Training and Retention of Medical Skills

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ABSTRACT

Understanding the rate at which specific skills are acquired and the rate at which they decay is critical for designing training curricula, simulation-based training, certification standards, and refresher training. Retention rates of specialized medical skills are of particular interest and relevance to the military due to the nature of military deployment cycles. For example, surgical skills such as those required for performance of laparoscopic surgical procedures have been reported to decay during long military deployments as these specialized skills are not utilized within deployed settings. In an effort to better understand the nature of medical skills acquisition and decay, a study was conducted examining initial training and retention over several weeks of standardized laparoscopic surgical psychomotor skills using the Fundamentals of Laparoscopic Surgery (FLS) manual skills training platform. Of particular interest in this study was the role of skill acquisition and retention with the dominant versus the non-dominant hand. Expert surgeons have indicated that ambidexterity plays a significant role in surgical skill proficiency. The results of this study indicate significant differences in performance between the dominant and non-dominant hands during the early stages of training, with ambidexterity increasing as trainees reach proficiency. This research lays the groundwork for a longitudinal research study in which retention of the trained skills will be assessed following a 6-month period of nonuse. Implications for objective assessment of medical skill acquisition, proficiency, and retention are discussed, including implications for training and retention of a broad range of medical skills involving psychomotor components using simulation-based training.

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BACKGROUND

Sustainment of skills is a challenge for all healthcare professionals; however, it presents a particularly severe issue for military surgeons and physicians due to the unique requirements of their jobs. Military healthcare personnel are expected to maintain medical specialties as well as military unique skills required for combat casualty care, treating chemical/biological/radiological casualties, tropical and travel medicine, humanitarian medicine, and military operational medicine. Deering, Rush, Lesperance, and Roth (2011) report that for most physicians, military-unique readiness medical skills are practiced only during periodic deployments of 6 to 18 months, and during that time, most clinicians do not practice their specialty and subspecialty skills. The result is a self-reported significant loss in specialty skills following deployments.

Research is needed to develop methods and tools to proactively refresh medical skill competencies at optimal times throughout deployment cycles. Such methods and tools require exploration of skill decay rates, including the underlying cognitive, psychomotor, and perceptual skills; the causes of the decay; and validated training strategies capable of slowing the rate of decay. Accurate assessment of skills will allow military medical personnel to know their readiness level with increased precision, enabling them to seek refresher training of under-used skills and knowledge and feel confident in the skills and knowledge they already possess. Guidance through refresher materials and training based on such assessments will allow surgeons to focus only on the skills and knowledge that require maintenance and retraining.

General Skill Acquisition and Decay

Past research has demonstrated that many variables influence skill decay. In a review of previous skill decay and retention literature, Arthur, Bennett, Stanush, and McNelly (1998) identify the following major factors influencing the retention of skills during periods of nonuse: length of retention interval, degree of overlearning, task characteristics, methods of testing for original learning and retention, conditions of retrieval, instructional strategies and training methods, and individual differences.

The skill decay literature focuses primarily on task types that generally differentiate between cognitive and physical (or psychomotor) tasks. Closely related to task type, task complexity, and task demands are the types of skills required by a task. Currently, a validated taxonomy of skill types does not exist. Within the skill acquisition (training) literature it is also common to differentiate between knowledge, skills, and abilities. Knowledge is typically classified as declarative or procedural (e.g., Kim, Koubek, & Ritter, 2007). Ability refers to individuals' general capacities, which can be applied within a variety of tasks (Fleishman, 1967). Fleishman's human performance taxonomy categorizes abilities as cognitive, physical, and perceptual-motor (Fleishman & Quaintance, 1984). Skills result when capacities become concretized in particular behaviors that have a central psychomotor component. There is evidence that various types of knowledge, skills, and abilities are acquired and retained at different rates, depending on a variety of methodological and task-specific variables. However, current models of skill acquisition, and particularly decay, are limited. The relationships and interactions are complicated, and a model of skill decay must account for this complexity. Such models must be based on empirical data, which is currently limited within the domain of medical skills.

The rate of skill decay specifically within military tasks has been researched extensively in the past, (e.g., Arthur, Bennett, Stanush, & McNelly, 1998; Arthur, et al., 2007; Wisher, Sabol & Ellis, 1999). Hurlock & Montague (1982) concluded that within the context of Naval tasks the primary factors associated with skill retention are the amount of learning prior to a period of nonutilization, the length of the nonutilization period, previous experience, ability level, the type of skill in question, the quantity of practice, and the quality of feedback. Healy, Ericsson, and Bourne (1990) demonstrated that long-term memory representation for specific military tasks contains both motor and perceptual information, and that internal cognitive operations enhance memory performance. Wisher, Sabol & Ellis (1999) also identified specific task factors impacting skill acquisition and decay that are particularly relevant to procedural skills such as task complexity and task demands.

Military Medical Skill Acquisition and Decay

Within the domain of medical procedural skills, retention of cardiopulmonary resuscitation (CPR) and basic life support skills have been studied extensively, demonstrating extraordinarily poor retention rates of these skills by medical and civilian trainees in the absence of rehearsal or employment of these skills (Hamilton, 2005). Within the surgical skill acquisition literature, it has been established that perceptual skills (both visuospatial and perceptual motor) also correlate with surgical performance (Ritter et al, 2006; Singapogu et al, 2012).

In recent years, as minimally invasive surgery has become more prevalent, attempts have been made to establish standards for laparoscopic surgical skills training and evaluation, leading to development of the Fundamentals of Laparoscopic Surgery (FLS) training protocol by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES). The FLS training protocol includes training to specified proficiency levels using a video trainer box (Figure 1) on five manual skills tasks: peg transfer, circle cut, endoloop, extracorporeal suturing, and intracorporeal suturing.

Figure 1. Fundamentals of Laparoscopic Surgery (FLS) Training Apparatus

FLS manual skills training has been shown to result in laparoscopic manual skills that are durable up to 11 months (Stefanidis, Korndorffer, Markley, Sierra, & Scott, 2006), and retention of these skills was also shown by Hiemstra, Kolkman, Van de Put and Jansen (2009) to be durable for up to one year for three tasks similar to FLS tasks. However, the mechanisms by which these skills are acquired and lost are poorly understood, including the role of the dominant versus non-dominant hand in training and retention of these skills. Ambidexterity has been identified as one of the primary skills required to perform laparoscopic surgery by researchers that supported the development of the FLS training program (Rosser, Rosser, & Savalgi, (1997; Derossis, Fried, Abrahamowicz, Sigman, Barkun, & Meakins, 1998; Derossis, Bothwell, Sigman, & Fried, 1998). However, the current FLS scoring metrics do not account for level of ambidexterity. Additionally, formal studies have not been conducted investigating the role of ambidexterity in training or retention of FLS skills.

Additionally, while maintenance of laparoscopic manual skills through rehearsal and retraining has been shown to prevent decay, no standards currently exist for retraining, and few deployable systems exist that can be used where they are most needed—in far forward military medical facilities—to provide refresher training of critical skills during long deployments.

The current study seeks to examine training and retention of two of the FLS manual skills tasks, peg transfer and intracorporeal suturing (Figure 1), emphasizing performance by the dominant versus non-dominant hands over the course of training. The over-arching goal of this research is to develop an empirically-based model of laparoscopic skill acquisition and decay and to develop simulation-based refresher training that can be used to support skill maintenance during periods of nonuse such as military deployments. Further, this research will lay the groundwork for the development of methods, metrics, and technology tools to support improved training and retention of a wide variety of medical skills.

METHODS

Subjects

A total of 27 undergraduate students (9 males, 18 females) from The Catholic University of America (CUA) participated in the current study. Of these participants, 24 were right-handed, 2 were left-handed, and 1 was ambidextrous with a left-handed preference. This handedness distribution is representative of the general population (Hardyck & Petrinovich, 1977).

Experimental Procedures

All participants completed a total of 5 hours of training over the course of two training sessions on separate days during the 2012 Spring semester. These same participants will also complete a follow-up assessment and refresher training session during the 2012 Fall semester, following a 6-7 month retention period.

Training consisted of completion of the standardized FLS peg transfer task and a modified version of the FLS intracorporeal suturing task to enable equivalent rehearsal of the peg transfer and suturing skills with both the dominant and non-dominant hands. The FLS peg transfer task requires the trainee to lift six rubber objects, one at a time with a laparoscopic grasper instrument in one hand and to transfer the object midair to a grasper instrument held by the other hand. Each object is then placed on a peg on the opposite side of a peg board. Once all six rubber objects have been moved to the opposite side of the board, they are then moved back, one at a time, to the original side of the board. Participants were randomly assigned to start with the pegs on the side of either their dominant or non-dominant hand. The intracorporeal suturing task requires trainees to place a single stitch precisely through two dots marked on a penrose drain with an incision along its long axis. Participants are then required to tie a secure knot using laparoscopic locking grasper instruments by looping the thread around one grasper twice, pulling the free end through the loops, and tightening the knot. This task was performed from right to left, as well as left to right, alternating with each trial. All participants were randomly assigned to start each training session with either their dominant or non-dominant hand. This counterbalanced design controlled for learning effects resulting from completion of the first trial of each session.

Time and errors were recorded by a trained observer according to the FLS standardized assessment and scoring methods. However, in addition to recording time to complete the entire peg transfer task, which involves moving the pegs from one side of the board to the other and then back again to the starting position, the observer recorded separate times for the first half of the task (moving the pegs to one side of the board) and the second half of the task (moving the pegs back to the original side of the board).

Upon arriving for the initial data collection session, participants first completed a consent form and the experimental procedure was explained. Each participant then completed a demographic questionnaire, which included questions regarding frequency and proficiency of video game play, instrument playing, and text messaging, as well as self-reported handedness and spatial abilities skills. Participants also responded to a series of questions from the Annett Hand Preference Questionnaire (Annett, 1970) and complete a simple assessment task to determine which is their dominant hand.

Participants were then given a series of specific instructions for the two tasks, including a video demonstration of each. Participants then stood at the FLS video box training station and practiced each of the two tasks for a total of 1 hour each, with brief breaks every 20 minutes. The second training session lasted only 2 hours, including a total of 40 minutes of training on each task with brief breaks between each 20-minute training block. The mean time between Training Day 1 and Training Day 2 was 23 days.

RESULTS

Initial analysis looked at time to complete the tasks across all five of the 20-minute training sessions (three on Training Day 1 and two on Training Day 2). Subsequently, additional analyses were also conducted to compare Day 1 performance to Day 2 performance for both the Peg Transfer and Suturing tasks.

Peg Transfer Task

A 5 (Training Session) x 2 (Hand—dominant versus non-dominant) repeated measures analysis of variance (ANOVA) was conducted using the SPSS statistical software package. Mauchly's test of sphericity was significant for both Session and Session x Hand; thus, the Greenhouse-Geisser correction is reported for the degrees of freedom for these effects.

A significant main effect was found for Training Session [$F(1.93, 50.12) = 30.60$, $p<.001$]. A simple contrasts post hoc analysis (comparing Session 1 to each of the subsequent sessions) with Bonferroni adjustment resulted in significant contrasts between Session 1 and all four of the subsequent sessions, with a significance level of $p<.001$ for all contrasts. A repeated contrasts post hoc analysis (comparing each session to the subsequent session) with Bonferroni adjustment resulted in significant contrasts between Session 1 and Session 2 [$F(1,26) = 62.9$, $p<.001$], as well as between Session 2 and Session 3 [$F(1,26) = 9.94$, $p=.004$]. Significant contrasts were not present between Session 3 and Session 4 (between the two training days) or between Session 4 and Session 5 (the Day 2 training sessions).

A significant main effect was also found for Hand [$F(1, 26) = 7.57$, $p=.011$], with the average time for trials moving the pegs *from* the non-dominant side of the board being significantly faster (M=69.37) than the average time for trials moving the pegs *from* the dominant side of the board (M=73.69).

No significant interaction effect (Session x Hand) was present. Changes in task time across sessions were comparable for the dominant and non-dominant hands. Mean times for both the dominant and non-dominant hands across all 5 training sessions are presented in Figure 2.

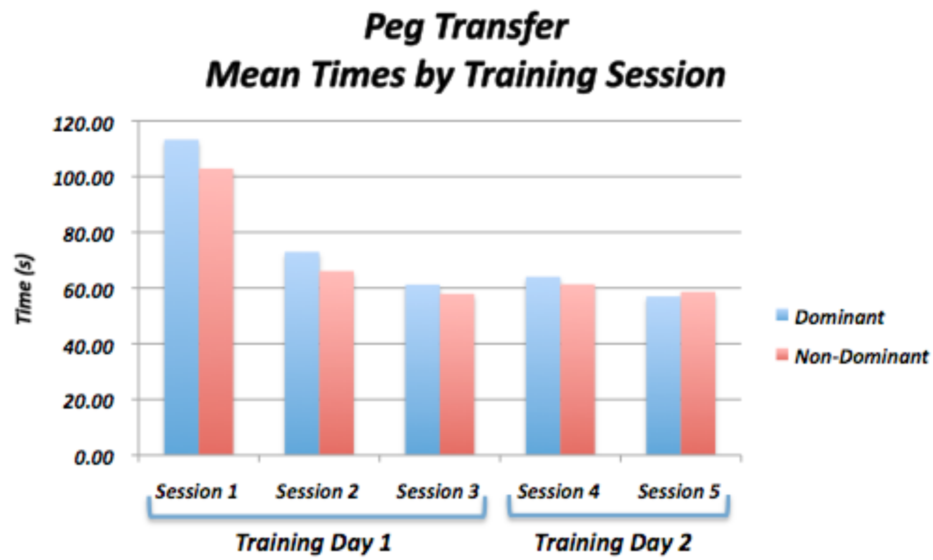

Figure 2. Peg Transfer Mean Times by Training Session

Additionally, a 2 (Training Day) x 2 (Hand—dominant versus non-dominant) repeated measures ANOVA was conducted to assess the effects across Training Day 1 and Training Day 2.

A significant main effect was found for Training Day [$F(1, 26) = 13.39$, p=.001], with the average time on Day 2 being significantly faster (M=60.24) than the average time on Day 1 (M=79.06).

A significant main effect was also found for Hand [$F(1, 26) = 5.361$, p=.029], with the average time for trials moving the pegs *from* the non-dominant side of the board (M=67.81) being significantly faster than the average time for trials moving the pegs *from* the dominant side of the board (M=71.49).

A statistically significant interaction effect (Day x Hand) was not present (p=.066); however, a trend was observed in which trials moving the pegs *from* the non-dominant side of the board were faster than the average time for trials moving the pegs *from* the dominant side of the board for both training days, but with a larger difference on Day 1 and almost no difference on Day 2. This trend may suggest increased ambidexterity on this task later in training. Mean times for both the dominant and non-dominant hands across the 2 training days are presented in Figure 3.

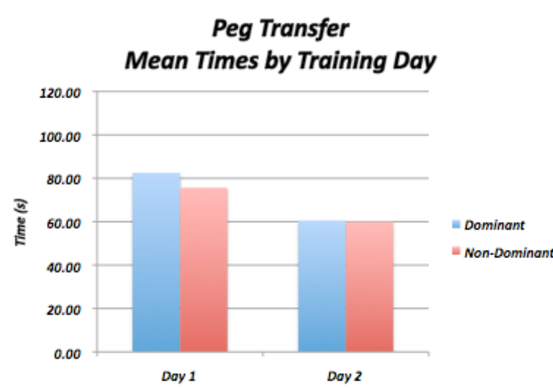

Figure 3. Peg Transfer Means by Training Day

T-tests were also conducted, comparing the mean times by training day for the dominant and non-dominant hands to ensure that no unplanned systematic variances were present. No significant effects were found for gender, dominant hand, starting hand, or length of retention period between training days (less than the mean number of days versus more than the mean number of days).

In order to further explore the changes in performance with the dominant and non-dominant hands over the course of training, a 2-tailed bivariate correlation was conducted in SPSS, comparing the total time for individual trials to the absolute value of the difference in time between moving the pegs *from* the non-dominant side of the board and time moving the pegs *from* the dominant side of the board (trial ambidexterity score). The average total trial times and average ambidexterity scores for all subjects across training sessions were strongly correlated, $r(132) = .54$, $p < .001$. These data are plotted in Figure 4.

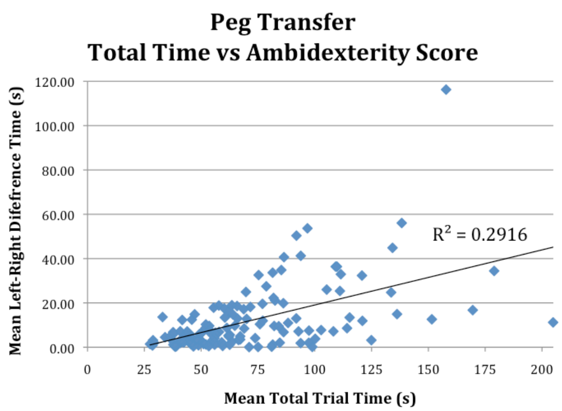

Figure 4. Peg Transfer Ambidexterity Correlation

This result is consistent with preliminary findings from the pilot study conducted at Wayne State University (WSU) under a complementary research effort.

Suturing Task

This task was much more difficult for some participants than the peg transfer task. Participants that were unable to complete one suture with each hand within the initial 20-minute training session have been excluded from the present analyses as comparisons of dominant and non-dominant are not possible for all sessions for these participants.

For the remaining 22 participants, a 5 (Training Session) x 2 (Hand—dominant versus non-dominant) repeated measures ANOVA was conducted using SPSS. Mauchly's test of sphericity was significant for both Session and Session x Hand; thus, the Greenhouse-Geisser correction is reported for the degrees of freedom for these effects.

A significant main effect was found for Training Session [$F(2.46, 51.69) = 29.51$, $p<.001$]. A simple contrasts post hoc analysis (comparing Session 1 to each of the subsequent sessions) with Bonferroni adjustment resulted in significant contrasts between Session 1 and all four of the subsequent sessions, with a significance level of p<.001 for all contrasts. A repeated contrasts post hoc analysis (comparing each session to the subsequent session) with Bonferroni adjustment resulted in significant contrasts between Session 1 and Session 2 [$F(1,21) = 20.44$, $p<.001$], between Session 2 and Session 3 [$F(1,21) = 6.35$, $p=.020$], and between Session 4 and Session 5 (the Day 2 training sessions) [$F(1,21) = 10.47$, $p=.004$]. A significant contrast was not present between Session 3 and Session 4 (between the two training days).

A significant main effect was not found for Hand, and no significant interaction effect (Session x Hand) was present. Mean times for both the dominant and non-dominant hands across all 5 training sessions are presented in Figure 5.

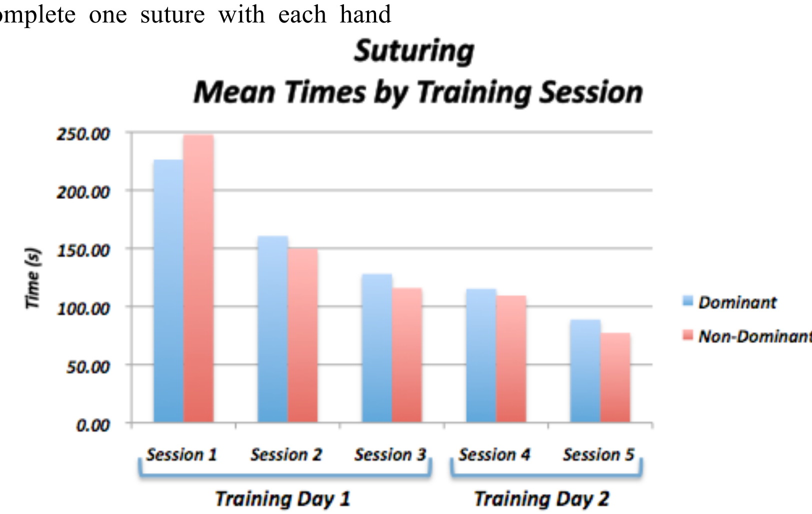

Figure 5. Suturing Task Mean Times by Training Session

Additionally, a 2 (Training Day) x 2 (Hand—dominant versus non-dominant) repeated measures ANOVA was conducted to assess the effects across Training Day 1 and Training Day 2.

A significant main effect was found for Training Day [F (1, 21) = 57.45, p<.001], with the average time on Day 2 being significantly faster (M=97.72) than the average time on Day 1 (M=171.40).

A significant main effect was not found for Hand, and no significant interaction effect (Session x Hand) was present. Mean times for trials led by both the dominant and non-dominant hands across the 2 training days are presented in Figure 6.

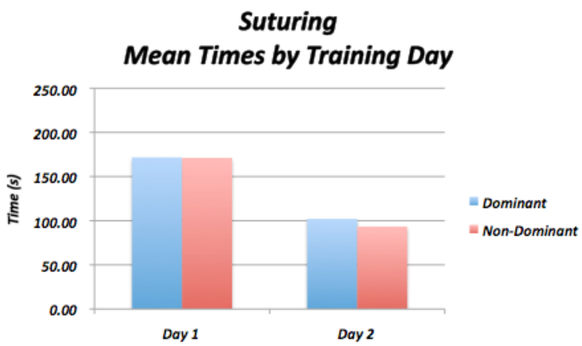

Figure 6. Suturing Task Mean Times by Day

T-tests were also conducted, comparing the mean times by training day for the dominant and non-dominant hands to ensure that no unplanned systematic variances were present. No significant effects were found for gender, dominant hand, starting hand, or length of retention period between training days (less than the mean number of days versus more than the mean number of days).

As with the peg transfer task, in order to further explore the changes in performance with the dominant and non-dominant hands over the course of training, a 2-tailed bivariate correlation was conducted in SPSS, comparing the total time for individual trials to the absolute value of the difference in time between trials led by the non-dominant hand and trials led by the dominant hand (trial ambidexterity score). The average total trial times and average ambidexterity scores for all subjects across training sessions were strongly correlated, $r(108) = .75$, $p < .001$. These data are plotted in Figure 7.

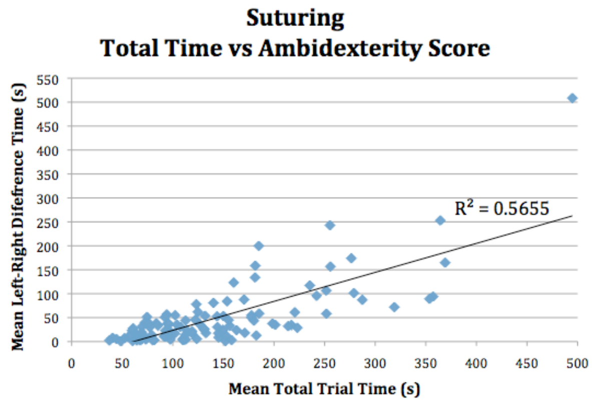

Figure 7. Suturing Ambidexterity Correlation

This result is consistent with the findings for the peg transfer task.

DISCUSSION

The present study demonstrated significant improvement in two components of laparoscopic skills, peg transfer and suturing, during multiple sessions on the same day. When training continued after an average delay of three weeks, there was no decay in performance. However, whereas the peg transfer task showed no subsequent improvement during continued training, suturing did.

Both tasks showed an initial effect of which aspects of a task were assigned to the dominant hand. For peg transfer this effect was largely eliminated with practice. However, for the suturing task there was a persistent hand dominance effect. For both tasks, decreased total performance time reflected a decrease in the difference between dominant and non-dominant times.

These results provide insight into the way in which medical psychomotor skills, in this case laparoscopic surgical skills, are acquired, including the role of the dominant versus non-dominant hands in skill acquisition over the course of training. These results indicate significant differences in performance between the dominant and non-dominant hands during the early stages of training, with ambidexterity increasing as trainees reach proficiency. Thus, degree of ambidexterity during task performance may be indicative of skill level, and may be useful in developing novel metrics for assessing initial skill acquisition, as well as skill decay. Implications of this research include the potential for development of novel assessment methods and metrics of medical skill acquisition, proficiency, and retention; as well as development of empirically-based skill decay models to support optimized refresher training.

Continuation of this research will include assessment of skill retention and retraining of the same skills with the same participants, following a 6-month retention period. Additionally, subsequent research is planned involving military medical students, residents, and surgeons, and will explore the effects of simulation-based refresher training on skill sustainment. These empirical studies are intended to lay the groundwork for the development and validation of a skill acquisition/decay model, novel objective metrics, and simulation-based training strategies for the prevention of laparoscopic surgical skills attrition. The ultimate goal of this effort is to develop a deployable training system and to integrate the resulting system within standardized military medical training curricula for enhanced training and sustainment of these critical skills.

Additionally, future research is needed to leverage these outcomes to support training and retention of a broad range of medical skills involving psychomotor components within both military and civilian medical education and practice. Although civilian physicians and surgeons are not subject to deployments, they often experience periods of nonuse of specialty skills. For example, like military physicians civilian clinicians may be absent on maternity leave or assigned to administrative and managerial positions for extended periods of time, potentially leading to skill decay.

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