HIPPOCAMPAL RESPONSE AT TRAINING PROMOTES INSIGHT AFTER SLEEP

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INTRODUCTION
Insight denotes a mental restructuring leading to a sudden gain in explicit knowledge allowing qualitative changes in behavior (1). It has been reported that sleep, by restructuring new memory representations (2), facilitates extraction of explicit knowledge and insightful behavior (3). Here we aimed to evidence the functional neuroanatomical basis of sleep-dependent changes promoting insight. To do so, we tested whether the neural basis of memories formed during the training session is different in subjects who would gain insight after a night of sleep than in subjects who would not.

METHODS
Subjects were trained to the Number Reduction Task (4), in which each trial requires to compute 7 responses from a given 8-digit sequence, by applying two explicit rules. However, a third rule, hidden in the material, allows giving the response after two digits only (the last 3 responses mirrors the previous 3 responses such that the second response coincides with the final solution). When participants gain insight, they select the final solution anticipatively and speed up the decision process.
Thirty-six healthy subjects (age: 22+/-1.76; 17 females) were trained for 4 blocks (30 trials each), then retested for 7 blocks after eight hours of sleep. Mean reaction time (RT) was computed for each of the sequential responses (up to 7) at each session. Only correct responses were considered.
Subjects were scanned during training and testing sessions using a 3T fMRI scanner (Siemens, Erlangen; 32 slices, voxel size:3.4x3.4x3, TR:2130ms, TE:40ms, FA:90°). Using SPM2 (http://www.fil.ion.ucl.ac.uk/spm/spm2), responses to inputs 2-4 (HALF1) and to inputs 5-7 (HALF2; determined by the hidden rule) and their modulation by RTs were modelled at the individual level. Individual summary statistic images were used in a random effect analysis. Inferences were made at $p<0.05$, corrected for multiple comparisons on small volumes of interest (5 mm radius).

RESULTS
Four participants who demonstrated explicit knowledge of the hidden rule during the training session were excluded from analyses. Sixteen participants gained insight at testing ('solvers', S), whereas 16 others did not ('nonsolvers', NS).
No significant difference in RTs was found between S and NS during training ($p=0.94$). A two-way ANOVA revealed a general decrease of RTs across sessions [$F(4,16)=15.7$, $p<0.001$] and RTs' difference between input positions [$F(6,26)=12.9$, $p<0.001$]. Planned comparisons showed shorter RTs for responses contingent upon to the hidden rule (positions 5 and 7), as compared to their mirror (positions 2 and 4).
The differential BOLD response between HALF2 and HALF1 components (reflecting the implicit learning of the hidden rule) was significantly larger in S than NS subjects in the left hippocampus [–24 –18 –20; Z-value =3.54; $p_{svc}=0.01$] (Fig.1).

CONCLUSION

Our findings indicate that hippocampal activity at training is a crucial factor in the sleep-dependent restructuration of memories that will lead to insightful behavior.

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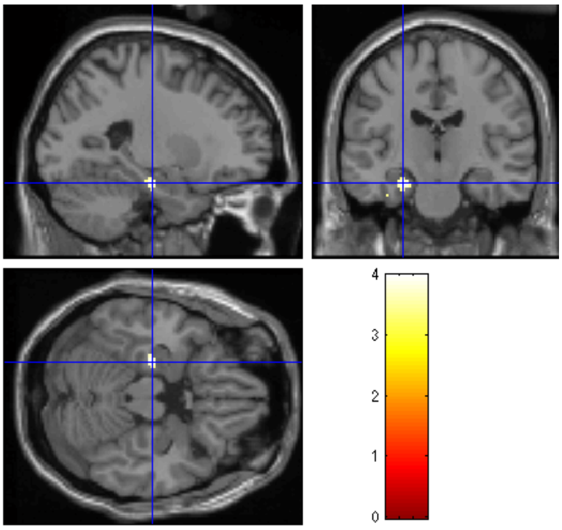

Figure 1: Input condition [HALF2 vs HALF1; modulated by RTs] by subsequent insight behaviour [S vs NS] during training session in the left hippocampus