



# A PROBABILISTIC SEQUENCE LEARNING PARADIGM REVEALS NO OFFLINE CONSOLIDATION OF SEQUENCE LEARNING, BUT DAYTIME CONSOLIDATION OF OVERALL SPEED.

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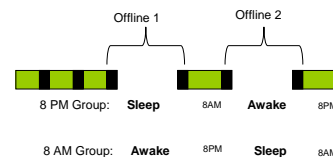
## ABSTRACT AND BACKGROUND:

Using a probabilistic sequence learning task, the Alternating Serial Response Time (ASRT) task (Howard and Howard 1997), it was found that no consolidation, whether during awake or sleep, occurred for motor sequence learning. The ASRT task contains an alternating regularity, which causes certain triplets of trials to occur at a higher frequency than others. In this modified version, cues and instructions were added allowing for half the subjects to also gain explicit knowledge of the pattern. Probe blocks in which cues were removed, allowed for implicit learning to also be measured in the group with explicit knowledge.

No consolidation of sequence learning was found either over sleep or over the day. This was true for both reaction time and accuracy. However, daytime consolidation was found for overall speed. This finding is in contrast to other studies (Walker et al. 2002, Robertson et al 2004) which use deterministic sequence learning paradigms. Using a Serial Response Time (SRT) task, Robertson et al. (2004) found that awareness modified sleep benefits with sleep-dependent consolidation for explicit sequence learning, and time-dependent consolidation for implicit sequence learning. Further studies using TMS showed that offline improvements during the day were different in nature from improvements that occurred during the night, and that goal orientation was consolidated overnight, where motor sequence was consolidated over the day (Robertson et al., 2005, Cohen et al. 2005).

Several features of the present study may account for our different results. First, consolidation might be different for the probabilistic sequences used here compared to the deterministic ones used earlier. Second, the present study likely offers a purer measure of implicit learning in that the nature of the regularity makes it difficult to gain awareness. Third, the present design offers a continuous measure of implicit learning (trial type effects) that is distinct from overall speed and accuracy. Fourth, our design might not be offering a good measure of the effects of explicit learning, since explicit knowledge does not necessarily increase the trial type effect.

## METHODS:



### Alternating Serial Response Time Task (ASRT)

Repeating sequence every other trial, alternating with random events (e.g. 1r2r3r4r...).

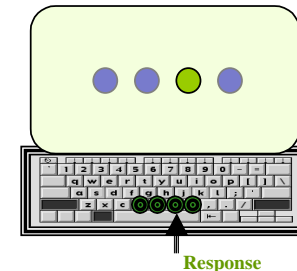
Initial Session: Nine epochs of 5 blocks each, 80 trials per block.  
Second and Third Session: 4 epochs of 5 blocks each.

CUED epochs (in green): Event colors alternate; Gray trials follow a pattern and black trials do not.

UNCUED epochs (in black): All trials black.

For CUED epochs, subjects are explicitly told the nature of the regularity (Intentional instructions) or are not told of any regularity (Incidental instructions).

For UNCUED epochs, no subject is told of the regularity, although the regularity is identical to that in the cued epochs.



### Participants:

- 32 undergraduates from Georgetown
- 9 in each cell, varying instruction (incidental or intentional) and time of first testing (8am or 8pm)

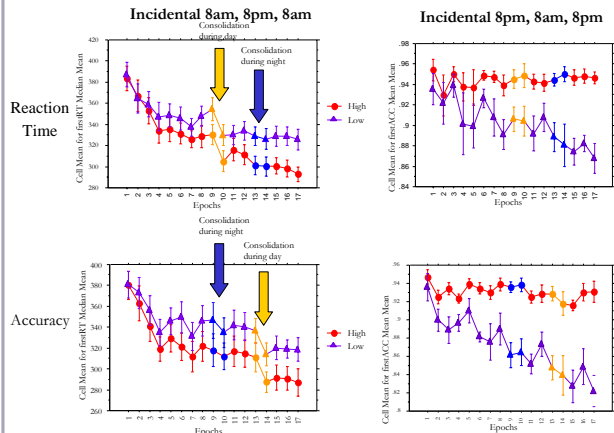
### Tests of Explicit Awareness:

- Sequence Generation Task
- Interview
- Post-test Generation Task
- Card Sorting

## RESULTS: OFFLINE CONSOLIDATION

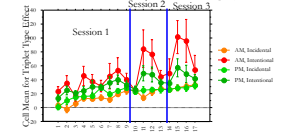
### Box 1: No offline consolidation for implicit or explicit learning of sequence

- Measure of sequence learning: Difference (in accuracy or in RT) between high versus low frequency “triplets” of trials (Howard et al. 2004). (i.e., triplet type effects)
- Low frequency triplets always fall on random trials. High frequency triplets may fall on pattern or random trials.

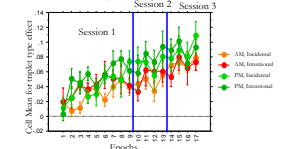


### Box 2: Triplet Type Effects For Incidental and Intentional Groups

#### Reaction Time (Low - High)



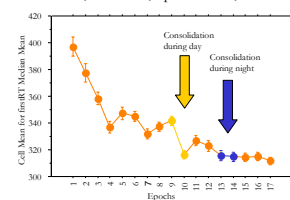
#### Accuracy (High - Low)



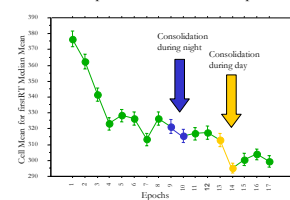
### Box 3: Awake Time leads to offline consolidation for overall speed

#### Overall Reaction Time (Mean of Median RT)

Incidental, 8am first, 8pm second, 8am third

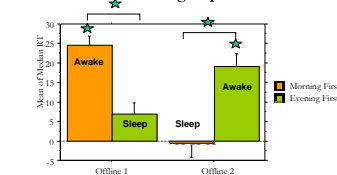


Incidental, 8pm first, 8am second, 8pm third

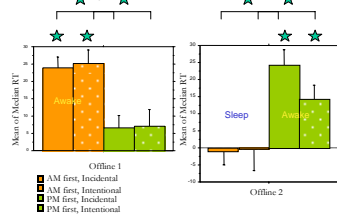


#### Offline Changes for Overall RT

##### Both instruction groups



##### Split by instruction



Offline 1 = RT epoch 10 - RT epoch 9  
Offline 2 = RT epoch 14 - RT epoch 13

★ = P < 0.01

## CONCLUSION:

- No offline consolidation for implicit sequence learning (Box 1)
  - regardless of whether people have explicit knowledge (Box 2)
- Offline consolidation during the day for overall speed (Box 3)
  - regardless of whether people have explicit knowledge (Box 3)

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