Detecting memory reactivation in human sleep with EEG classifiers

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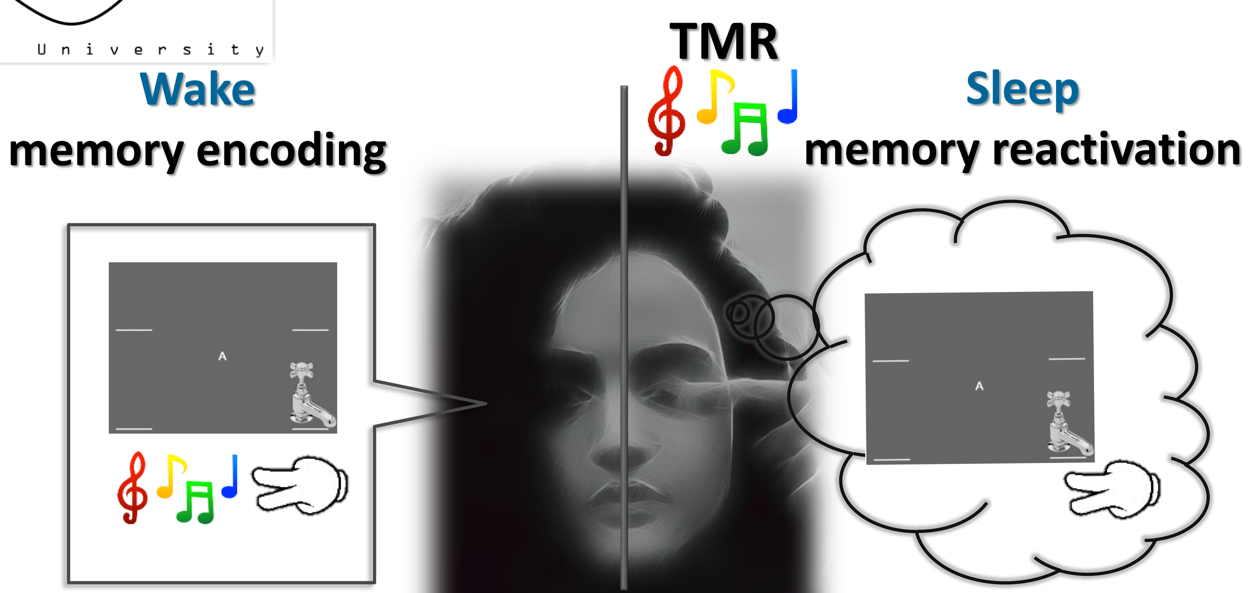

1. Introduction

Memories are spontaneously reactivated during our sleep. Targeted Memory Reactivation (TMR) is a method in which sounds/odours that were associated with a memory during encoding are subsequently re-presented during sleep to trigger memory reactivation [1, 2, 3]. Here, participants performed a serial reaction time task in which sounds cued four different finger presses. The sounds were then re-played in order during slow wave sleep (SWS) or rapid eye movement sleep (REM). We used machine learning to identify reactivations after this TMR in sleep and study the characteristics of these reactivations.

2. Methods

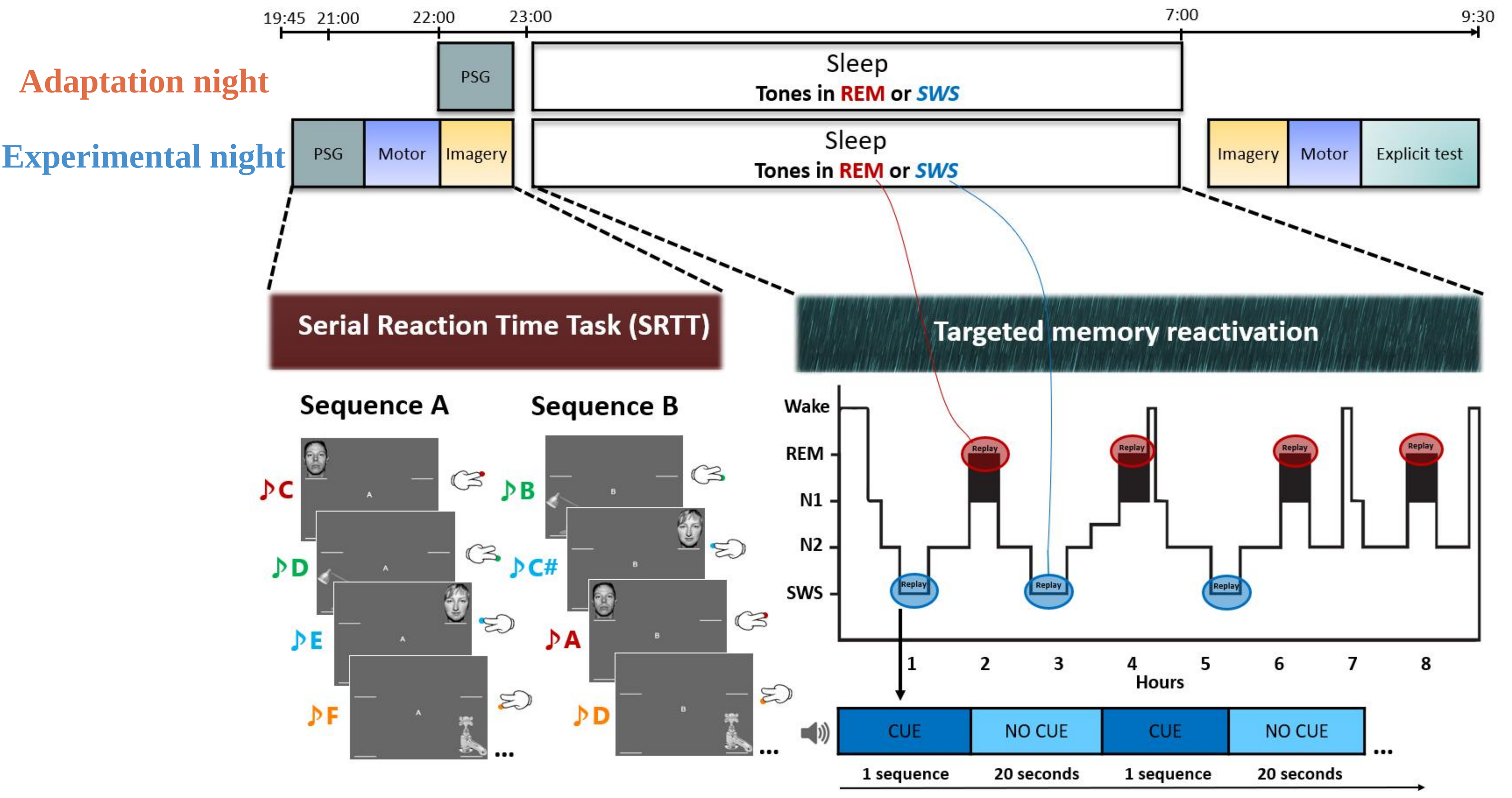

Fig. 1: Adaptation night : tones are played during sleep, but these are not yet associated with any task.
Motor : Training on Serial Reaction Time Task (SRTT) ~ 1 hour.
Imagery : Participants imagine doing the SRTT while seeing and hearing stimuli, but not moving.
Experimental night : Tones played during sleep to reactivate this task.

3. Motor Imagery classification during wake to locate time of interest (toi)

- Wake-to-wake motor imagery classification of left vs. right hand to determine a Time of Interest (TOI)..
- Features were extracted by calculating time-domain amplitude averages of 80ms around time points.
- The classifier was trained on a specific time point and tested with all time points to build one row in the time x time classification illustrated in Figure 2. A threshold of 0.85 was used to determine the TOI ([0.7 to 1.1] sec.).

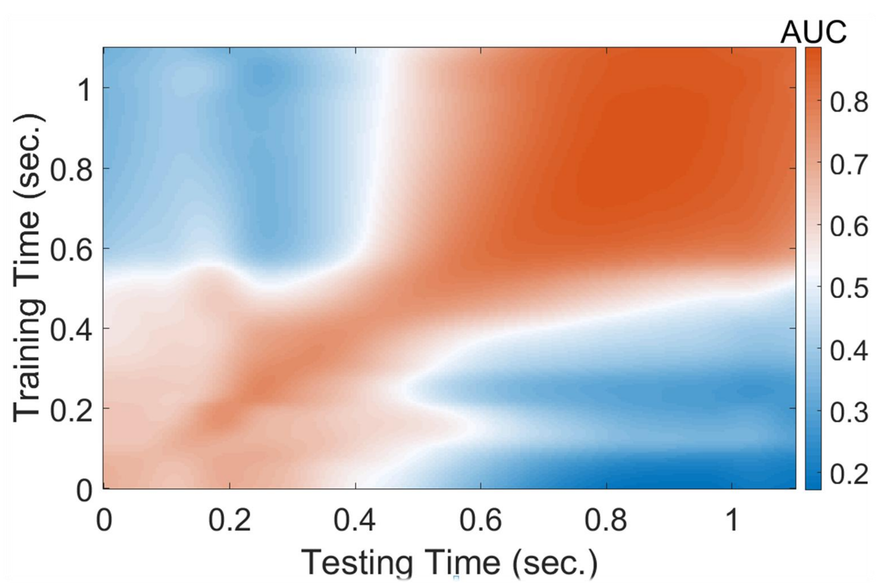

Fig. 2: Grand average classification AUC of wake motor imagery using a sliding 80ms smoothing window and LDA classifier. TOI is defined from [0.7 1.1] sec.

4. Classification of Memory reactivation across time reveals more than one reactivation after each sound cue

- Training classifier with wake and testing with sleep.
- Features were the concatenated averages inside the TOI.
- Classifier was applied it to sleep using the sliding window approach as shown in Figure 3.

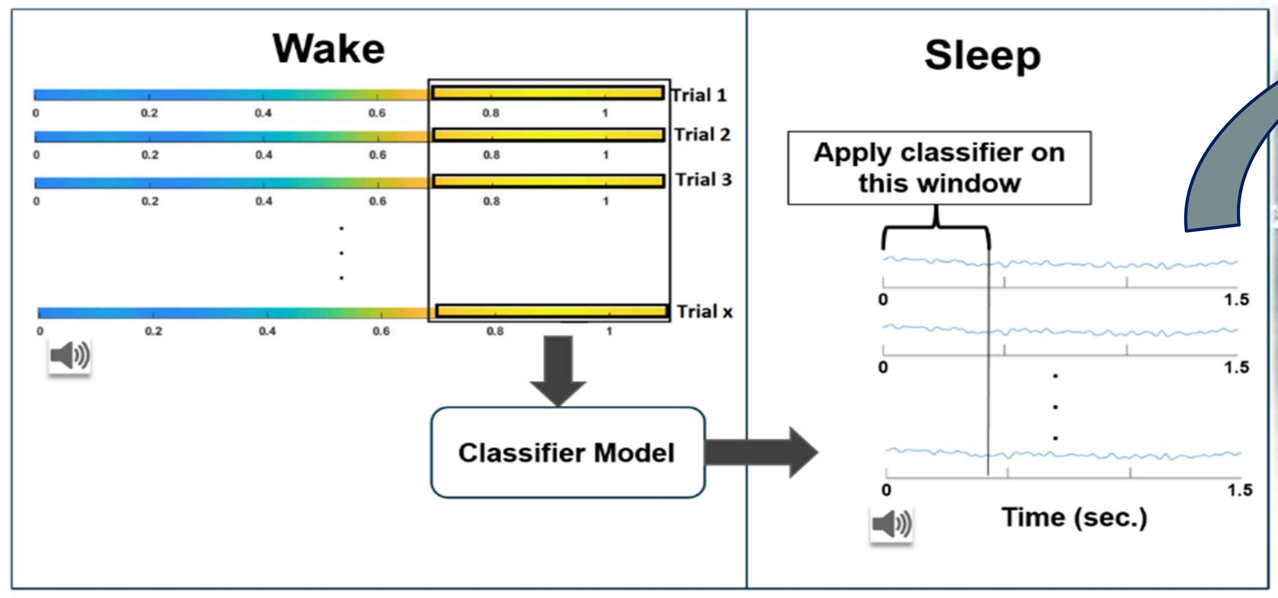

Fig. 3:
- A sliding window wake-to-sleep classification was applied for both the experimental night (exp) and adaptation (adp) "control" night.

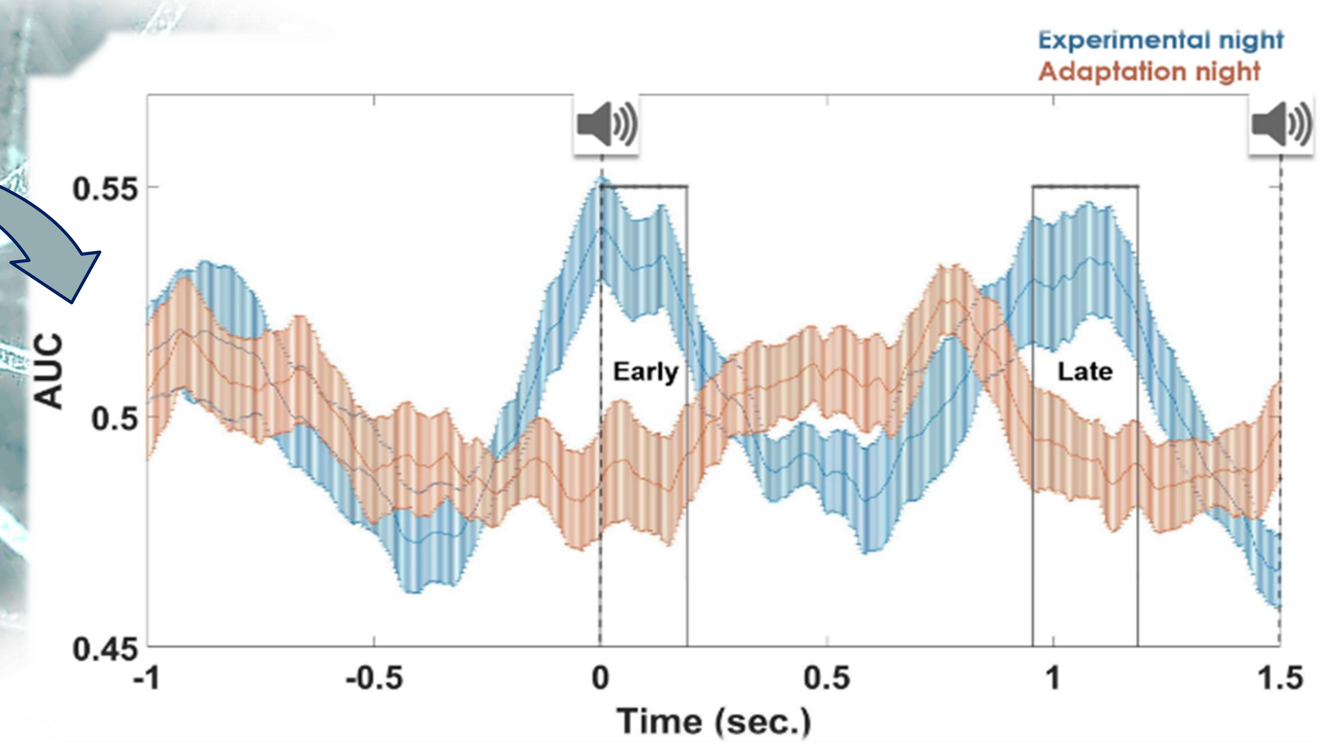

Fig. 4:
- Two clusters showed higher classification performance for experimental vs. adaptation night.
- Classification was derived from motor channels, (early cluster, $p < 0.01$ late cluster, $p < 0.01$).

5. Types of reactivations

- Not a re-occurring reactivation, only one reactivation type in most trials: early or late (with proportions: 46.2% and 45.1% respectively of total reactivations).
- Performance of the two classification peaks differed across stimulation time, as the late peak drops in performance for a period near the centre.

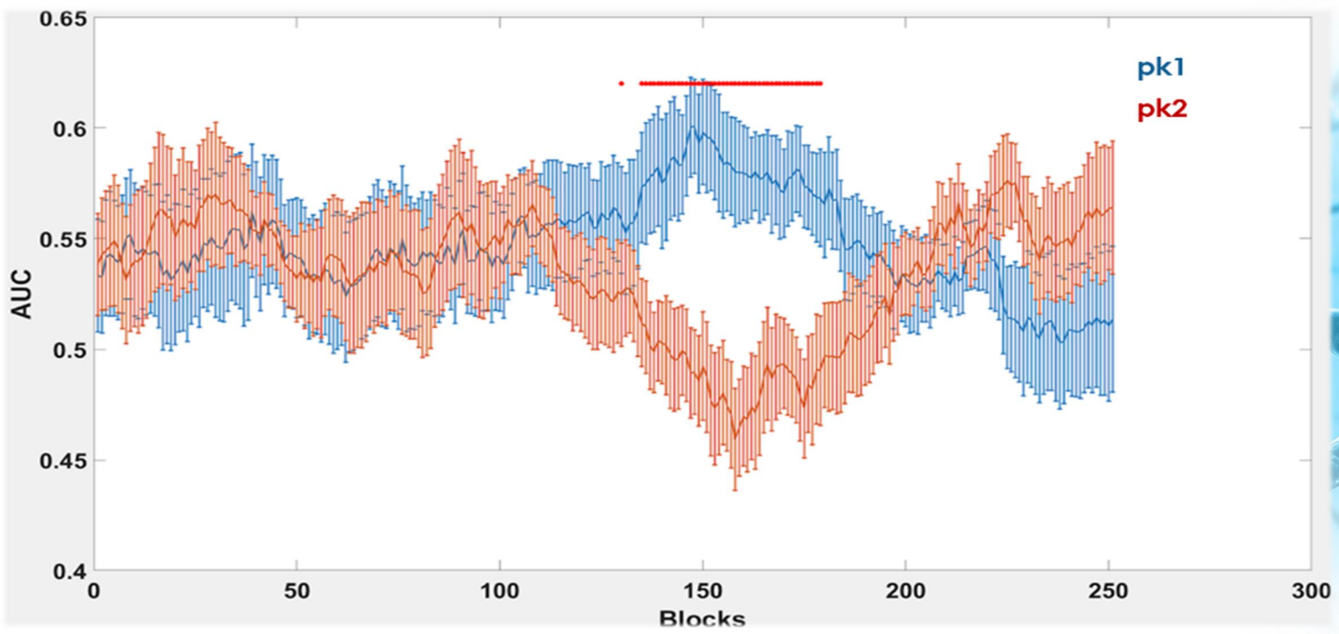

Fig. 5: performance of classification peaks throughout stimulation time, x-axis shows the beginning of each 50-trial block.

6. TMR should preferably occur on the down-to-up transition of the SO

- Sounds during the down-to-up transition of the SO in order trigger a higher proportion of correct classification.

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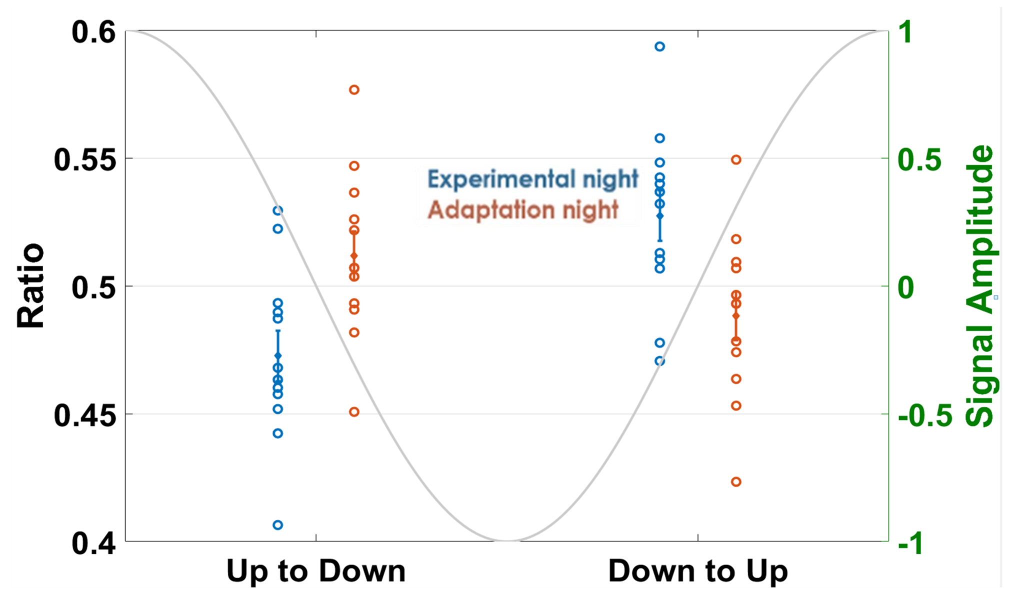

Fig. 6: Comparing proportion of correct trials at the two transitions for the experimental and adaptation nights (paired t-test, P = 0.018).

7. Correlation of classification performance with behaviour

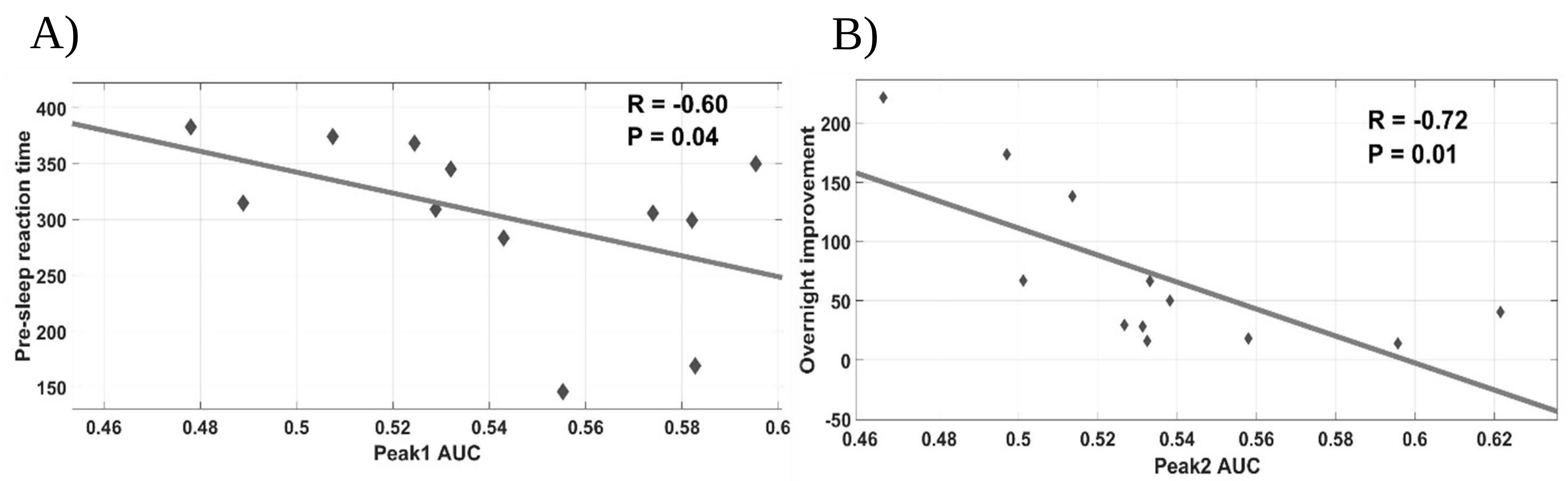

Fig. 7:
A) The faster participants are pre-sleep the stronger the early reactivation (R= -0.60, p=0.04).
B) Classification of the second peak predicted overnight performance decay (R= -0.72, p=0.01).

8. Can we predict reactivation using pre-cue SO features?

- We trained a second classifier using pre-cue SO features to discriminate between correct and incorrect trials.
- The features included: SO amplitude, phase, negative and positive halves duration, etc.
- Classification in the experimental night was greater than when we classify correct and incorrect trials of the adaptation night, p = 0.04.
- This suggests that the features of the ongoing SO play an important role in determining reactivation
- In future, we may be able to use this to guide us on when to deliver TMR sounds.

References

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