Sleep Optimizes Motor Skill in Older Adults

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OBJECTIVES: To determine whether sleep benefits motor memory in healthy elderly adults and, if so, whether the observed sleep-related benefits are comparable with those observed in healthy young adults.

DESIGN: Repeated-measures cross-over design.

SETTING: Boston, Massachusetts (general community) and Harvard University.

PARTICIPANTS: Sixteen healthy older and 15 healthy young participants.

MEASUREMENTS: Motor sequence task (MST) performance was assessed at training and at the beginning and end of the retest session; polysomnographic sleep studies were recorded for the elderly participants.

RESULTS: After 12 hours of daytime wakefulness, elderly participants showed a dramatic decline in MST performance on the first three retest trials, and only a nonsignificant improvement by the end of retest (the last 3 retest trials). In contrast, when the same participants trained in the morning but were retested 24 hours after training, after a day of wake plus a night of sleep, they maintained their performance at the beginning of retest and demonstrated a highly significant 17.4% improvement by the end of the retest session, essentially identical to the 17.3% improvement seen in young participants. These strikingly similar improvements occurred despite the presence of other age-related differences, including overall slower motor speed, a lag in the appearance of sleep-dependent improvement, and an absence of correlations between overnight improvement and sleep architecture or sleep spindle density in the elderly participants.

CONCLUSION: These findings provide compelling evidence that sleep optimizes motor skill performance across the adult life span. **J Am Geriatr Soc 59:603–609, 2011.**

Key words: sleep; motor skill; memory consolidation

Research on sleep-dependent memory processing in healthy young adults has produced unequivocal evidence confirming the unique role sleep plays in memory processing. There is now a large body of literature demonstrating the relationship between various sleep stages, as well as several electroencephalography (EEG) signatures of specific sleep stages, and sleep-dependent memory consolidation. Different forms of learning and memory (e.g., word pairs, emotional stories, spatial navigation, visual discrimination, motor adaptation, and motor sequence learning), as well as different stages in the consolidation process (e.g., stabilization, enhancement, and integration), correlate with different stages of sleep and different EEG signatures.[1,2] Some of the clearest evidence of sleep's mnemonic power has been observed in the procedural memory domain. One task that has yielded consistent evidence of an active role of sleep in memory processing is the finger-tapping motor sequence task (MST).[3] The MST is a simple motor task that requires participants to repeatedly type a sequence of digits (e.g., 4-1-3-2-4) as quickly and accurately as possible across a number of timed trials.[4] Performance of the MST requires the development and execution of a repetitive motor routine analogous to a number of activities, such as typing, playing a musical instrument, data entry, and myriad other tasks requiring fine, coordinated finger movements. After a normal night of sleep, healthy college students typically show a highly significant 17% to 20% enhancement of motor skill speed across three retest trials, whereas performance after a period of wakefulness increases by only a nonsignificant 3% to 4%.[4–6] Remarkably, extra training trials across a day of wakefulness only produce small incremental increases in motor speed, on the order of 1% for each additional trial, whereas a night of sleep that follows this extra daytime training imparts an additional 12% jump in performance, a clear demonstration of the potent and unique effect of sleep on motor skill processing.[6]

The enhancements of motor skill that emerge in young adults as a function of sleep appear to depend on specific physiological components of sleep, namely the amount of Stage 2 non-rapid eye movement (non-REM) sleep, and sleep spindles, which are a defining signature of Stage 2 sleep. Sleep spindles are intermittent, synchronous, thalamocortical bursts (12–16 Hz) that occur between three to seven times per minute.[7] The amount of Stage 2 sleep

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obtained over a night of sleep[4,8] or over a daytime nap,[5] and the number and density (number of spindles per minute) of Stage 2 sleep spindles[9,10] have been shown to correlate with sleep-dependent improvement on motor memory tasks. Spectral power in the spindle frequency range (12–16 Hz) also correlates with this improvement,[5,8] strongly suggesting that Stage 2 sleep physiology is important for motor memory processing.

Motor Skill and Sleep in Aging

Motor skills generally decline with age,[11] and typing skills in particular are susceptible to deterioration in an age-dependent fashion, although not all aspects of typing performance are found to suffer in older adults. For example, inter-keystroke interval does not vary with age when participants are asked to transcribe a printed text, although on a choice reaction time task, requiring participants to respond to computer presentation of the letters "L" and "R" as quickly as possible, performance is highly correlated with age, with average reaction times increasing 2 ms per year from age 20 to 70.[12] This age-related decline in performance is also observed in the serial reaction time task (SRTT), which requires participants to respond to elements in a 10-item repeating sequence that appear, one at time, at one of four different spatial locations on a computer screen. Recent research demonstrates that reaction times during SRTT training in healthy older adults (mean age 59) are approximately twice those seen in young adults.[13,14] These results suggest that, although general typing speed is preserved for tasks that are well learned (text transcription), speed monotonically decreases with age when participants are required to respond quickly to novel, or unpredictable, stimuli.

Such changes in motor skill performance across the life span develop in parallel with changes in sleep patterns. Age-related decreases in total sleep time and, more dramatically, in slow wave sleep (SWS), along with increases in sleep fragmentation, are consistently observed in polysomnographic sleep studies,[15–17] although there is often the misperception that these age-related changes in sleep are an indication of impaired sleep quality. In fact, in a recent survey of 248 older community-dwelling individuals reporting no other medical complaints, 90% rated their sleep quality as excellent, very good, or good, whereas those with medical conditions were up to four times as likely to rate their sleep as fair to poor.[18] This finding is corroborated in an excellent review,[19] which concludes that compromised sleep quality in older adults is mostly a result of underlying comorbidity, including changes in circadian rhythmicity, medication effects, or sleep disorders such as obstructive sleep apnea and REM sleep behavior disorder.

Although research findings are scant, a handful of studies suggest that aging may also be associated with decrements in sleep-dependent memory consolidation. Middle-aged participants (mean age 50) improve less after an interval of nocturnal sleep than young participants on a word pair recall task, and this recall difference is associated with less SWS in the older participants.[20] The two studies that have examined the effect of sleep on motor skill memory in older adults present a mixed picture. In one study, young participants became faster on the SRTT after a night of sleep, whereas reaction times in older participants (mean age 59) slowed after sleep.[14] In contrast, a study using a simple pursuit rotor task found that, although young participants learned the task with greater facility than elderly participants, percentage improvement in performance (relative to training) seen 1 week later did not differ between the two groups.[9] These findings suggest that there may be qualitative differences between tasks (e.g., task difficulty or complexity) that influence sleep's effect on motor memory processing.

Given the authors' extensive knowledge of the sleep-dependent enhancement of MST performance in healthy young participants, the current examined whether sleep also enhances MST performance in healthy elderly individuals.

Using a repeated-measures cross-over design, the present study assessed MST performance in a group of healthy elderly participants across a 12-hour period of wakefulness and across a 24-hour period containing a day of wakefulness and a night of sleep. College students were also trained and tested across an identical 24-hour interval to assess age-related differences in MST performance at training and after sleep-dependent consolidation.

METHODS

Participants

The Beth Israel Deaconess Medical Center institutional review board approved the study, and all participants provided written consent before participation.

Elderly Participants

Sixteen healthy, right-handed elderly participants (11 female, mean age = 68.0 ± 6.6, range 60–79) with an average of 3.1 ± 3.1 years of college education participated in the study. An additional three participants completed the study but were excluded from data analysis because of a failure to consistently type the correct five-digit sequence, producing an average accuracy (percentage of correctly typed keystrokes) of only 50%, more than five standard deviations below the lowest accuracy rate (80%) of the other 16 participants. People with psychiatric disease, dementia, motor or vision impairment, drug or alcohol dependence in the past 15 years, or diagnosed current sleep disorders were excluded from participation. Potential participants were also excluded if they consumed more than two 12-ounce caffeinated beverages per day, were taking medications known to affect sleep, reported difficulty initiating sleep, or reported an average total sleep time of less than 6 hours per night. Participants reported no sleep complaints before participation and no previous diagnoses of sleep disorders. Participants were not allowed to nap during the course of the study. A daily sleep log was completed to monitor the regularity of each participant's sleep–wake cycle. Ambulatory polysomnographic recordings were conducted in each participant's home on the night across which MST performance was tested.

Young (Control) Participants

Fifteen healthy, right-handed university students (11 female, mean age 20.1 ± 1.2) participated in the study.

Participants were instructed to abstain from caffeine and alcohol for 24 hours before and during the study. All young participants were medication free (except for birth control, n = 1), and all reported habitual total sleep times greater than 6 hours per night. Regularity of participants' sleep schedules was assessed using a 3-day retrospective sleep log.

Motor Sequence Task

The MST has been used in a number of previous studies.[3] Participants were instructed to repeatedly type a five-digit series of numbers (4-1-3-2-4 or 2-3-1-4-2) with their left (nondominant) hand "as quickly and accurately as possible" for each of twelve 30-second trials. The five-digit number was always displayed at the top of the screen, and a dot on the screen starting from the left edge of the monitor represented each keystroke. Participants were given a 30-second rest period between trials. They completed 12 trials during the training session and 12 trials at retest. As in previous research, the average number of correct sequences across the last three training trials was used as the measure of training performance (Figure 1, dashed line), whereas the mean of the first three retest trials (Figure 1, Trials 1–3) was the measure of immediate retest performance, consistent with earlier studies in which the retest session consisted of only two or three retest trials.[4–6] In the present study, the retest session for all groups was extended to 12 trials to examine how performance might change across a longer retest session, because it has previously been found that healthy midlife adults (mean age 44 ± 6) require two to three retest trials before performance reaches a stable plateau.[21] The average of the last three retest trials was therefore also examined as a measure of plateau performance (Figure 1, trials 10–12).

Analyses

The primary dependent measures were immediate improvement (first 3 retest trials–last 3 training trials), plateau improvement (last 3 retest trials–last 3 training trials), percentage improvement ((first 3 retest trials–last 3 training trials/last 3 training trials) × 100, and (last 3 retest trials—last 3 training trials/last 3 training trials) × 100).

Procedure

Elderly Participants

MST testing and sleep recordings were done in participants' homes. Each participant completed two training-retest sessions; during one session, they were trained on a sequence (e.g., 4-1-3-2-4) in the morning (9 a.m.) and retested after 12 hours of wakefulness (9 p.m.); in the other session, they were trained on a second sequence (e.g., 2-3-1-4-2) in the morning (9 a.m.) and tested 24 hours later (9 a.m.), after a day of wakefulness and a night of sleep. Session and sequence orders were counterbalanced across participants. The Stanford Sleepiness Scale[22] was administered before each training and retest session to assess level of alertness or sleepiness.

On the night of the 24-hour session, polysomnographic (PSG) sleep recordings were acquired using an Embla A-10 ambulatory PSG system, with Somnologica software (Embla Systems, Broomfield, CO). Central (C3/C4) and occipital (O1/O2) EEG, left and right eye movements (electrooculography; EOG), and chin muscle activity (electromyography; EMG) were recorded. Sleep Stages 1 to 4 and REM sleep were scored in accordance with standard criteria.[23] Spectral analysis was conducted to assess EEG power (μV^2) within the spindle frequency range. Before spectral analysis, EEG data were filtered between 0.5 and 35 Hz. EEG power in slow (12–14 Hz) and fast (14–16 Hz) spindle frequency bands was analyzed using Hanning windowing on all artifact-free 30-second epochs and was then averaged across central EEG channels C3 and C4.

Young Participants

Participants arrived at the computer laboratory at 9 a.m. They completed the sleep log and the Stanford Sleepiness Scale and then trained on the MST. As with the elderly participants, young participants performed 12 trials at training and then another 12 trials at retest 24 hours later, at 9 a.m. the following morning.

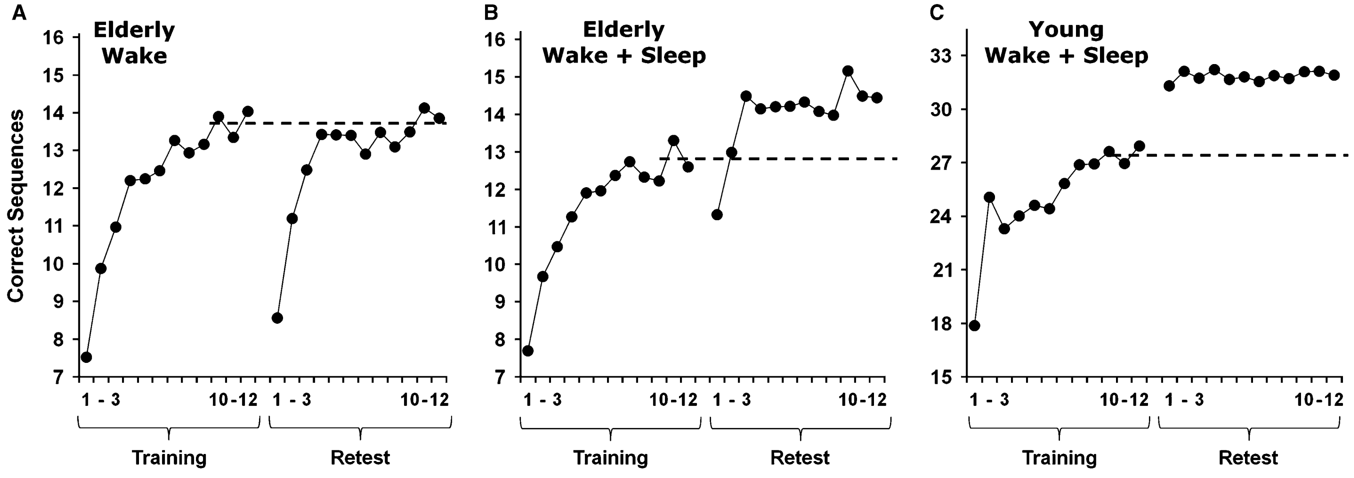

Figure 1. Motor sequence task performance in elderly (A and B) and young (C) participants. The dashed lines represent training performance (average of the last 3 training trials). Retest Trials 1 to 3 represent immediate retest; retest trials 10 to 12 represent plateau retest trials. The y-axis represents the number of correct sequences per 30-second trial.

RESULTS

Sleep Log and PSG Data

Before each training session, participants reported a number of subjective sleep variables by sleep log, including the amount of time spent in bed, the amount of sleep they obtained, how long it took to fall asleep, and sleep quality. The measure of sleep quality was based on a scale from 1 to 4 (1 = excellent, 2 = good, 3 = fair, 4 = poor). Young and elderly participants reported similar values for all of these subjective measures (all $P > .10$).

MST Performance—Elderly Participants

No evidence was observed of carryover effects from the first to the second MST sequence (paired-samples t-test for number of correct sequences at training; Sequence 1, 13.1 ± 1.1; Sequence 2, 13.6 ± 1.2, $t(15) = 0.97$, $P = .35$). Nor were there differences between the wake and wake plus sleep conditions in subjective sleepiness (Stanford Sleepiness Scale, $P > .50$ at training and retest), improvement during training (percentage improvement from the first 3 to the last 3 training trials: 55.7 ± 12.3% vs 50.7 ± 10.2, $t(15) = .46$, $P = .65$) or training accuracy (93.2 ± 1.4% vs 93.2 ± 1.3%, $t(15) = .00$, $P > .9$), although a difference in training performance was observed between the wake and wake plus sleep conditions (14.0 ± 1.2 vs 12.7 ± 1.0, $t(15) = 2.53$, $P = .02$), presumably a sampling artifact, given the identical training conditions and counterbalancing of order and sequence.

Performance at immediate retest after 12 hours of wakefulness dropped by 3.0 correct sequences from training performance (Figure 1A, dashed line), from 14.0 to 11.0 correct sequences (−22%, $P < .001$; Figure 1A, and Figure 2 left, striped bar). In contrast, after a 24-hour period containing a day of wake and a night of sleep, performance was maintained relative to training, increasing nominally from 12.7 to 12.9 correct sequences (+2%, $P = .69$; Figure 1B, and Figure 2 left, filled bar). Overall, participants demonstrated significantly better immediate improvement after 24 hours containing a night of sleep than after 12 hours without sleep (paired samples t-tests: numeric improvement, $t(15) = 3.7$, $P = .002$; percentage improvement, $t(15) = 4.2$, $P = .001$).

Across the retest session, there was a significant increase in correct sequences from the first three to the last three retest trials in both conditions (wake, 3.1 ± 0.5 sequences, $t(15) = 5.90$, $P < .001$; wake plus sleep, 1.8 ± 0.3, $t(15) = 6.05$, $p < .001$), which resulted in significant plateau improvement in the wake plus sleep condition (+17.4%, $t(15) = 4.49$, $P < .001$) but not in the wake condition (+4.0%, $t(15) = .81$, $P = .43$; Figure 1A and B, and Figure 2 right). The difference between conditions for plateau improvement was also significant ($t(15) = 2.66$, $P = .02$), indicating that participants in the wake condition failed to exhibit improvement comparable with that seen after a night of sleep.

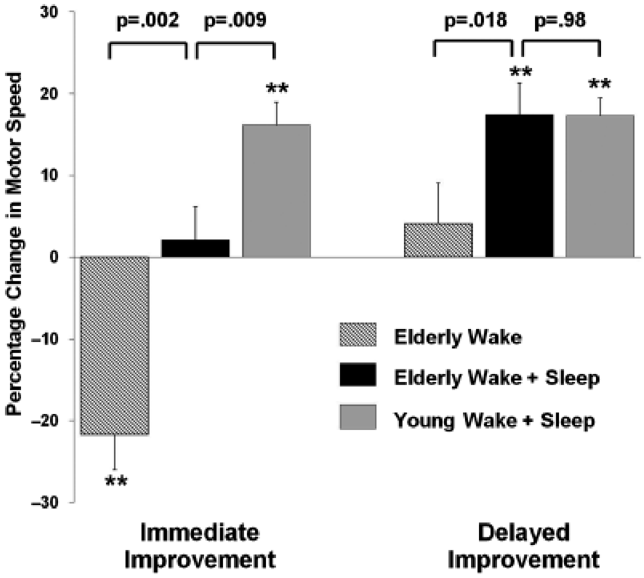

Figure 2. Motor sequence task (MST) immediate and plateau improvement in elderly and young participants. MST change in performance across a 12-hour period of wakefulness (striped bars) and across a 24-hour interval containing a day of wake and a night of sleep in elderly (black bars) and young (gray bars) participants. Bars represent means ± standard errors of the mean. $^{**}P < .001$.

Correlation Between Overnight Improvement and Sleep Measures—Elderly Participants

Polysomnographic sleep data for the elderly sample are presented in Table 1. Average total sleep time was 5.7 hours, with an average sleep efficiency of 77%, values similar to normative values obtained for a comparably aged cohort from the Sleep Heart Health Study (6.0 hours and 81.8%, respectively).[16]

A number of studies have established a link between PSG-recorded sleep parameters and overnight motor skill improvement in young participants, especially between improvement and amount of Stage 2 sleep[4,8] and sleep spindle activity during Stage 2 sleep.[5,9] One study, using a similar motor task, also found that overnight improvement

Table 1. Polysomnographic Data for Elderly Participants

	Mean ± Standard Deviation	
Sleep Parameter	**Minutes**	**Percentage of Total Sleep Time**
Time in bed[*]	445.4 ± 67.9	
Sleep onset latency[†]	28.5 ± 39.6	
Total sleep time	341.6 ± 75.4	
Sleep efficiency, %[‡]	76.5 ± 11.9	
Wake after sleep onset[§]	131.4 ± 71.5	
Stage 1	41.8 ± 19.2	12.5 ± 5.2
Stage 2	204.5 ± 63.7	59.2 ± 9.3
Stage 3	25.4 ± 14.1	7.9 ± 5.3
Stage 4	1.5 ± 3.8	0.5 ± 1.3
Slow-wave sleep[‖]	26.9 ± 17.2	8.4 ± 6.5
Rapid eye movement sleep	68.5 ± 24.7	19.9 ± 6.9

Sleep data in the 24-hour wake plus sleep condition.

[*] Interval from the time the participant got into bed in the evening to the time the participant got out of bed in the morning.

[†] Time between lights out and the first epoch of Stage 1 sleep.

[‡] (Total sleep time/time in bed) × 100.

[§] Amount of wake time during the night after sleep onset.

[‖] Amount of Stage three+Stage four sleep.

Table 2. Correlation Between Sleep Parameters and Motor Task Performance

	Percentage Change Immediate Improvement*		Percentage Change Plateau Improvement†	
Sleep Parameter	***r***	***P*-Value**	***r***	***P*-Value**
Sleep stage data				
Stage 1 percentage	– 0.07	.80	– 0.33	.22
Stage 2 percentage	– 0.15	.59	– 0.32	.23
Slow-wave sleep percentage	– 0.15	.58	0.28	.29
Rapid eye movement percentage	0.38	.14	0.42	.11
Slow (12–14 Hz) and fast (14–16 Hz) spindle power				
C3 slow	– 0.07	.83	0.03	.92
C3 fast	0.06	.85	0.11	.73
C4 slow	– 0.05	.87	0.01	.97
C4 fast	0.05	.88	0.07	.81

Correlations between sleep stage parameters and spindle frequency (12–16 Hz) power (μV^2) with 24-hour motor sequence task improvement, measured as percentage change in number of correctly typed sequences from training to retest.

* Difference between performance on the first three retest trials and the last three training trials,

† Difference between performance on the last three retest trials and the last three training trials.

correlated with amount of REM sleep.[24] However, no sleep correlations were seen in a prior MST study of healthy middle-aged participants.[21] Similar to that study, the current study found no significant relationships between sleep and sleep-related motor skill enhancement in this healthy elderly sample. Nor were any significant relationships observed between slow or fast spindle spectral power and immediate or plateau retest performance (Table 2).

MST Performance Data—Young Participants

Young participants averaged 27.5 correct sequences at training (Figure 1C, dashed line). Twenty-four hours later, on the first three retest trials, performance jumped to 31.7 ± 6.4 sequences (Figure 1C), which represented a significant immediate improvement of 16.2% over training (paired-samples *t*-test, $t(14) = 6.93$, $P < .001$; Figure 2 left, gray bar). Unlike the elderly participants, who demonstrated a highly significant increase from the first three to the last three retest trials (+1.8 sequences, $P < .001$), the younger cohort showed no such change (+0.3 sequences, 1.7%; paired-samples *t*-test, $t(14) = .43$, $P = .68$; Figure 1C), although plateau improvement was still highly significant (+4.5 sequences, 17.3 ± 2.2%; paired-samples *t*-test, $t(14) = 7.83$, $P < .001$; Figure 2 right, gray bar), demonstrating that, although MST speed jumps dramatically from training to the first three retest trials, performance thereafter remains unchanged.

Age Differences—24-Hour Wake Plus Sleep

In a 24-hour wake plus sleep protocol, young and elderly participants produced similar learning curves across the training session, with young participants improving by 5.4 sequences, versus a 3.4-sequence increase in the elderly participants, from the first three to the last three training trials. Accuracy across the 12 training trials was also similar (young, 93.0 ± 1.2%; elderly, 93.2 ± 1.3%, $t(29) = .10$, $P = .92$), although there was a notable difference in overall MST speed, with young participants typing more than twice the number of correct sequences by the end of training (27.5 ± 1.6 sequences) as the elderly sample (12.7 ± 1.0, $t(29) = 7.95$, $P < .001$).

Although the two age groups showed a similar degree of learning during the training session, the young participants demonstrated 16.2% immediate improvement after 24 hours, whereas the elderly participants only maintained their performance across the 24-hour interval, improving by a nonsignificant 2% ($t(29) = 2.81$, $P = .009$; Figure 2, left). Nevertheless, by the end of the retest session, the elderly participants attained a level of motor skill improvement strikingly similar to that of the young participants, increasing their performance by 17.4 ± 3.9%, compared with 17.3 ± 2.2% for young participants ($t(29) = .03$, $P = .98$; Figure 2, right). This finding clearly shows that elderly participants showed robust postsleep MST improvements that paralleled those observed in healthy young participants, although full expression of these improvements was not seen until the third retest trial (Figure 1B).

DISCUSSION

The primary objectives of the present study were to examine motor skill proficiency in healthy elderly participants and, more importantly, to determine whether motor skill performance is subject to sleep-dependent enhancement, as has been shown numerous times in healthy young participants.[4,6,24] Using a within-subjects design, MST performance was examined after a 12-hour period of wake and a 24-hour period containing a full day of wakefulness followed by a full night of sleep. Compared with a 22% performance decrease at immediate retest after 12 hours of wakefulness, performance after a full night of sleep was maintained (+2% change). Across the first three retest trials, wake participants showed rapid improvement (Figure 1B), but by the last three retest trials still had improved only by a nonsignificant 4% above training performance. This modest over-wake improvement stands in stark contrast to the significant 17% improvement observed at the retest plateau after 24 hours containing a full night of sleep. After 12 hours of wakefulness, retest performance in this group did not cross the training performance threshold until trial 11 of the retest session (Figure 1A), but after a 24-hour interval that included sleep, performance surpassed training performance on the second retest trial and was 14% above training levels by the third retest trial (Figure 1B), remaining essentially constant across the remainder of the retest session. These findings strongly suggest that sleep makes a unique and powerful contribution to the enhancement of motor skill performance in older adults, although the fullest expression of this enhancement is only expressed after the first few retest trials.

It might be suggested that the performance advantage observed after a 24-hour period including sleep over a briefer 12-hour period that contains wake only is a result of the mere passage of time, but if time were related to performance in a linear fashion, two outcomes would be expected: that immediate retest performance 24 hours after training would decrease by twice the 22% seen at the 12-hour time point, or that the plateau 4% improvement after 12 hours of wake would increase another 4% after an additional 12-hour interval. However, the findings suggest a clear nonlinear improvement over time, similar to previous research,[6] such that an additional 12-hour interval that includes a night of sleep produces immediate performance maintenance (24% above immediate retest performance after 12 hours of wakefulness) and a four fold greater plateau improvement.

Previous research has shown that aspects of motor skill ability decline with age.[25,26] The current study found that elderly participants performed a procedural motor sequence task much more slowly than healthy college participants. Although this observed difference in training performance is dramatic, with young participants completing more than two times as many sequences as the elderly participants at the start and end of training (Figure 1), both groups produced similar learning curves and similar accuracy over the 12-trial training session, suggesting that both groups executed and learned the task similarly, with elderly participants simply performing at a slower rate.

The age differences observed at training were also evident in immediate retest performance. In contrast to young participants who showed a robust 16% improvement at immediate retest, no performance enhancement was found in elderly participants, whose performance was virtually unchanged (+2%) from training to immediate retest. This nominal change in performance is also considerably less than the 12% improvement in one study of MST performance in healthy middle-aged participants,[21] although comparable with the nonsignificant 4.2% improvement seen in a second such study.[27]

When plateau improvement was examined across the last three retest trials in the elderly participants, a significant 17.4% increase was found in performance over training levels, which is essentially identical to the 17.3% enhancement achieved at the end of retest in the young participants. Thus, although young participants started the retest session well above training levels, their performance was unchanged across the remaining retest trials, increasing only 1% by the last three retest trials. The immediate retest performance lag in the elderly participants suggests that the task may have been more difficult for the elderly participants and that the first few retest trials were necessary to permit complete expression of the overnight improvement. Previous research showing that, when young participants perform a difficult, bi-manual 9-digit finger tapping sequence, they show a similar retest performance lag on the first retest trial, followed by a substantial speed increase across trials 2 and 3, supports the idea that this delayed expression of overnight improvement is related to task difficulty, rather than to age per se.[28]

The finding that MST performance is enhanced in healthy elderly participants after a time interval containing a night of sleep is consistent with previous research examining sleep-dependent motor skill performance in elderly adults. For example, one study showed that elderly participants' performance on a pursuit rotor task, when retested after a week's delay, showed the same proportional degree of improvement observed in their sample of young participants.[9] However, using a more-complex motor task, the SRTT, another study found that, after a night of sleep, reaction times of elderly participants were actually slower than their reaction times at training, whereas reaction times were significantly faster in young participants.[14] The difference in outcomes across this small sampling of studies may relate to the fact that the MST and pursuit rotor task are considerably simpler to execute and acquire than the SRTT, a task that requires greater mental agility and attentional resources to execute, because the 10-element sequences in this task require the processing of spatial and contextual information embedded within each sequence. It may be that the elderly participants in that study did not attain the level of task proficiency required to trigger sleep-dependent enhancement processes or that sleep in elderly adults loses its capacity to process these more complex tasks.

In young participants, multiple studies have revealed a relationship between overnight MST enhancement, the amount of Stage 2 sleep across the night,[4,8] and sleep spindle activity,[5,9,10] but in the current study's healthy elderly participants, there was a distinct lack of correspondence between sleep parameters and overnight MST performance. One possible explanation of this difference pertains to the study design employed here. The participants in the present study were trained in the morning and retested 24 hours later, with the sleep episode occurring at least 12 hours after training on the task. Previous studies with young participants have examined the effect of PSG-recorded sleep only when it closely followed training, suggesting that long periods of posttraining wakefulness may introduce additional factors that reduce the amount of variance that specific sleep correlates explain, such as the amount of Stage 2 sleep. Nevertheless, the similar lack of sleep-stage correlations in a midlife sample trained shortly before sleep[27] suggests that the lack of correlation may result simply from changes in sleep with age. Indeed, yet-unidentified age-related changes in the sleep–wake cycle may limit ability to observe the effect of specific sleep characteristics on motor skill enhancement. Further research examining the relationship between recorded sleep stages and overnight performance will be necessary to confirm whether this is a consistent finding in elderly samples.

Although general memory function and sleep quality change in an age-related fashion, this study demonstrates that sleep in elderly adults continues to optimize motor skill performance to levels proportional to those seen in healthy young participants, even though elderly participants perform at a markedly slower pace. It is hoped that these findings will pave the way for further exploration of the benefits of sleep on cognition in elderly adults.

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Author Contributions: Stickgold: study conception. McKinley: data acquisition. Tucker, McKinley, and Stickgold: study design, data analysis, manuscript preparation, and interpretation of results.

Sponsor's Role: None.

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