Sleep Enhances Off-line Spatial and Temporal Motor Learning After Stroke

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INTRODUCTION

•Sleep facilitated off-line motor learning of a continuous tracking task in individuals with stroke[1,2].

•Individuals with damage to the prefrontal cortex (as a result of either stroke, tumor, or trauma) benefited from sleep to promote off-line learning of a finger sequencing task[3].

•Sleep does not appear to be important for learning and memory consolidation in older individuals[1,2,4,5].

•The role of sleep in off-line motor learning of a task where either spatial or temporal accuracy can be improved to facilitate motor learning is largely unknown.

- •Spatial regularities of the SRT task were enhanced by sleep in young, healthy individuals; the motor component improved over the day without sleep[6].
- •Suggests that distinct aspects of motor memory may be supported by different mechanisms of off-line learning for young, healthy individuals[7].

•Presently unclear if particular components of a motor skill task (i.e., spatial and/or temporal components) are preferentially enhanced off-line by sleep in individuals following stroke.

Purpose: Investigate whether spatial tracking accuracy, temporal tracking accuracy, or both are enhanced by sleep during off-line motor learning of the component parts of a continuous tracking task in a group of individuals with chronic middle cerebral artery stroke.

METHODS

Participants: 15 individuals with stroke (ST) and 15 sex- and age-matched neurologically intact individuals (CT) practiced a continuous tracking task in the evening (sleep groups) or in the morning (no-sleep groups) and underwent retention testing 12 hrs later (+/- 1 hour).

Hand Used: ST - ipsilesional hand; CT - same as matched ST

Task Description:
Practice: 10 blocks of 10 trials per block; each trial 1 random and 1 repeated segment in counterbalanced order (12.5s each segment; trial length 25s with 2s baseline trial divider).
Delayed Retention: 1 block of 10 trials

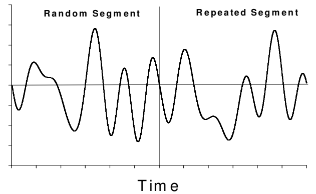

Figure 1. Example of trial. This example shows the random segment followed with repeated segment.

METHODS (cont'd)

Participants:

	Sex	Age	SSS1	SSS2	PSQI	GDS	Average sleep
ST Sleep (n=8)	6 M; 2 F	59.5 (12.5)	2.50 (1.2)	2.38 (1.2)	4.88 (2.2)	5.25 (3.8)	6.89 (1.3)
ST No-Sleep (n=7)	4 M; 3 F	64.0 (6.1)	1.71 (.95)	2.45 (.79)	6.14 (3.5)	5.57 (5.6)	7.93 (.68)
CT Sleep (n=8)	6 M; 2 F	60.0 (12.9)	2.88 (1.36)	2.25 (.71)	6.63 (3.7)	5.86 (1.9)	7.05 (.74)
CT No-Sleep (n=7)	4 M; 3 F	62.8 (6.2)	2.71 (1.11)	2.71 (.76)	6.14 (2.9)	4.80 (3.2)	7.12 (1.5)

Table 1. Descriptive Information for participants. Data are mean (standard deviation). M= male; F= female; SSS1= Stanford Sleepiness Scale at practice session; SSS2= Stanford Sleepiness Scale at retention testing; PSQI= Pittsburgh Sleep Quality Index; GDS= Geriatric Depression Scale; Average sleep=average amount of sleep the week prior to testing determined by sleep log. For those participants who did not keep a sleep log, the average amount of sleep filled in for the PSQI was used to calculate an average sleep score.

	Time Post-Stroke (months)	UEFM	Orpington
ST Sleep	79.6 (61.0)	39.0 (17.6)	2.80 (.83)
ST No-Sleep	42.6 (31.6)	55.4 (12.4)	2.11 (.50)

Table 2. Descriptive information for stroke participants. Data are mean (standard deviation). Orpington Prognostic Score & upper extremity motor portion of the Fugl-Meyer (UEFM) utilized to characterize ST upper extremity function.

Group	*Subject Number*	*Lesion Side*	*Lesion Classification*	*Specific Lesion Location*
Sleep	1	Right	Sub-cortex	Basal ganglia
	2	Right	Cortex	Frontal, parietal, superior temporal cortices
	3	Right	Sub-cortex	Posterior limb of internal capsule
	4	Right	Cortex & Sub-cortex	Frontal and parietal cortex, basal ganglia
	5	Right	Cortex & Sub-cortex	Internal capsule; temporal and parietal lobes
	6	Left	Cortex & Sub-cortex	Postcentral gyrus, insular cortex, temporal and frontal lobes
	7	Right	Cortex & Sub-cortex	Parieto-temporal lobe, putamen
	8	Right	Cortex	Superior and middle temporal gyrus of frontal lobe
No-sleep	1	Right	Cortex	Temporal-parietal-occipital cortex
	2	Left	Sub-cortex	Lenitiform nucleus, putamen, claustrum, insula
	3	Right	Sub-cortex	Posterior limb of internal capsule
	4	Right	Cortex & Sub-cortex	Insular, parietal cortex
	5	Left	Sub-cortex	Thalamus and posterior limb of internal capsule
	6	Right	Sub-cortex	Corona Radiata and upper portion of internal capsule
	7	Left	Sub-cortex	Cingulate Gyrus; Posterior cingulate cortex

Table 3. Lesion location of participants after stroke.

METHODS (cont'd)

Data Analysis:
•Root Mean Square Error (RMSE) was calculated for repeated segment of each trial
•Median RMSE was calculated for each block
•Time series analysis deconstructed overall tracking accuracy into spatial and temporal components:

- •Each participant's tracking pattern data points were serially correlated with the target pattern data points until maximum correlation coefficient achieved (Fig 2)
- •Time lag of tracking (temporal tracking accuracy) = number of data points the participant's tracking data was moved along the target data represents; converted to ms by multiplying by 20 ms
- •Adjusted RMSE (spatial tracking accuracy) = RMSE that remained following the lag correction

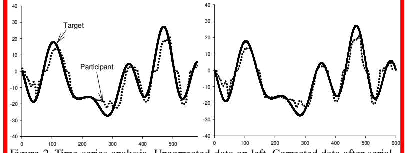

Figure 2. Time series analysis. Uncorrected data on left. Corrected data after serial correlation on right.

•Off-line learning score for adjusted RMSE and time lag of tracking = Median RMSE of repeated segment block at retention – last repeated segment block at practice

Statistical Analysis: Parameter estimates determined significant change in performance from the last practice block to retention. One-way ANOVAs examined group differences on descriptive tests.

RESULTS

Spatial Tracking Accuracy: Only the stroke sleep group demonstrated off-line improvement at retention.

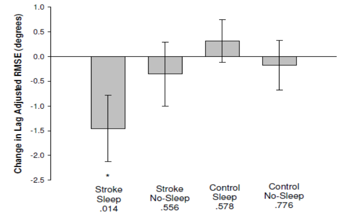

Figure 3. Off-line learning of spatial tracking component. A negative score indicates less spatial tracking error at retention compared to the last block of practice. Error bars are SEM. * indicates significance.

RESULTS (cont'd)

Temporal Tracking Accuracy: Only the stroke sleep group demonstrated off-line improvements at retention.

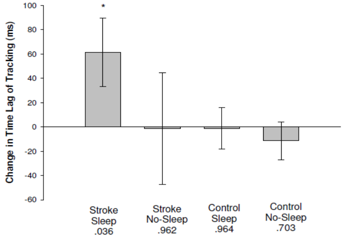

Figure 4. Off-line learning of temporal tracking component. A positive score indicates improved time lag of tracking at retention compared compared to the last block of practice. Error bars are SEM. * indicates significance.

Group Descriptives: No group difference in age (p=.783), Stanford Sleepiness Scale at practice (p=.268) or retention (p=.783), PSQI (p=.713), GDS (.975), average sleep (p=.378), time-post stroke (p=.173), Orpington (p=.08), FM (p=.06)

DISCUSSION

•Sleep enhances both spatial and temporal accuracy components of a continuous tracking task in individuals with stroke.

•Healthy older adults fail to demonstrate off-line improvements of either component of movement regardless of the passage of sleep or time.

•Findings may be due to:

- Change in sleep architecture following stroke; possibly maintain REM sleep and increase in stage-2 non-REM sleep[8] compared to published norms[9] as well as increase in sleep spindle activity[10].
- Spared hippocampus may support off-line learning of spatial tracking accuracy component of task[11].
- Spared cerebellum may support off-line learning of temporal tracking accuracy component of task[11].

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