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ORIGINAL RESEARCH

Influence of Circadian Rhythms on the Temporal Features of Motor Imagery for Older Adult Inpatients

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Abstract

Objective: To examine the circadian modulation on motor imagery quality for older adult inpatients to determine the best time of day to use motor imagery in rehabilitation activities.

Design: Time series posttest only.

Setting: Inpatient rehabilitation center.

Participants: Participants included older adult inpatients (N=34) who were hospitalized for diverse geriatric or neurogeriatric reasons. They were able to sit without assistance, manipulate objects, and walk 10m in <30 seconds without technical help or with a walking stick.

Intervention: None.

Main Outcome Measures: The executed and imagined durations of writing and walking movements were recorded 7 times a day (9:15 AM–4:45 PM), at times compatible with the hours of rehabilitation activities. Motor imagery quality was evaluated by computing the isochrony index (ie, absolute difference between the average duration of executed and imagined actions) for each trial and each inpatient. The cosinor method was used to analyze the time series for circadian rhythmicity.

Results: Imagined movements duration and isochrony index exhibited circadian modulations, whereas no such rhythmic changes appeared for executed movements. Motor imagery quality was better late in the morning, at approximately 10:18 AM and 12:10 PM for writing and walking, respectively.

Conclusions: Cognitive and sensorimotor aspects of motor behaviors differed among the older adults. The temporal features of motor imagery showed a clear circadian variation. From a practical perspective, this study offers information on an effective schedule for motor imagery in rehabilitation activities with older adult inpatients.

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Motor imagery practice is described by cognitive neuroscientists as the mental rehearsal of voluntary motor acts without any overt motor output.[1] Many experimental studies have shown its usefulness in motor learning and rehabilitation.[2-4] The beneficial effect of motor imagery on motor performance can be explained by simulation theory, which posits that imagined and executed actions share common mechanisms[5] and result in similar structural and functional effects. However, motor imagery interventions are not always successful for patients or healthy subjects.[6,7] The efficiency of motor imagery may vary depending on several factors, including motor imagery quality, motor imagery modality, sex, and age.[8] In the present experiment, we specifically examined circadian modulation on motor imagery quality in a geriatric hospitalized population to determine the best time of day to use motor imagery in rehabilitation activities.

In motor learning and rehabilitation programs, motor imagery practice relies on the subjects' ability to generate motor images.[9-14] Motor imagery questionnaires[15-17] and mental chronometry[18-20] have been used to assess motor imagery ability. Motor imagery questionnaires provide information about the vividness of motor imagery, whereas mental chronometry provides information about the temporal coupling between executed and simulated actions (ie, isochrony principle). Some experiments have shown that the temporal congruence between overt and covert actions can vary throughout the day for young healthy participants. Gueugneau et al[21] were the first to question the possible circadian modulation of imagined actions that

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engaged different parts of the body (eg, upper and lower limbs). For both writing and walking tasks (8m), those authors reported similar rhythmic changes within a period of 24 hours for the duration of executed and simulated actions and for the isochrony principle. They observed that the ability to form accurate motor images is higher in the afternoon (2:00 PM−8:00 PM) than in the morning (8:00 AM−11:00 AM) or evening (11:00 PM). The influence of both task constraints (duration, complexity) and circadian modulations on isochrony between overt and covert actions has been examined for simple (8m), complex (7m slalom with 25kg), short (2m), and long (40m) walking tasks.[22] For the complex, short, and long walking tasks, no influence of circadian modulation was detected. By contrast, circadian modulation influences isochrony between the executed and simulated actions for the simple walking task; participants' imagery quality was higher between 2:00 PM and 8:00 PM, as observed for writing and walking.[21] These data suggested that circadian modulation on motor imagery is not systematic but task-related; however, this aspect has not always been reported. Task difficulty did not actually modify circadian modulation for arm pointing movements,[23] with higher temporal equivalence between executed and imagined arm movements in the afternoon. Overall, these studies emphasized that motor imagery quality was not constant throughout the day; however, questions remain regarding the importance of task difficulty in these circadian modulations. This time-of-day effect on motor action simulation should be considered when scheduling motor imagery practice during motor learning or rehabilitation sessions. However, if task constraints prevail over that of circadian modulation in some circumstances, this means that the daily schedule of motor imagery practice may not be generalizable. The fluctuations in motor imagery quality throughout the day for older hospitalized adults remain an important and unresolved issue in rehabilitation science. This question is all the more important because a task that is simple for young adults may be more complicated for older adults.

The effect of age on circadian rhythms has been highlighted in the literature for a wide range of cognitive tasks measuring memory, attentional capacities, and executive functioning.[24] Many studies assessing cognitive aging have shown that performance of the older adults deteriorates throughout the day, whereas it improves for younger adults.[25,26] The general pattern that emerges is that time-of-day modulation in cognitive abilities revealed higher accuracy in the early afternoon and lower accuracy in the morning for young adults. By contrast, time-of-day accuracy in older adults tends to be in the morning. However, there is a more complex picture than a mere morning advantage regarding the cognitive abilities of older adults. There is some evidence that aging is associated with a reduction in the amplitude of circadian modulation on cognitive abilities[27,28] and nonoptimal time of day.[26]

To our knowledge, no study to date has investigated the effects of circadian modulation on motor imagery quality in a geriatric hospitalized population engaged in a daily program of rehabilitation activities. The use of motor imagery to help reduce the impact of age-related sensorimotor impairment is justified by behavioral and neuroimaging studies.[29] Psychophysiological data revealed that motor imagery quality is relatively preserved with aging for a wide range of movements, except for constrained movements (eg, fast and accurate arm displacements between small targets).[30] Neuroimaging data confirmed engagement of the motor network during simulation of actions in older adults.[29] Although temporal congruence between executed and simulated actions has been shown to be equivalent in younger and older adults for unconstrained and usual movements,[31,32] the importance of circadian modulation on motor imagery efficiency for older adult inpatients in rehabilitation programs remains to be examined. It may be that results reported for young adults are not applicable to older inpatients[21-23] in light of the finding that cognitive abilities in older adults decline from morning to afternoon, whereas the reverse phenomenon appears true for younger adults. Therefore, the aim of the present study was to examine possible changes in motor imagery quality for older adult inpatients throughout the day to effectively schedule motor imagery practice in their rehabilitation activities.

> ***List of abbreviations:***
> **ANOVA analysis of variance**

Methods

Participants

Thirty-four right-handed older adult inpatients voluntarily participated (mean age, 80.2±6.7y; 16 men). They were hospitalized for diverse geriatric or neurogeriatric reasons (eg, cerebral ischemic accident, asthenia, general state alteration, fall, chronic obstructive pulmonary disease, depression, chondrocalcinosis, knee hemarthrosis). All inpatients were able to sit without assistance, manipulate objects, and walk 10m in <30 seconds without technical help or with a walking stick. Inpatients were excluded from participation if they had nonstabilized infections or clinical evaluations incompatible with the protocol (eg, uncorrected optical problems, severe dementia, psychiatric condition). All inpatients gave informed written consent for their participation in the study, and the protocol was approved by the ethics committee of the rehabilitation center where the experiment took place.

The Edinburgh Handedness Inventory[31] was used to evaluate patients' laterality (mean, .90±.15). The short version of the Kinesthetic and Visual Imagery Questionnaire[17] was used to ensure that all patients were able to simulate movements. The test measures the clarity of visual and kinesthetic images of movements from the first perspective with a 5-point scale (maximum score of 25 for each modality). Patients' scores indicated good visual (18.24±3.95) and kinesthetic (16.21±4.57) imagery abilities. Because all patients were hospitalized, the schedule allowed for similar diurnal activity and nocturnal rest. The experiment took place in a quiet room with a constant ambient temperature (22°C±1°C).

Tasks and materials

Participants performed 2 tasks: a writing task and a walking task.[21] During the writing task the participants were seated in a comfortable chair in front of a table. They were asked to write or imagine writing the French words "simulation mentale" on a sheet of paper in a natural self-selected speed. In both cases the patients performed the task with their eyes open and the pen held above the paper. The only difference was that no writing movement was made when patients imagined writing. During the walking task the patients stood upright before walking at a natural self-selected speed along a straight path of 10m. For the imagined walking task the patients were allowed to sit to avoid becoming tired.

For both tasks, the duration of executed and imagined movements was recorded with an electronic stopwatch[21] (Geonaute