the same time, or if the introduction of distractions should merely be a mechanism for assessing the gain of automaticity. For instance, by training on a simulator, a surgery resident could experience distractions in the simulation at the same time that they are practicing the task. At the end of their training time, the learner would perform the task under a 'no distraction' and a 'distraction' conditions, and performance would then be compared between the two. From the literature, it is unclear whether a learner who trained under distraction conditions would always do better on the final test of automaticity than a learner who trained under a 'no distractions' condition. There is some indication, though, that training with distractions may have some performance benefits. One of the studies reviewed also examined how first-year residents performed with distractions after training either in distractive or non-distractive conditions; those who trained in the distractive conditions outperformed their counterparts in the distraction-filled test [27]. These results suggest that a good first step would be to further investigate the learning gains that may result from distraction filled training sessions.

While technical training exercises such as the ones described in this review are important, so is the development of nontechnical skills such as effective communication and decision-making. The ability to manage a high cognitive load and prioritize stimuli is crucial; negative coping strategies are associated with poor technical performance. Novice surgeons would benefit from training on how to recognize and minimize stressors and distractions, which would provide a set of knowledge and skills not necessarily learned by the mere accumulation of hours in the OR [36]. While current training for surgery residents includes simulations designed to increase proficiency in medical handling of cases, there is currently little to no training that addresses the need to maintain a mental balance between the current physical task, distractions affecting multiple senses at once, and ongoing sources of stress.

Conclusion

The conclusion from this systematic review is that OR protocols should ensure that distractions from intermittent auditory and mental distractions are significantly reduced. In addition, surgical residents would benefit from training for intermittent auditory and mental distractions in order to develop automaticity and high skill performance during distractions, particularly during more difficult surgical tasks. Automaticity for distraction mitigation can be achieved by residents being (1) presented with intermittent distractions during training sessions until automaticity of the primary task is achieved or (2) trained solely on surgical manipulation tasks to a level of automaticity that is subsequently tested through the presentation of intermittent distractions. In both cases, the intention is to ensure residents attain a level of cognitive self-management and task automaticity that can be transferred to the OR in order to mitigate the effects of the most significant OR distractions.

Acknowledgements

Design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication was supported by grants from the National Institute of Medicine (NIH NIBIB 2R01 EB005807-05A1, 1R01 EB010037-01, 1R01 EB009362-01A2, 1R01 EB014305-01A1).

Disclosures

Helena Mentis, PhD, Amine Chellali, PhD, Caroline G.L. Cao, PhD, Kelly Manser, BA, and Steven D. Schwaitzberg, MD have no financial support from any private institution, and the authors have no financial relationships with any pharmaceutical or device companies.

References

1. Hodge B, Thompson JF (1990) Noise pollution in the operating theatre. Lancet 335:891–94
2. Shapiro RA, Berland T (1972) Noise in the operating room. N Engl J Med 287:1236–38
3. Healey AN, Sevdalis N, Vincent CA (2006) Measuring intra-operative interference from distraction and interruption observed in the operating theatre. Ergonomics 49:589–604
4. McDonald J, Orlick T, Letts M (1995) Mental readiness in surgeons and its links to performance excellence in surgery. J Pediat Orthop 15:691–97
5. Sarker SK, Vincent C (2005) Errors in surgery. Int J Surg 3:75–81
6. Zheng B, Martinec DV, Cassera MA, Swanström LL (2008)A quantitative study of disruption in the operating room during laparoscopic antireflux surgery. Surg Endosc 22:2171-77
7. Wiegmann DA, Eggman AA, ElBardissi AW, Henrickson SE, Sundt TM (2010) Improving cardiac surgical care: a work systems approach. Appl Ergon 41:701-12
8. Suh IH, Chien J-H, Mukherjee M, Park S-H, Oleynikov D, Siu K-C (2010) The negative effect of distraction on performance of robot-assisted surgical skills in medical students and residents. Int J Med Robotics Comput Assist Surg 6:377–81

9. Rose DJ, Christina RW (2005) A Multilevel Approach to the Study of Motor Control and Learning. 2nd ed. Benjamin Cummings, Redwood City, CA
10. Hsu KE, Man F-Y, Gizicki RA, Feldman LS, Fried GM (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
11. Van Selst MV, Ruthruff E, Johnston JC (1999) Can practice eliminate the psychological refractory period effect? J Exp Psychol 25:1268–83
12. Pashler H, Johnston JC, Ruthruff E (2001) Attention and performance. Annu Rev Psychol 52:629–651
13. Welford AT (1967) Single-channel operation in the brain. Acta Psychol 27:5-22
14. Park J, Waqar S, Kersey T, Modi N, Ong C, Sleep T (2011) Effect of distraction on simulated anterior segment surgical performance. J Cataract Refract Surg 37:1517-22
15. Schneider W, Shriffin, RM (1977) Controlled and automatic human information processing: I. Detection, search, and attention. Psychol Rev 84:1-66
16. Feanny MA, Scott BG, Mattox KL, Hirshberg A (2005) The impact of the 80-hour work week on resident emergency operative experience. Am J Surg 190: 947-49
17. Derossis AM, Bothwell J, Sigman HH, Fried GM (1998) The effect of practice on performance in a laparoscopic simulator. Surg Endosc 12:1117–20
18. Feldman LS, Hagarty SE, Ghitulescu G, Stanbridge D, Fried GM (2004) Relationship between technical skills and subjective intraining evaluations in surgical residents. J Am Coll Surg 198:105–10
19. Peters JH, Fried GM, Swanstrom LL, Soper NJ, Sillin LF, Schirmer B, Hoffman K (2004) Development and validation of a comprehensive program of simulation in laparoscopy. Surg 135:21–27
20. Fried GM, Feldman LS, Vassiliou MC, Fraser SA, Stanbridge D, Ghitulescu G, Andrew CG (2004) Proving the value of simulation in laparoscopic surgery. Ann Surg 240:518–28
21. Wiegmann DA, ElBardissi AW, Dearani JA, Sundt TM (2006) An empirical investigation of surgical flow disruptions and their relationship to surgical errors. Paper presented at the Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting, Hilton San Francisco Hotel, 16-20 October 2006
22. Healey AN, Primus CP, Koutantji M (2007) Quantifying distraction and interruption in urological surgery. Qual Saf Health Care 16:135-39
23. Lee JY, Lantz AG, McDougall EM, Landman J, Gettman M, Sweet R, et al (2013) Evaluation of Potential Distractors in the Urology Operating Room. J Endourol 27:1161-1165
24. Persoon M, Broos HJHP, Witjes JA, Hendrikx AJM, Sherpbier AJJM (2011) The effect of distractions in the operating room during endourological procedures._Surg Endosc 25:437-43
25. Sevdalis N, Healey AN, Vincent CA (2007) Distracting communications in the operating theatre. J Eval Clin Prac 13:390-4
26. Sevdalis N, Undre S, McDermott J, Giddie J, Diner L, Smith G (2014) Impact of intraoperative distractions on patient safety: a prospective descriptive study using validated instruments. World J Surg 38(4):751-758.

27. Szafranski C, Kahol K, Ghaemmaghami V, Smith M, Ferrara JJ (2009) Distractions and surgical proficiency: an educational perspective. Am J Surg 198:804-10
28. Pluyter JR, Buzink SN, Rutkowski A-F, Jakimowicz JJ (2010) Do absorption and realistic distraction influence performance of component task surgical procedure? Surg Endosc 24:902-07
29. Siu K-C, Suh, IH, Mukherjee M, Oleynikov D, Stergiou N (2010a) The impact of environmental noise on robot-assisted laparoscopic surgical performance. Surgery 2010a; 147:107-13
30. Siu K-C, Suh I, Mukherjee M, Oleynikov D, Stergiou N (2010b) The effect of music on robot-assisted laparoscopic surgical performance. Surg Innov 2010b; 17:306-11
31. Moorthy K, Munz Y, Undre S, Darzi A (2004) Objective evaluation of the effect of noise on the performance of a complex laparoscopic task. Surgery 136:25-30
32. Conrad C, Konuk Y, Werner P, Cao CG, Warshaw A, Rattner D, Jones DB, Gee D (2010) The effect of defined auditory conditions versus mental loading on the laparoscopic motor skill performance of experts. Surg Endosc 24:1347-52
33. Conrad C, Konuk Y, Werner PD, Cao CG, Warshaw AL, Rattner DW, et a (2012) A quality improvement study on avoidable stressors and countermeasures affecting surgical motor performance and learning. Ann Surg 255: 1190-94
34. Goodell KH, Cao CGL, Schwaitzberg SD (2006) Effects of cognitive distraction on performance of laparoscopic surgical tasks. J Lap & Adv Surg Tech 15:94-98
35. Feuerbacher RL, Funk KH, Spight DH, Diggs BS, Hunter JG (2012) Realistic distractions and interruptions that impair simulated surgical performance by novice surgeons. Arch Surg 147:1026-30
36. Wong SW, Smith R, Crowe P (2010) Optimizing the operating theatre environment. ANZ J Surg 80:917-24

Tables

Table 1: Observation studies of distractor frequency and severity in the OR.

Study	*Top 4 Most Frequent*	*Top 4 Most Distracting*
Healey (2006)	Movement around monitor Case-irrelevant communication Bleeper Procedural	Case-irrelevant communication Equipment Environment Procedural
Healey (2007)	Case-irrelevant conversations Environment Phone calls Equipment	Equipment Procedure Conversation Movement around monitor
Persoon (2011)	Door movement Case-irrelevant communication Radio Equipment	Case-related communication Equipment problems Procedure problems Pager
Sevdalis (2007)	Case-irrelevant communication Teaching Equipment Phone calls/bleeps	Equipment/provisions Patient-related communications Irrelevant comments/queries Teaching
Sevdalis (2014)	Equipment Case-irrelevant communication Phone calls/Bleeps Ergonomic	Coordination with other Dept. Teaching Equipment/provisions Team members' error

Table 2 Categories of distractors from observation studies in the OR: Rankings of frequency and severity

Distraction Category	*Number of Studies*	*Frequency Ranking*	*Mean Events per Procedure*	*Severity Ranking*	*Mean Severity Rating*
Movement (monitor or door)	3	1	4.93	6	2.26
Case-irrelevant communication	5	2	3.43	3	5.01
Phone calls/ pagers/bleepers	5	3	1.91	4	3.33
Radio	2	4	1.36	5	2.57
Procedure	3	5	1.29	2	5.80
Equipment	5	6	1.29	1	6.98

Table 3 Laboratory studies' experimental design and outcomes.

Study	*Distractions*		*Subjects*	*Task*	*Standard Measurements Used*	*Outcomes on Surgical Performance*		
	Timing	*Process*				*Time to Task Completion / Speed*	*Economy of Motion*	*Errors / Accuracy*
Feuerbacher (2012)	Intermittent	Visual or Auditory	Eighteen (18) inexperienced residents	Simulated laparoscopic cholecystectomy	Frequency of errors.	NA	NA	More participants made errors with auditory distractions (p=.02). Errors committed by both inexperienced and experienced residents. No effect from visual.
Szafranski (2009)	Intermittent over a Continuous	Visual, Auditory & Vibrate	Seven (7) inexperienced residents	Sensable Technologies VR ring transfer task	Economy of Movement (gesture level proficiency, hand movement smoothness, tool movement smoothness), Time elapsed, Cognitive errors.	Increased time by 125% under auditory distractions (p<.05). No effect from visual or vibration distractions.	Decreased proficiency (31%), hand movement (33%), and tool movement (26%) under auditory distractions (p<.05). No effect from visual or vibration distractions.	Increased errors by 97% under auditory distractions (p<.05). No effect from visual or vibration distractions.
Pluyter (2010)	Continuous	Visual & Auditory	Twelve (12) inexperienced residents	Clip & Cut module of Xitact LC 3.0 virtual reality simulator	Time to task completion, Task errors, Economy of movement.	No effect.	No effect.	Errors increased (mean 7.08 to 35.83) (z=-2162; p=.03).

Study	*Distractions*		*Subjects*	*Task*	*Standard Measurements Used*	*Outcomes on Surgical Performance*		
	Timing	*Process*				*Time to Task Completion / Speed*	*Economy of Motion*	*Errors / Accuracy*
Siu (2010a)	Continuous	Auditory	Twelve (12) inexperienced med students	Mesh alignments, suture tying, bimanual carrying (in order of decreasing difficulty).	Time to task completion, Total distance travelled.	Completion time increased by 23% (p=.046). Greater difference with increasing task difficulty (inc by 37%, p=.012).	Distance travelled increased by 8% (p=.011). Greater difference with increasing task difficulty (inc. by 14% p=.035).	NA
Siu (2010b)	Continuous	Auditory	Ten (10) inexperienced med students	Two dVSS tasks: mesh alignment and suture tying (in order of decreasing difficulty).	Time to task completion, Total distance travelled.	Faster with hip-hop (p=.036) and Jamaican music (p=.001) than no music for both tasks.	Shortest distance with Jamaican music than hip-hop or no music (p=.038) for both tasks.	NA
Moorthy (2004)	Continuous	Auditory	Twelve (12) experienced attending surgeons	Suture placement	Performance (number of movements, path traveled by hand, speed of hand movements); Expert rating (nonpurposeful movement, accuracy of suturing, quality of knots).	No difference	No difference	No difference

Study	*Distractions*		*Subjects*	*Task*	*Standard Measurements Used*	*Outcomes on Surgical Performance*		
	Timing	*Process*				*Time to Task Completion / Speed*	*Economy of Motion*	*Errors / Accuracy*
Suh (2010)	Continuous	Mental or Auditory	Ten (10) inexperienced med students & four (4) experienced residents and fellows	Suture-tying task	Time to task completion, Total distance traveled, Average speed.	Time to task completion increased from mental (math: p=.006, decision-making: p=.039, memory:p=.03). Speed decreased from mental (math: p=.008, decision-making: p=.015, memory: p=.03). No difference for auditory distractions. No difference between experience levels.	No differences.	NA
Conrad (2010)	Continuous	Mental or Auditory	Eight (8) experienced attending surgeons	Three (3) SurgicalSIM VR, laparoscopic simulator, tasks (not specified)	Time to task completion, Task accuracy.	Time to task completion increased with dichotic music (6/8 participants) or mental loading (4/8 part.), but decreased with classical music (7/8 part.). *No inferential statistics presented.	NA	Accuracy increased with dichotic music (6/8 participants) or classical music (7/8 part.) but decreased with mental loading (6/8 part.). *No inferential statistics presented.

Study	*Distractions*		*Subjects*	*Task*	*Standard Measurements Used*	*Outcomes on Surgical Performance*		
	Timing	*Process*				*Time to Task Completion / Speed*	*Economy of Motion*	*Errors / Accuracy*
Conrad (2012)	Continuous	Mental or Auditory	Thirty-one (31) inexperienced surgeons	4 Surgical SIM VR tasks (lifting a structure and cutting below it; object targeting; feeding a rope; object alignment)	Time to task completion, Accuracy.	Speed decreased due to mental distractions (118% worse than silence, $p<.001$) and dichotic music (115% worse, $p<.001$). Classical music was not significantly different from silence.	NA	Accuracy decreased due to dichotic music (64% less accurate than silence, $p<.05$) and mental distractions (126% less, $p<.001$). Classical music was not significantly different from silence.
Hsu (2008)	Continuous	Mental	Thirty-one (31) inexperienced med students & residents, & nine (9) experienced fellows & attending surgeons	FLS peg transfer task	Simulation score (Speed, Errors).	No difference for inexperienced or experienced groups.	NA	No difference for inexperienced or experienced groups.
Goodell (2006)	Continuous	Mental	Thirteen (13) inexperienced med students & residents	MIST-VR tasks: acquire-place, withdraw-insert, diathermy, manipulate-diathermy, stitch start, half square knot	Time to task completion, Number of errors, Economy of motion.	Time to task completion increased for all six tasks (average of 35% increase, $p<.05$). Task type did not have an effect.	No difference	No difference.

Study	*Distractions*		*Subjects*	*Task*	*Standard Measurements Used*	*Outcomes on Surgical Performance*		
	Timing	*Process*				*Time to Task Completion / Speed*	*Economy of Motion*	*Errors / Accuracy*
Park (2011)	Continuous	Mental	Fourteen (14) inexperienced ophthalmic surgeons & seven (7) experienced ophthalmic surgeons	Intraocular object removal task	Total time, Errors (lens injury, corneal injury, operating without red reflex score), Economy of motion (odometer score).	No difference for experts or novices.	Decrease in odometer score (increase in distance travelled) by novices ($p=.028$). No difference for experts.	No difference for experts or novices.