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AVOIDING SURGICAL SKILL DECAY: A SYSTEMATIC REVIEW ON THE SPACING OF TRAINING SESSIONS

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ABSTRACT

Objective

Spreading training sessions over time instead of training in just one session leads to an improvement of long-term retention for factual knowledge. However, it is not clear whether this would also apply to surgical skills. Thus, we performed a systematic review to find out whether spacing training sessions would also improve long-term retention of surgical skills.

Design

We searched the Medline, PsycINFO, Embase, Eric and Web of Science online databases. We only included articles that were randomized trials with a sample of medical trainees acquiring surgical motor skills in which the spacing effect was reported. The quality and bias of the articles were assessed using the Cochrane Collaboration's risk of bias assessment tool.

Results

With respect to the spacing effect, 1955 articles were retrieved. After removing duplicates and articles that did not meet the inclusion criteria, 11 articles remained. The overall quality of the experiments was "moderate". Trainees in the spaced condition scored higher in a retention test than students in the massed condition.

Conclusions

Our systematic review showed evidence that spacing training sessions improves long-term surgical skills retention when compared to massed practice. However, the optimal gap between the re-study sessions is unclear.

INTRODUCTION

Traditionally, surgical skills have mostly been taught through mentoring and apprenticeship. Recently, McGaghie (2015) stated that the underlying assumption of apprenticeship-based clinical training is that students gain competence over time simply by exposing them to patients and experience.[1] He argued that it lacks structured learning objectives, skill practice and objective assessment with feedback. In the past decades, medical skills training has been shifting towards simulation-based mastery training,[2,3] and currently it is appreciated that deliberate practice in a simulation lab is a valuable add-on to learning surgical skills.[4] This type of training lays emphasis on achieving defined learning objectives and offers students an opportunity to practice skills without time restrictions.[5] It can be tailored to individual student's needs concerning skills, knowledge, attitudes and the decision-making process, which, in turn, allows students to learn at their own pace in a safer, more ethical environment.

Surgical skills training requires a large amount of instructor time, effort and resources. Furthermore, an acquired surgical skill will decay over time after periods of non-use, which could potentially be a threat to patient safety. Most skills training sessions focus on student learning rather than long-term retention.[1] Research revealed that some students had not been able to proficiently perform the required skill one,[6] six,[7,8] or twelve months[7] after they had finished their training. These findings imply that practicing until proficiency may not be enough to guarantee long-term retention. Thus, improving long-term retention of surgical skills becomes crucial to safeguard patient care. Based on cognitive psychology, several guidelines for medical skills training suggest the spacing effect as a way to avoid skills decay.

The spacing effect refers to spacing training sessions over time rather than training in just one session (massed learning).[9] A comprehensive review that investigated several learning techniques showed that the spacing effect was the most effective strategy for students' learning when compared to other techniques.[10] Spaced training has been shown to improve long-term knowledge and skills retention, for instance in tasks concerning verbal recall,[11] English as a second language,[12] computerized spelling,[13] reading,[14] biology,[15] mathematics,[16] medical knowledge,[17] arm movements,[18] command-and-control simulation[19] and dynamic balance. [20]

The key to improve long-term retention is the time between training sessions, which is known as the inter-session interval. The space between the training sessions will determine the retention interval, which is the time between the last training session and the final test. The longer the required retention interval, the longer the inter-session intervals should be.[11] A review from the psychology literature suggested that for the best knowledge retention the inter-session interval should be about 10-15% of the retention interval.[9]

In the medical education literature, some authors recommend spacing the training sessions to increase skills retention,[21,22] but it remains unclear how often trainees should practice or what the duration of the intervals between the training sessions should be. To optimize skills training and foster retention, we performed a systematic review to answer the following research questions:

1. Is spaced practice better than massed practice for acquiring and retaining surgical skills?
2. If so, what would be the optimal inter-session interval?

To answer our research questions, we conducted a systematic review on studies on the spacing effect related to surgical skills retention. We strived to identify underlying theories as well as aspects of the spacing effect that were taken into account in the design of skills training programmes.

METHODS

We conducted a systematic review using principles of the PRISMA Guidelines[23] and guidelines provided in Medical Education.[24]

Search strategy and data sources

We searched the Medline, PsycINFO, Embase, Eric and Web of Science online databases in February 2016. No language or other limitations were imposed on the search. We first searched the terms *skills retention, skills acquisition*, and *spacing effect*. Since we noticed that the terms *distributed* and *retrieval* were often used as synonyms for *spacing* and *testing,* we included these words as key-words. The search strategy used for Medline was:

1. ((((“skill* retention” OR “skill* development” OR “skill* retrieval” OR “skill* acquisition” OR “skill* retrain*”)))) AND (distribut* OR spac* OR massed)
2. (“distributed practice”) AND skill*
3. (“spacing effect”) AND skill*

The search strategy was adapted for the other databases. Subsequently, we hand-searched the reference lists of identified articles for citations of additional relevant articles. Web of Science and Google Scholar were searched for citing articles of all included articles.

INCLUSION CRITERIA

Studies were included if they met the following criteria:

- Population: Medical trainees.
- Intervention: The intervention had to be on surgical skill acquisition.
- Comparison: Comparisons had to include at least two of the following conditions: control, massed, and spaced.

- Outcomes: Change in surgical task performance as measured by motor skill performance.
- Study design: Randomized trial.

Study selection

Two authors (D.C-F and RT) independently reviewed the titles and abstracts of the retrieved publications. Each paper was initially categorized as "maybe" or "excluded" based on the information of the titles and abstracts. If one of the reviewers had classified an article as "maybe", the full text was retrieved to verify whether the article met the inclusion criteria. In the subsequent stage, the same authors independently reviewed the full articles. All articles that matched the inclusion criteria were included in the review.

Data extraction

The first author extracted and documented information about type of task, design of the experiment, participants, groups and practice schedule, length of the retention interval, measures, spacing and main findings. The other authors verified the retrieved information.

Quality criteria

We assessed the quality and bias of the articles using the Cochrane Collaboration's risk of bias assessment tool based on the sequence generation, allocation concealment, blinding of participants and outcome assessors and outcome data.[25]

RESULTS

In total, 1955 articles were retrieved (Embase=374, Eric=320, Medline=354, PyscINFO=228, and Web of Science=679). After removing the duplicates, 1302 articles were identified. Subsequently, 1254 articles were excluded because the titles and abstracts did not meet the inclusion criteria. The main reason for excluding articles was that the investigated skills were not surgical skills (n=974). We retrieved the remaining 48 full articles for further investigation of which 39 papers were excluded. These 39 papers were excluded because the investigated skill was not surgical (n=5), there was no comparison between at least two of the three conditions (n=23), the participants were not randomly assigned to the groups (n=9) and when the full paper was not available (n=2). One more article was found through hand-searching for citing articles and another article was retrieved by NCBI alert. Finally, 11 articles were included. For an overview, see Figure 1.

Based on the Cochrane Collaboration risk of bias tool, [25] we assessed the quality of the 11 papers. The overall quality of the experiments was "moderate".[25] Risk assessment revealed that 7 studies were considered as having unclear bias and 4 studies as having low risk of bias in their methodology for selection, performance, attrition and detection.

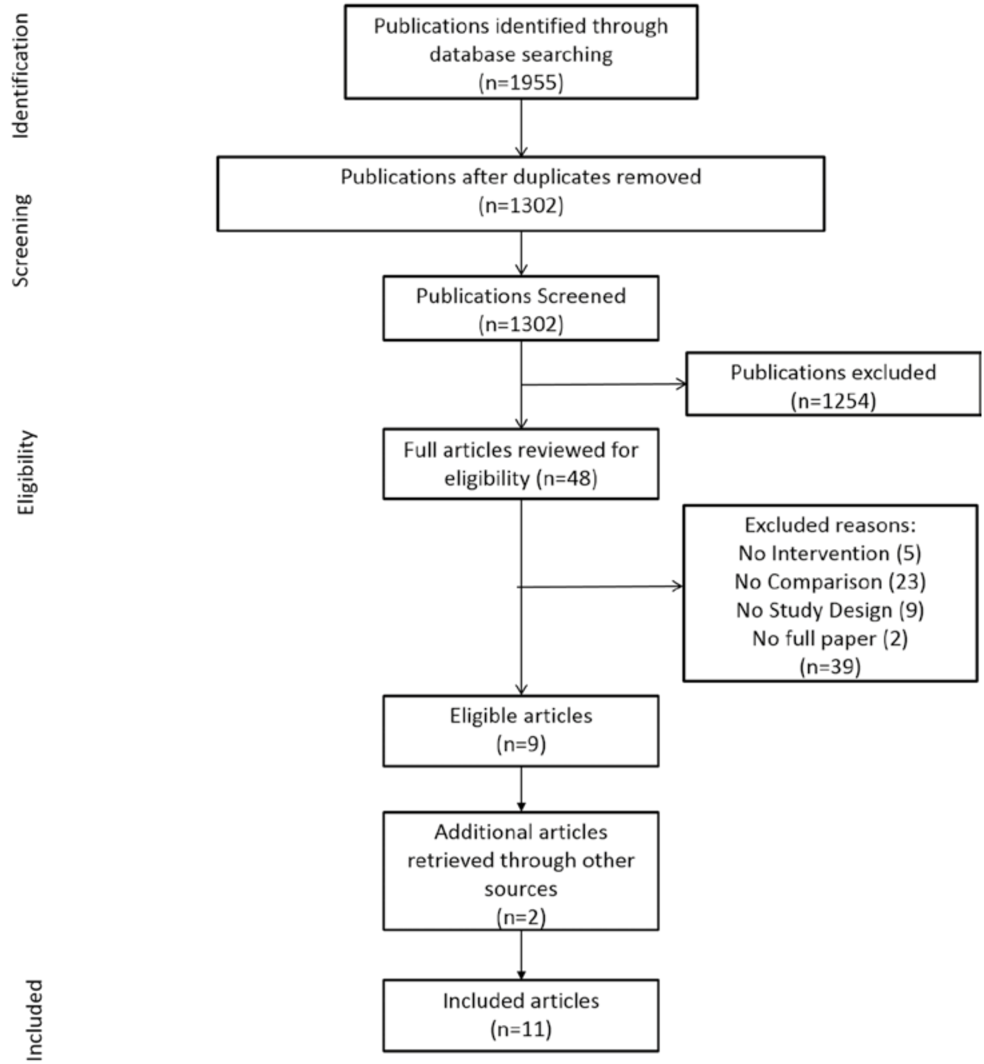

Figure 1. PRISMA flow diagram of search and selection of articles for spacing effect

The overall risk of bias across study domains is described in Table 1. It was not possible to assess the blinding of participants and instructors or selection bias. Most articles did not address either of these issues; in particular random sequence generation and allocation concealment were not clearly explained. Random sequence generation assesses whether a study used a randomized sequence of assignments. Allocation concealment assesses whether those sequences are protected and concealed from the participants, assessors and instructors.

TABLES

Table 1. Risk of bias of included studies.

Reference	Overall Bias	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessors (detection bias)	Incomplete outcome data (attrition bias)
Spruit et al. (2015)[26]	Unclear Risk	Unclear	Unclear	High risk	High risk	Low risk
Akdemir (2014)[27]	Low risk	Low Risk	Low risk	High risk	Low risk	Low risk
De Win et al. (2013)[28]	Unclear Risk	High risk	Unclear	Unclear	Unclear	Unclear
Willis et al. (2013)[29]	Unclear Risk	High risk	Unclear	Low risk	Unclear	Unclear
Van Bruwaene et al. (2013)[30]	Unclear Risk	Low risk	Unclear	Unclear	High risk	Low risk
Robinson et al. (2012)[31]	Unclear Risk	High risk	Unclear	High risk	Low risk	Unclear
Gallagher et al. (2012)[32]	Low Risk	Low risk	Low risk	Low risk	Low risk	Unclear
Mitchell et al. (2011)[33]	Low Risk	Unclear	Unclear	High risk	Low risk	Low risk
Stefanidis et al. (2006)[34]	Unclear Risk	Low risk	Unclear	Unclear	Unclear	Low risk
Moulton et al. (2006)[35]	Low Risk	Low risk	Unclear	High risk	Low risk	Low risk
Mackay et al. (2002)[36]	Unclear Risk	Unclear	Unclear	Unclear	Unclear	Unclear

Table 2 displays the following characteristics of the included studies: type of task, design of the experiment, who the participants were, which groups and practice schedules were included, length of the retention interval, measures, the effect of spacing, and also the main findings. The surgical tasks were suturing and knot-tying, a laparoscopic

Table 2. Summary of included studies.

Reference	Skill	Research Design	Participants	Groups/Practice Schedules
Spruit et al. (2015)[26]	Laparoscopic	Randomized	41 medical students	Massed: Practice in one day (n = 21) Spaced: practice once a week for three weeks (n = 20)
Akdemir (2014)[27]	Basic Laparoscopic (salpingectomy)	Randomized	22 gynecology residents	Training: After the basic training, 1 hour per week for 4 weeks Control: No training after, the basic training
De Win et al. (2013)[28]	Laparoscopic knots	Randomized	145 Medical students	All groups participated on 6 sessions training. Group 1= 3 sessions daily (n=22). Group 2 = 2 sessions daily (n=25). Group 3 = 1 session per day (n=21). Group 4 = 1 session on alternative days (n=24). Group 5 = 1 session weekly (n=26). Group 6 = 1 session weekly with “deliberate practice” between sessions. (n=27).
Willis et al. (2013)[29]	Laparoscopic transfer task	Randomized	75 preclinical medical students	Mass practice = 3 training separated by 5 minutes breaks. Similar surgical exercise = 3 session separated by a similar task Dissimilar surgical exercise = 3 training separated by simple running suturing. Observation = 3 session separated by watching for 10 minutes an expert performing the task. Rest = 3 session separated by watching 15 minutes of unrelated video.

transfer task, end-to-side vascular anastomosis, laparoscopic suturing and microvascular anastomosis. The complexity and difficulty of the tasks differed. All tasks had an emphasis on motor skills. The goal of all articles was to improve learning and retention of the motor skill of the task.

Retention Interval	Measures	+-0	Main Findings
2 weeks and 1 year	Completion time and accuracy	+	At the end of training, spaced group performed better than the massed group in almost all measurements. After two weeks and one year training, spaced group performed better than the massed group in fewer measurements.
5 weeks	Time, economy of movement scores, and error scores.	+	At the final test, the training group performed better than the control group in time and economy of movement.
1 and 6 months.	The cumulative time to approximate the skin edges adequately was used as measurement. 3 validated video-trainer tasks—Southwestern Drills—checkerboard, bean drop, and running string.	+	For 1 month the one training per day seems most beneficial and for long-term distributed shorter session is better than massed practice. Daily and weekly training are comparable and deliberative practice reduces skill decay.
Mass, Similar and Dissimilar = after the non-target task Observation = after 5 minutes Rest = after 15 minutes	Pre and Posttests consisted in 1 peg transfer trial.	+	Participants in mass practice group performed worse than the other groups.

Table 2. (continued)

Reference	Skill	Research Design	Participants	Groups/Practice Schedules
Van Bruwaene et al. (2013)[30]	Suturing on a box trainer and on a cadaver porcine Nissen model.	Randomized controlled	39 medical students	Group 1: without additional training (n=9) Group 2: one supervised training session (150 min) after 2.5 months (n=10). Group 3: five monthly unsupervised training sessions of 30 min on a box trainer (n=10). Group 4: five monthly unsupervised training sessions of 30 min on LapMentor (n=10).
Robinson et al. (2012)[31]	End-to-side vascular anastomosis	Randomized	37 junior residents	Short course was three weeks with 1 hour teaching per week (n=18). Long was six weeks long with 1 hour teaching per week (n=19).
Gallagher et al. (2012)[32]	Laparoscopic box-trainer task	Randomized controlled	Study 1: 24 novices Study 2: 16 novices	Study 1: Massed condition completed the training of all 6 MIST VR tasks 3 times in 12 hour (n=8). Interval condition completed the 6 MIST VR tasks once per day on 3 consecutive days (n=8). Control group did not receive any training on MIST VR tasks (n=8). Study 2: Practice group: one additional practice (n=8). Non practice: no additional practice (n=8).
Mitchell et al. (2011)[33]	End-side vascular anastomosis	Randomized	24 surgical interns	Weekly group: one training per week (n=12). Monthly group one training per month (n=12).
Stefanidis et al. (2006)[34]	Laparoscopic suturing	Randomized controlled	18 medical students	Control Group: No additional training (n=9). Ongoing training group: practiced until proficiency after 1 and 3 months retention tests (n=9).
Moulton et al. (2006)[35]	Microvascular anastomosis	Stratified randomized	38 surgical residents	Massed group: practices 4 sessions in one day (n=19). Distributed group: practices the 4 sessions once a week (n=19).

Retention Interval	Measures	+-0	Main Findings
5 months	Retention testing included suturing on a box trainer and on a cadaver porcine Nissen model.	+	On the box trainer, groups 2 and 3 were significantly better than groups 1 and 4. No difference was found on the porcine Nissen.
1 and 16 weeks	Knowledge and technical proficiency were measured with a standard 50-point vascular skills assessment (SVSA).	0	There was no statistical difference between both groups after 1 or 16 weeks.
Study 1: Assessment every day after laparoscopic cutting task Study 2: 1 and 2 weeks after the last training	Study 1: The cutting task performance was judged as correct or incorrect. Study 2: The same as the first study.	+ +	Study 1: The practice condition group was significant better than Massed and Control groups. Study 2: Practice group performed better than no practice group in T3.
4 months	Validated procedural checklist scores and global rating scores. Final product analysis and overall performance.	0	There was no statistical difference between groups.
1, 3 and 6 months	The students performed three repetitions of laparoscopic suturing at 2 weeks, 1, 3, and 6 months	+	The ongoing training group showed better skill retention after six months than the control group.
1 month	Expert-Based Evaluations of Performance Computer-Based Measures Clinically Relevant	+	The distributed group performed significantly better than the massed group in most of the outcomes on the retention test.

Table 2. (continued)

Reference	Skill	Research Design	Participants	Groups/Practice Schedules
Mackay et al. (2002)[36]	Laparoscopic transfer place	Randomized controlled	41 undergraduate or postgraduate students	Group A: 20 minutes training without interval (n=14). Group B: 5 blocks of 4 minutes with 2 1\2 minutes interval (n=14). Group C: 5 blocks of 3 minutes with 2 1\2 minutes interval (n=13).

Is spaced practice better than massed practice for surgical tasks?

In five studies massed practice was compared to spaced practice.[26,28,32,35,36] The inter-session interval ranged from five minutes to one week. The retention interval ranged from five minutes to one year (for details see: Table 2). In all of these studies spaced practice outperformed massed practice at the final measurement.

What is the optimal inter-session interval?

Different inter-session intervals were compared in six studies.[28,29,30,31,33,36] The length of the intervals ranged from five minutes to one month. The lengths of the inter-session interval that were compared differed per study: weekly versus daily, one additional training versus the same amount of time spread over five sessions, one hour per week training for three weeks versus six weeks, weekly versus monthly.

The retention interval of the included studies ranged from five minutes to seven months. In none of the studies a significant effect on retention was found between the lengths of inter-session intervals, except in De Win, *et al.* (2013)[28] who did find differences in retention between various inter-session intervals: six months after the last training session, the group with one session per day outperformed the other groups (for details see: Table 2).

Underlying theory and implementation of the spacing effect

Although all 11 studies addressed the spacing effect, in only two of them[26,27] the term "spacing effect" was mentioned. In two of the studies no theory related to the spacing effect or distributed practice was explicitly mentioned.[31,34] The seven remaining studies referred to the term "distributed practice",[28,29,30,32,33,35,36] but only in three of them a definition was provided.[29,32,36] Nine studies[26,27,28,29,30,31,33,35,36] were based on previous studies stating that distributed practice improves long-term retention compared to massed practice. Furthermore, several explanations for using distributed practice were given. Two studies referred to psychological theory[26,29] and three other constructs were cited: (1) deliberate practice,[26,33] (2) overlearning[26,33] and (3) ongoing training.[30,34]

Retention Interval	Measures	+-0	Main Findings
5 minutes	Overall scores, time, errors, and path length economy	+	Group B performs better than group A in overall scores and time. There was no difference between Groups A and C.

The way spaced practice was implemented differed per study. However, none of the studies referred to the spacing effect in the design of the training programme. Besides, none of the training schedules was based on literature.

DISCUSSION

From the literature, we know that spacing the study sessions improves the long-term retention of factual knowledge. However, it is not clear whether surgical skills' long-term retention would benefit from spacing the training sessions. Thus, the purpose of our systematic review was to find experimental studies on the spacing effect in acquiring and retaining a surgical skill. Our results showed that students who practiced under the spaced condition scored higher on a retention test than those that practiced under the massed condition. This finding is in concordance with educational and psychological literature, which also found that the spacing effect increases long-term retention.[37] However, the optimal training schedule remained unclear.

To determine the optimal gap between the training sessions, it might be beneficial to take the complexity of the tasks into account. Previous research has shown that for simple motor tasks, the inter-session interval should be shorter whereas for complex motor tasks, the inter-session interval should be longer.[38] However, our review demonstrated that even suturing, which is considered a simple motor task in surgery, benefits from spacing the training sessions.

An interesting question is therefore why complex tasks profit more from the spacing effect. The answer may lie in the nature of the knowledge that is required for a particular task. Cognitive psychology distinguishes knowledge between declarative and procedural, where procedural knowledge refers to "knowing how", and declarative knowledge refers to "knowing what", i.e., knowledge about facts.[39] Interestingly, it is assumed that declarative knowledge will be forgotten over time if not used, whereas procedural knowledge does not show such decay.[40] This implies that tasks that rely on declarative knowledge profit from spacing because it counteracts the decay that would otherwise occur, while tasks relying on procedural knowledge only do not show decay, and hence do not profit from repeated practice sessions.

The difference between very simple and highly complex motor skills may lie in the amount of declarative and procedural knowledge that is necessary for the task: more complex tasks such as end-to-side vascular anastomosis may require more declarative knowledge than more simple tasks such as suturing, and therefore would profit more from spacing. This may also explain our somewhat unexpected finding that even suturing profited from spacing. But when we look more closely at the suturing task, we can see that also for this so-called simple motor skill declarative knowledge was required: knowledge of the anatomical structures that were sutured, knowing the preferred position of the knot, how many knots were necessary, etcetera. This may imply that dividing the components of a skill into declarative and procedural knowledge may be a way to optimize skill training,[40] since it allows us to use the best teaching strategies based on the necessary knowledge.

This study has a few limitations. First, the final number of articles obtained in the systematic review is low. Despite our comprehensive search in different databases, we only retrieved 11 articles about the spacing effect with respect to surgical skills acquisition. In our search, we only included randomized trials, forcing us to exclude studies that did address the spacing effect in other fashions. The participants included in the reviewed articles ranged from medical students to residents. Interestingly, however, in all the studies, participants in the spaced group scored higher on the retention test than those in the massed group. Because of the small number of articles and differences in methodology and measurements, it was not possible to conduct a meta-analysis. Despite these limitations, the results of our systematic review suggest that spacing the training sessions may improve long-term retention of surgical skills.

For the training of surgical residents, simulation training is nowadays common practice. Very often massed training sessions are being used for logistic reasons. Based on our findings we believe that such a training strategy may be less effective than spreading multiple sessions over time. The optimal gap between the study sessions however has yet to be established.

CONCLUSION

Our systematic review showed evidence that the spacing effect improves surgical skills retention. When setting up a skills training for novices, spacing the training sessions should be used to use simulation lab time as effectively as possible.

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