

Insufficient chunk concatenation may underlie changes in sleep-dependent consolidation of motor sequence learning in older adults

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Sleep enhances motor sequence learning (MSL) in young adults by concatenating subsequences (“chunks”) formed during skill acquisition. To examine whether this process is reduced in aging, we assessed performance changes on the MSL task following overnight sleep or daytime wake in healthy young and older adults. Young adult performance enhancement was correlated with nREM2 sleep, and facilitated by preferential improvement of slowest within-sequence transitions. This effect was markedly reduced in older adults, and accompanied by diminished sigma power density (12–15 Hz) during nREM2 sleep, suggesting that diminished chunk concatenation following sleep may underlie reduced consolidation of MSL in older adults.

[Supplemental material is available for this article.]

Optimal execution of motor skills relies on precise temporal sequencing of associated events. For young adults, sleep following learning, in the absence of further practice, enhances performance on motor sequence learning (MSL) tasks (Walker et al. 2002; Fischer et al. 2005; Nishida and Walker 2007; Doyon et al. 2009; Barakat et al. 2011; Wilson et al. 2012; Pace-Schott and Spencer 2013). This enhancement is significantly greater than that observed over an equivalent interval of wake, and is not merely a consequence of general increases in motor responding (Fischer et al. 2002; Spencer et al. 2006, 2007).

Recent work has suggested the importance of stage 2 non-rapid eye movement sleep (nREM2) for enhancing MSL (Walker et al. 2002; Nishida and Walker 2007; Peters et al. 2007; Tucker and Fishbein 2009). High frequency (12–15 Hz) thalamocortical oscillations, or sleep spindles, occurring during nREM2 have been implicated as a possible mechanism for sleep-related MSL improvements. These electrophysiological events induce long-term potentiation in the neocortex, a process crucial for memory consolidation (Sejnowski and Destexhe 2000; Rosanova and Ulrich 2005; Fogel and Smith 2006; Nishida and Walker 2007; Bergmann et al. 2008; Tucker and Fishbein 2009; Foge et al. 2013).

As motor sequence learning develops, distinct subsequences of movements are grouped together, a process termed “chunking” (Rosenbaum et al. 1983; Klapp 1995; Sakai et al. 2003). For instance, during the execution of a seven-item sequence (e.g., 2–4–2–3–4–1–3), items may be represented in memory as smaller subsequences, or “chunks” (e.g., 2–4–2, 3–4, and 1–3; Kennerly et al. 2004; Bo and Seidler 2009; Bo et al. 2009). With each chunk representing a distinct memory unit, slowest transitions are expected “between” chunks, reflecting additional memory retrieval effort. Conversely, the fastest transitions indicate movements “within” chunks, or within a memory unit. Consequently, efficient learning of the MSL task relies on motor

chunk concatenation, represented behaviorally as faster transitions between chunks (Verwey 2001; Wright et al. 2010). Kuriyama et al. (2004) demonstrated that this selective enhancement of the slowest transitions occurs maximally over sleep in young adults.

Post-sleep enhancement of MSL is reduced in older age (Spencer et al. 2007; Wilson et al. 2012; Fogel et al. 2013; Gudberg et al. 2015). Healthy older adults show general slowing in the execution of sequence learning tasks and fail to demonstrate a sleep benefit (Spencer et al. 2007; Wilson et al. 2012; Fogel et al. 2013). While prior studies in older adults showed no global change in response times following sleep or wake (Spencer et al. 2007; Wilson et al. 2012), no previous work has examined item-specific changes following sleep in an aging population. Such an approach has the potential to reveal the mechanism underlying the age-related decline in MSL.

We assessed changes in MSL performance in healthy young and older adults following an interval of sleep and wake. Of interest were the specific points in the sequence where improvements were greatest. To understand how age-related changes in sleep physiology contribute to MSL, sleep was recorded using polysomnography (PSG) (see Supplemental Materials). We hypothesized that failure to concatenate motor chunks over nREM2 underlies diminished sleep-dependent consolidation of MSL in older adults.

Thirty-four young (18–25 yr; Wake: $n = 14$; Sleep: $n = 20$) and 39 older adults (59–79 yr; Wake: $n = 19$; Sleep: $n = 20$), with no history of neurological, psychiatric, or sleep disorders (see Supplemental Materials for inclusion/exclusion criteria) were randomly assigned to be trained on an MSL task between 7

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Article is online at <http://www.learnmem.org/cgi/doi/10.1101/lm.043042.116>.

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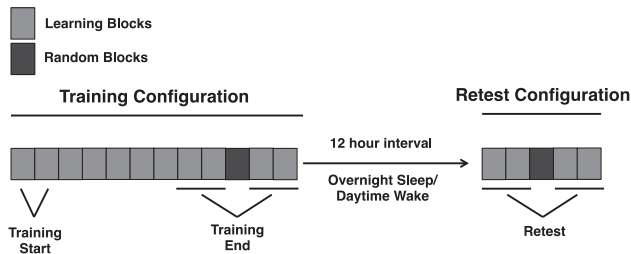


Figure 1. Experimental design for the motor sequence learning task showing 12 training and 5 retest blocks. A random sequence was presented during block 10 of Training and block 3 of Retest.

and 10 a.m. (Wake Condition) or 7 and 10 p.m. (Sleep Condition), then retested 12 h later. All procedures were approved by the Institutional Review Board, and participants provided informed consent prior to the experiment. Participants repeatedly typed a seven-item numerical sequence (4–1–3–2–4–2–3) on a computer keyboard using their nondominant hand in blocks consisting of 30-sec typing and 30-sec rest opportunities. Keypresses and time between keypresses were recorded; performance was measured as total number of correctly typed sequences (speed), and the ratio of correctly typed to total number of keypresses (accuracy) per block. Participants completed 12 blocks at Training, and five blocks at Retest. A random sequence was presented during Training block 10 and Retest block 3 in order to assess general changes in MSL performance that were not specific to the learned sequence (Fig. 1).

The Stanford sleepiness scale (SSS), which correlates strongly with objective measures of attention and memory (Hoddes et al. 1973), was used to measure alertness during each session. To assess the impact of age and time-of-day on subjective alertness, we conducted an Age (Young, Old) \times Condition (Wake, Sleep) ANOVA for SSS at session 1 (SSS₁) and 2 (SSS₂). A main effect of Age ($F_{(1,69)} = 4.696$, $P = 0.034$), a trend-level main effect of Condition ($F_{(1,69)} = 3.756$, $P = 0.057$), and a significant Age \times Condition interaction ($F_{(1,69)} = 10.047$, $P = 0.002$) was observed for SSS₁ scores. There were no main effects or significant interactions for SSS₂ scores. Due to these observed differences in alertness at session 1, comparisons of task performance across age groups and conditions are reported both with and without SSS₁ scores as a covariate. Means, standard deviations, and group comparisons for all other questionnaire measures can be found in Table 1 of the Supplemental Materials.

To examine general increases in MSL task performance, as well as possible time-of-day effects on motor sequencing performance, we measured differences in speed for the random blocks using an Age (Young, Old) \times Condition (Wake, Sleep) \times Block (Training Block 10 speed versus Retest Block 3 speed) mixed ANOVA. We found a main effect of Block ($F_{(1,69)} = 4.852$, $P = 0.032$), with all participants having superior performance on the random block during Retest ($M = 4.95$, $SD = 3.89$) compared with Training ($M = 4.03$, $SD = 3.10$). However, these differences were accounted for by sleepiness at encoding (SSS₁; $F_{(1,68)} = 2.466$, $P = 0.121$). All other main effects and interactions were nonsignificant ($P > 0.08$), and did not change when SSS₁ scores were added to the model.

Motor sequence learning was assessed across the training session by comparing speed and accuracy from Training Start (average of blocks 1 and 2) to Training End (average of blocks 8, 9, 11, and 12; random sequence block 10 was excluded) using Age (Young, Old) \times Condition (Wake, Sleep) \times Training (Training Start, Training End) mixed ANOVAs. Older adults completed fewer correct sequences across the training session compared with

young adults (main effect of "Age"; $F_{(1,69)} = 10.768$, $P = 0.002$; Fig. 2A). However, both age groups demonstrated significant improvement in speed with training (main effect of "Training"; $F_{(1,69)} = 151.995$, $P < 0.001$; Fig. 2A). There was a trend-level main effect of Condition ($F_{(1,69)} = 3.375$, $P = 0.071$), which was nonsignificant when SSS₁ scores were added to the model ($F_{(1,68)} = 2.488$, $P = 0.119$). No significant interactions were found ($P > 0.1$), and all other effects remained the same when controlling for SSS₁ scores (see Supplemental Materials). In contrast, although accuracy improved from Training Start to Training End (main effect of "Training"; $F_{(1,69)} = 5.309$, $P = 0.024$), the difference was no longer significant once SSS₁ scores were added to the model ($F_{(1,68)} = 0.047$, $P = 0.828$). In addition, we found a main effect of Condition ($F_{(1,69)} = 6.156$, $P = 0.016$), with overall accuracy being lower when learning occurred in the evening, not accounted for by subjective sleepiness ($F_{(1,68)} = 5.774$, $P = 0.019$). All other main effects and interactions were nonsignificant ($P > 0.2$), and did not change when controlling for SSS₁ scores (see Supplemental Materials).

Our data indicate an overall age-related decline in speed, not accuracy, of motor sequence execution. In addition, subjective alertness accounted for the variability in MSL speed across Wake and Sleep conditions, but not for accuracy. These baseline differences in accuracy between conditions may be relevant when considering post-training changes in task performance. However,

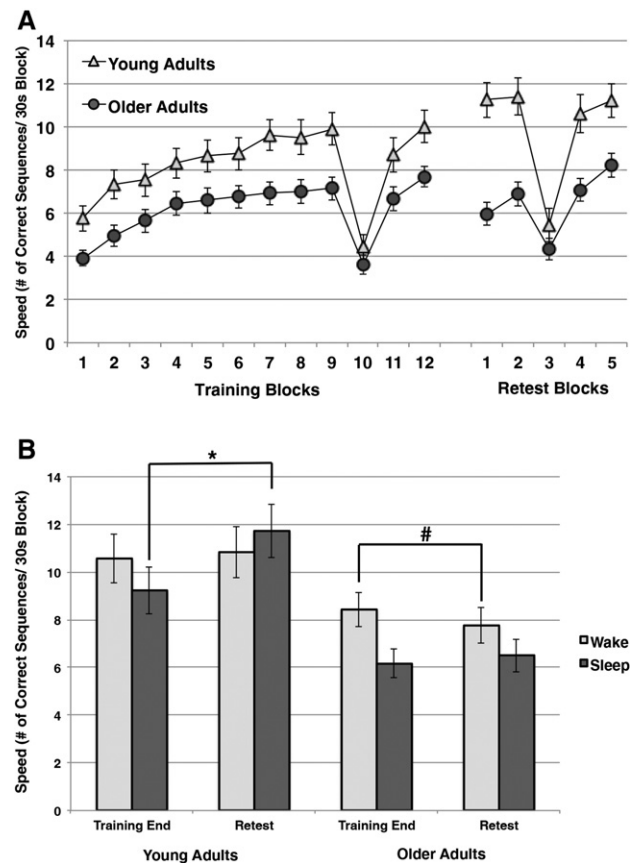


Figure 2. (A) Learning curves for motor sequence learning during Training and Retest Sessions for young and older adult groups (B) Comparison of MSL speed from Training End (average of trials 8, 9, 11, and 12 during session 1) to Retest (average of trials 1, 2, 4, and 5 during session 2). Error bars represent standard error. (*) $P < 0.001$, (#) $P < 0.06$.

optimal memory retrieval processes occur at different circadian schedules, based on age (Ancoli-Israel 2009) and the nature of the task (May et al. 2005): optimal implicit memory retrieval occurs at off-peak times (morning for young; evening for old), while explicit memory retrieval at on-peak times. MSL is a complex cognitive task involving both implicit and explicit memory systems (Willingham 1999). Therefore, in order to robustly account for individual variability in learning and retention across morning and evening testing times, we compare absolute measures of performance from Training to Retest as a repeated measure, in addition to controlling for individual differences in subjective sleepiness.

To assess MSL performance changes across the offline interval (daytime wake or overnight sleep), we compared speed and accuracy across Sessions (Training End, Retest), Conditions (Wake, Sleep), and Age groups (Young, Old), using mixed ANOVAs. Older adults demonstrated reduced offline MSL speed improvements relative to young adults (main effect of "Age"; $F_{(1,69)} = 15.654, P < 0.001$). We observed an overall improvement in speed from Training End to Retest (main effect of "Session"; $F_{(1,69)} = 7.760, P = 0.007$), which was reduced to a trend when SSS₁ scores were covaried ($F_{(1,68)} = 3.399, P = 0.070$). We also observed significant Session \times Age ($F_{(1,69)} = 12.617, P = 0.001$) and Session \times Condition ($F_{(1,69)} = 14.147, P < 0.001$) interactions. No additional main effects or interactions were observed ($P > 0.1$), and remained so when controlling for SSS₁ scores (see Supplemental Materials).

Given the significant interactions with Age and Condition, we conducted post hoc paired samples *t*-tests comparing speed from Training End to Retest within conditions, to highlight the differential effects of the offline interval on MSL task performance across young and older adults. For young adults, MSL speed did not change over the wake interval ($t_{(13)} = -0.379, P = 0.711$; Fig. 2B), but significantly improved over sleep ($t_{(19)} = -5.115, P < 0.001$; Fig. 2B). For older adults, there was a near-significant decline in MSL speed over wake ($t_{(18)} = 2.063, P = 0.054$; Fig. 2B), with no significant change following sleep ($t_{(19)} = -1.560, P = 0.235$; Fig. 2B). Therefore, there was a substantial benefit of sleep on MSL task performance in young adults, with enhanced execution of the sequence following an interval of overnight sleep. In contrast, older adults demonstrated retention of skills following sleep, with no further enhancement in task performance. Taking into account the marked reduction in speed following wake in older adults, these data suggest that an interval of overnight sleep following learning provides passive protection from waking interference, merely preventing loss of skills on the MSL task in aging.

The Session \times Age \times Condition mixed ANOVA for accuracy revealed lower accuracy in the Sleep, compared with Wake, Condition (main effect of "Condition"; $F_{(1,69)} = 7.120, P = 0.009$). We also observed a trend-level main effect of Session ($F_{(1,69)} = 3.310, P = 0.073$), indicating improvements in accuracy from Training End to Retest; however, this trend disappeared when SSS₁ scores were added to the model ($F_{(1,69)} = 2.483, P =$

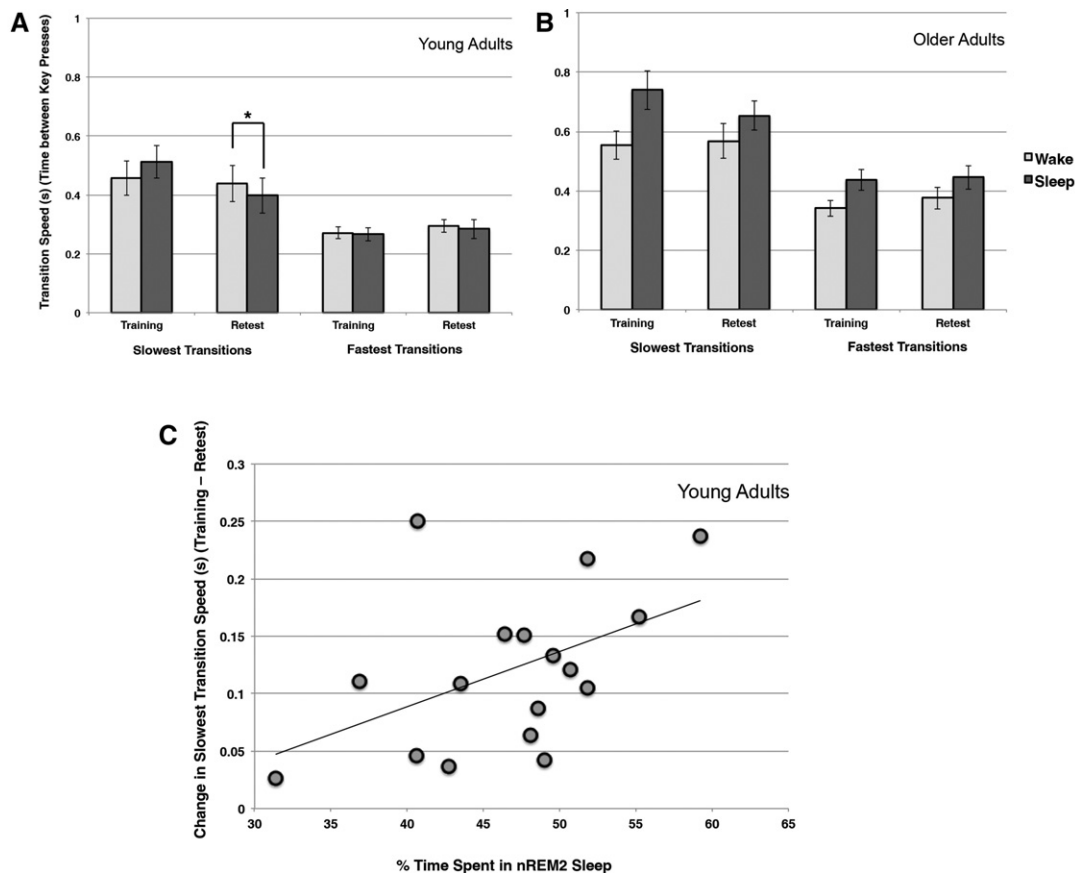


Figure 3. (A) Mean transition speeds for slowest and fastest transitions at Training End and Retest in young adults. (B) Mean transition speeds for slowest and fastest transitions at Training End and Retest in older adults. (C) Correlation between percentage of time spent in nREM2 across the night and change in the slowest transition speeds for young adults. Error bars represent standard error. (*) $P < 0.001$.

0.120). There was a significant Session \times Age ($F_{(1,69)} = 4.515, P = 0.037$) interaction, but all other main effects and interactions were nonsignificant ($P > 0.1$), and remained so when accounting for SSS₁ scores (see Supplemental Materials). Post hoc paired samples t -tests revealed a significant improvement in accuracy from Training End to Retest for the young adult Sleep ($t_{(19)} = -2.859, P = 0.01$), but not Wake condition ($t_{(13)} = -0.540, P = 0.598$). For older adults, accuracy at Training End and Retest were comparable for both the Sleep ($t_{(19)} = 0.096, P = 0.925$), and Wake ($t_{(18)} = 0.268, P = 0.792$) conditions.

To examine motor sequence chunk concatenation across the offline interval, fastest and slowest transition points (i.e., time between keypresses) within correctly typed sequences were identified at Training End for each participant, then compared with the corresponding transitions at Retest. Differences between conditions for transition speeds at Retest were determined using an ANCOVA, controlling for transition speeds at Training End (centered to the mean). In addition to controlling for individual variability in task performance, this statistical approach allowed us to account for possible effects due to regression to the mean (Barnett et al. 2005). At Retest, young adults in the Sleep condition were significantly faster on the slowest transition points compared with those in the Wake condition ($F_{(1,31)} = 12.283, P = 0.001$; Fig. 3A), while fastest transitions were equivalent across both conditions ($F_{(1,31)} = 0.096, P = 0.759$; Fig. 3A). Older adults in the Sleep and Wake conditions demonstrated equivalent transition speeds at Retest on the slowest ($F_{(1,36)} = 1.233, P = 0.274$; Fig. 3B) and fastest transitions ($F_{(1,36)} = 1.512, P = 0.227$; Fig. 3B). Effects did not change when SSS₁ scores were added to the model for both age groups (see Supplemental Materials).

Sleep physiology was analyzed from 17 young and 17 older adults (Supplemental Table 2). To determine the relationship between MSL performance benefits and sleep physiology, we used Pearson correlations, correlating the percentage time spent in nREM2, as well as nREM2 spectral power density in the alpha, beta, delta, sigma, and theta frequency ranges, and change in performance from Training End to Retest. For young adults, percent time spent in nREM2 was positively correlated with change in accuracy (Retest – Training; $r = 0.600, P = 0.011$), but not change in speed (Retest – Training; $r = 0.413, P = 0.100$). However, change in speed ($r = 0.579, P = 0.015$), not accuracy ($r = 0.331, P = 0.195$), was strongly correlated with sigma power density during nREM2. Further, we observed a near-significant positive correlation between change in transition speed (Training – Retest) for the slowest transitions and percent time in nREM2 ($r = 0.476, P = 0.054$; Fig. 3C), but not with sigma power density during nREM2 ($r = 0.083, P = 0.753$). There was no significant relationship between spectral power in any other frequency range and performance changes on the MSL task. Despite greater retention of skills over sleep relative to wake in older adults, there was no significant correlation between sleep physiology and overnight performance changes on the MSL task (see Supplemental Table 3).

Consistent with previous research in young adults (Kuriyama et al. 2004), our findings support the importance of sleep for achieving faster task execution by means of motor sequence chunk concatenation. Specifically, greater unification between chunks following sleep resulted in more fluid execution of the sequence as a whole. Furthermore, our findings emphasize the significance of both the quantity and the microarchitectural properties of nREM2 sleep on MSL performance benefits. While we did not see a direct correlation between improvements on the slowest transition points and sigma power density, this does not preclude the role of sleep spindles in motor chunk concatenation: nREM2 sleep duration “in conjunction” with sleep spindle activity has been shown to result in the activation of the neocor-

tical circuits necessary for experience-dependent changes (Sejnowski and Destexhe 2000; Tucker and Fishbein 2009).

A number of studies have indicated a weakening of the relationship between sleep and memory with age, particularly for procedural tasks (Siengsukon and Boyd 2009; Korman et al. 2015). In the current study, young adults showed an enhancement in task performance following sleep, whereas older adults demonstrated a preservation of learned motor sequencing skills over an interval of sleep. This lack of post-sleep enhancement in MSL has been attributed to a greater susceptibility to interference in aging (Roig et al. 2014; King et al. 2016). The detriment to task performance that we observe following a period of wake supports such an explanation; however, our data illustrate that reduced sleep benefit on MSL is specifically a consequence of insufficient chunk concatenation. Using fMRI, King et al. (2016) demonstrated that aging is associated with altered temporal dynamics of hippocampal and striatal engagement through the various stages of sequence learning. We postulate that nREM2-mediated processes underlying offline sequence learning are compromised as a result of age-related changes, and may be compensated via additional training and perhaps additional sleep bouts. Further research will need to address this claim.

Acknowledgments

The study was supported by NIH R01 AG040133. We would also like to acknowledge Jesse McClure, PhD for his contribution to MSL task optimization.

References

- Ancoli-Israel S. 2009. Sleep and its disorders in aging populations. *Sleep Med* **10**(Suppl 1): S7–S11.
- Barakat M, Doyon J, Debas K, Vandewalle G, Morin A, Poirier G, et al. 2011. Fast and slow spindle involvement in the consolidation of a new motor sequence. *Behav Brain Res* **217**: 117–121.
- Barnett AG, van der Pols JC, Dobson AJ. 2005. Regression to the mean: what it is and how to deal with it. *Int J Epidemiol* **34**: 215–220.
- Bergmann TO, Molle M, Marshall L, Kaya-Yildiz L, Born J, Roman Siebner H. 2008. A local signature of LTP- and LTD-like plasticity in human NREM sleep. *J Neurosci* **27**: 2241–2249.
- Bo J, Seidler RD. 2009. Visuospatial working memory capacity predicts the organization of acquired explicit motor sequences. *J Neurophysiol* **101**: 3116–3125.
- Bo J, Borza V, Seidler RD. 2009. Age-related declines in visuospatial working memory correlate with deficits in explicit motor sequence learning. *J Neurophysiol* **102**: 2744–2754.
- Doyon J, Korman M, Morin A, Dostie V, Hadj Tahar A, Benali H, et al. 2009. Contribution of night and day sleep vs. simple passage of time to the consolidation of motor sequence and visuomotor adaptation learning. *Exp Brain Res* **195**: 15–26.
- Fischer S, Hallschmid M, Elsner AL, Born J. 2002. Sleep forms memory for finger skills. *Proc Natl Acad Sci* **99**: 11987–11991.
- Fischer S, Nitschke MF, Melchert UH, Erdmann C, Born J. 2005. Motor memory consolidation in sleep shapes more effective neuronal representations. *J Neurosci* **25**: 11248–11255.
- Fogel SM, Smith CT. 2006. Learning-dependent changes in sleep spindles and stage 2 sleep. *J Sleep Res* **15**: 250–255.
- Fogel SM, Albouy G, Vien C, Popovicci R, King BR, Hoge R, Jbabdi S, Benali H, Karni A, Maquet P, Carrier J, Doyon J. 2013. fMRI and sleep correlates of the age-related impairment in motor memory consolidation. *Hum Brain Mapp* **35**: 3625–3645.
- Gudberg C, Wulff K, Johansen-Berg H. 2015. Sleep-dependent motor memory consolidation in older adults depends on task demands. *Neurobiol Aging* **36**: 1409–1416.
- Hoddes E, Zarcone V, Smythe H, Phillips R, Dement WC. 1973. Quantification of sleepiness: a new approach. *Psychophysiology* **10**: 431–436.
- Kennerley SW, Sakai K, Rushworth MF. 2004. Organization of action sequences and the role of the pre-SMA. *J Neurophysiol* **91**: 978–993.
- King BR, Saucier P, Albouy G, Fogel SM, Rumpf J, Klann J, Buccino G, Binkofski F, Classen J, Karni A, Doyon J. 2016. Cerebral activation during initial motor learning forecasts subsequent sleep-facilitated memory consolidation in older adults. *Cereb Cortex*: 1–14.

- Klapp ST. 1995. Motor response programming during simple and choice reaction time: the role of practice. *J Exp Psychol Hum Percept Perform* **21**: 1015–1027.
- Korman M, Dagan Y, Karni A. 2015. Nap it or leave it in the elderly: a nap after practice relaxes age-related limitations in procedural memory consolidation. *Neurosci Lett* **606**: 173–176.
- Kuriyama K, Stickgold R, Walker MP. 2004. Sleep-dependent learning and motor-skill complexity. *Learn Mem* **11**: 705–713.
- May CP, Hasher L, Foong N. 2005. Implicit memory, age, and time of day: paradoxical priming effects. *Psychol Sci* **16**: 96–100.
- Nishida M, Walker MP. 2007. Daytime naps, motor memory consolidation and regionally specific sleep spindles. *PLoS One* **2**: 341.
- Pace-Schott EF, Spencer RMC. 2013. Age-related changes in consolidation of perceptual and muscle-based learning of motor skills. *Front Aging Neurosci* **5**: 83.
- Peters KR, Smith V, Smith CT. 2007. Changes in sleep architecture following motor learning depend on initial skill level. *J Cogn Neurosci* **19**: 817–829.
- Roig M, Ritterband-Rosenbaum A, Lundbye-Jensen J, Nielsen JB. 2014. Aging increases the susceptibility to motor memory interference and reduces off-line gains in motor skill learning. *Neurobiol Aging* **35**: 1892–1900.
- Rosanova M, Ulrich D. 2005. Pattern-specific associative long-term potentiation induced by a sleep spindle-related spike train. *J Neurosci* **25**: 9398–9405.
- Rosenbaum DA, Kenny SB, Derr MA. 1983. Hierarchical control of rapid movement sequences. *J Exp Psychol Hum Percept Perform* **9**: 86–102.
- Sakai K, Kitaguchi K, Hikosaka O. 2003. Chunking during human visuomotor sequence learning. *Exp Brain Res* **152**: 229–242.
- Sejnowski TJ, Destexhe A. 2000. Why do we sleep? *Brain Res* **15**: 208–223.
- Siengsukon CF, Boyd LA. 2009. Sleep to learn after stroke: implicit and explicit off-line motor learning. *Neurosci Lett* **451**: 1–5.
- Spencer RMC, Sumn M, Ivry RB. 2006. Sleep-dependent consolidation of contextual learning. *Curr Biol* **16**: 1001–1005.
- Spencer RMC, Gouw AM, Ivry RB. 2007. Age-related decline in sleep-dependent consolidation. *Learn Mem* **14**: 480–484.
- Tucker MA, Fishbein W. 2009. The impact of sleep duration and subjective intelligence on declarative and motor memory performance: how much is enough? *J Sleep Res* **18**: 304–312.
- Verwey WB. 2001. Concatenating familiar movement sequences: the versatile cognitive processor. *Acta Psychologica* **106**: 69–95.
- Walker MP, Brakefield T, Morgan A, Hobson JA, Stickgold R. 2002. Practice with sleep makes perfect: sleep-dependent motor skill learning. *Neuron* **35**: 205–211.
- Willingham DB. 1999. Implicit motor sequence learning is not purely perceptual. *Mem Cognit* **27**: 561–572.
- Wilson JK, Baran B, Pace-Schott EF, Ivry RB, Spencer RMC. 2012. Sleep modulates word-pair learning but not motor sequence learning in healthy older adults. *Neurobiol Aging* **33**: 991–1000.
- Wright DL, Rhee JH, Vaculin A. 2010. Offline improvement during motor sequence learning is not restricted to developing motor chunks. *J Mot Behav* **42**: 317–324.

Received May 27, 2016; accepted in revised form June 14, 2016.