Sleep to Remember

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There is evidence that sleep after learning can provide a qualitative change to memories. Wagner and others (2004) showed this using a number reduction task originally developed by Thurstone and Thurstone (1941) for testing intelligence. In this task, participants are shown strings of digits and are instructed to process each string as fast as possible and name the final result as soon as they know it. They are taught how to reach the solution by sequentially processing the digits according to a set of rules. However, there is a hidden structure in the sequences, such that the participant, once gaining insight into this hidden structure, can give the correct answer without having to go through the whole sequence (Fig). In the experiment, the participants first practiced 3 blocks each containing 30 sequences, which was not sufficient to produce insight into the hidden structure but still induced a memory representation of the task. Then, an eight-hour interval followed that covered a period of overnight sleep or wakefulness or a wake period during daytime, before participants were retested on another 10 blocks. At retesting, more than twice as many participants of the sleep group gained insight into the hidden structure as compared to both wake-control groups. Importantly, additional controls showed that sleep did not facilitate insight when the participants had not practiced the tasks before sleep, that is, when no representation of the task was encoded beforehand.



Fig. Sleep facilitates gain of explicit knowledge.

A, Number reduction task, illustrated by an example trial. On each trial, a different string of eight digits was presented. Each string was composed of the digits 1, 4, and 9. For each string, participants had to determine a digit defined as the "final solution" of the task trial. This could be achieved by ①sequentially processing the digits pairwise from left to right according to two simple rules. One, the "same rule," states that the result of two identical digits is just this digit (for example, 1 and 1 results in 1, as in response 1 here). The other rule, the "different rule," states that the result of two nonidentical digits is the remaining third digit of this three-digit system (for example, 1 and 4 results in 9, as in response 2 here). After the first response, comparisons are made between the ②preceding result and the next digit. The seventh response indicates the final solution (Fin), to be confirmed by pressing a separate ③key. Instructions stated that only this final solution was to be determined and this could be done at any time. Not mentioned to the participants, the strings were generated in such a way that the last three responses always mirrored the previous three responses. This implies that in each trial the second response coincided with the final solution (arrow). Participants who gain insight into this hidden structure abruptly cut short sequential responding by pressing the solution key immediately after the second response.

B, Experimental design: An eight-hour period of ④nocturnal sleep, nocturnal wakefulness, or daytime wakefulness separated an initial training phase (three blocks) from later retesting (10 blocks).

C, Effects of sleep and wakefulness on the occurrence of insight. ⑤Columns indicate percentage of participants gaining insight into the hidden structure in the three conditions of the main experiment (gray), in which participants either slept (at night) or remained awake (at night or during daytime) between initial training and retesting, and in two supplementary conditions (hatched), where participants were tested after nocturnal sleep or daytime wakefulness in the absence of initial training before these periods. Modified from Wagner and others (2004).

＊In statistical hypothesis testing, P（p-value or probability value）is the probability of obtaining test results at least as extreme as the results actually observed during the test, assuming that the null hypothesis is correct. The null hypothesis（帰無仮説）is a general statement or default position that there is no relationship between two measured phenomena or no association among groups.

[*The Neuroscientist*, 2006]
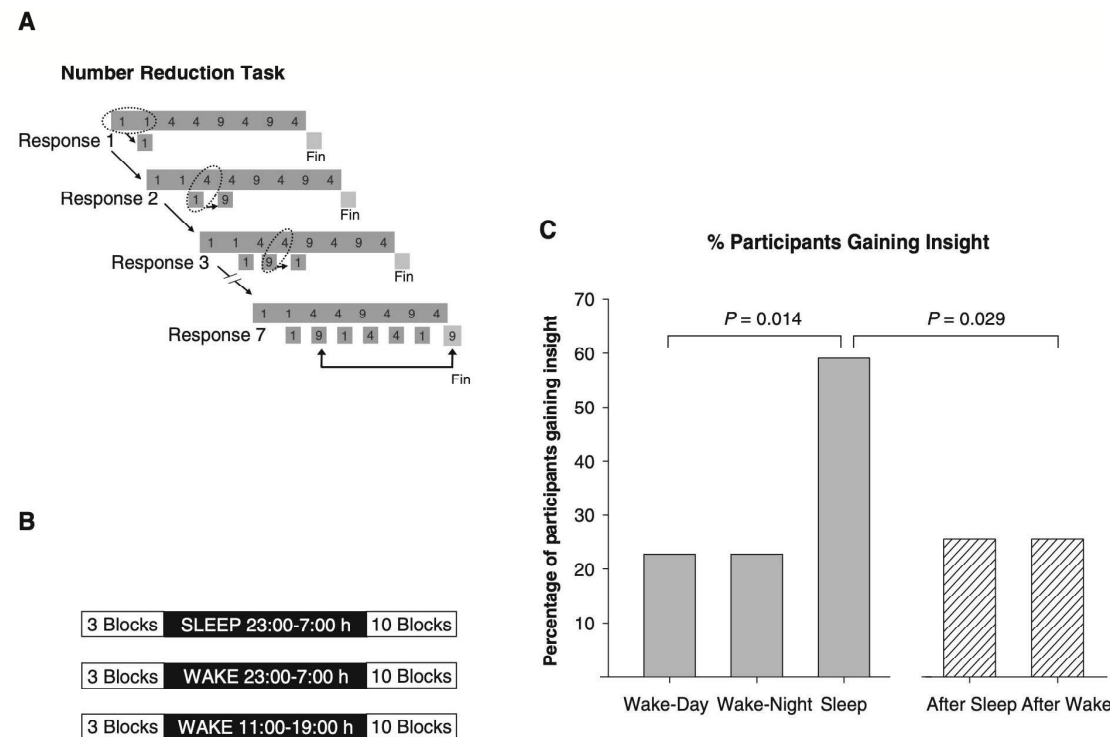
問１　空所に適当な数値または日本語を補え.

　この実験すべてを含めると，被験者は [　　] のグループに分けられ，最大で [　　] の文字列について一連の操作を行い，答えを見つける作業を行った．実験の結果としては，訓練とテストとの間の８時間に [　　　　] グループは，対照群と比べると p 値 [　　] で洞察を得られる確率が高まることが分かった．また，予め訓練をせずテストのみを受けた対照群は，p 値 [　　] で [　　　　] に拘わらず，洞察を得る確率が低かった．

問２　被験者が行う演算の規則を示す表に，適当な値を補え.

　この実験で扱う文字列を $s_n = (d_1, d_2, d_3, d_4, d_5, d_6, d_7, d_8)$ とし，行う演算を [ ] で表す．１回の試行につき行う７つの演算の結果を r_k とすると，
　　$r_1 = [d_1, d_2]$ ；　$r_k = [r_{k-1}, d_{k+1}]$ 　$(2 \leq k \leq 7)$
であり，被験者は最終結果 r_7 のみを答えれば良いのである．
d_k がとることのできる値を a, b, c と表記すると，演算 $[m, n]$ は下表のようになる．

m＼n	a	b	c
a			
b			
c			

問３　下線部の hidden structure の内容を，r_1 や r_k などを用いた数式で答えよ.

問４　①〜⑤の語の文中での意味を日本語で答えよ.

　①　　　　　　　　　　②　　　　　　　　　　③

　④　　　　　　　　　　⑤

問５　波線部を日本語に訳せ.

問６　次の問いに英語で答えよ.

　What does this experiment show you ought to do to acquire an insight into the solution of a problem you have at hand?

3. endocrinólogy *n.* 内分泌学（endo- 内部）　　　5. reduction *n.* 削減；還元；単純化
6. participant / participation *n.*　　　　　　　　← partícipate *v.*
7. string *n.* 紐；弦；文字列
9. sequéntial(ly) *a(d).*　　　　　　　　← séquence *n.*
10. insight into 〜
11. go through
14. induce *v.*
14. representátion *n.*　　　　　　　　← represént *v.*
16. re-test *v.*
○18. control group　　　　　　　　≒ control *n.*
18. importantly *ad.*　　　　　　　　≒ what is more important
18. facílitate *v.*　　　　　　　　← facility *n.*
19. that is (to say)
20. encode / decode *v.*
20. beforehand *ad.*
21. explicit / implicit *a.*
22. reduction *n.*　　　　　　　　← reduce *v.*
22. íllustrate *v.*
23. digit *n.*　　　　　　　　→ *a.* digital.
23. presént *v.*
24. detérmine v.　　　　　　　　→ *n.* determination
24. define A as B
25. could 婉曲の仮定法，can でも大差ない.
25. pairwise *ad.*　　　　　　　　*cf.* otherwise, likewise, clockwise, ...
26. idéntical *a.*　　　　　→ identity *n.*　　　　identify *v.*
27. result in/from
30. precéde *v.*　　　　　　31. confírm *v.*
32. was to be determined　義務　　　34. mirror *v.*
35. implý *v.*　　　　　　　　→ *n.* implicátion
35. coincíde with 〜　　　　　　　→ *n.* coíncidence
36. abrupt(ly) *a(d).*　　　　　　36. cut O short
38. noctúrnal *a.*
39. inítial *a.n.*　　　　　　39. phase [féiz] *n.*
41. (have) an effect on
41. occúr(red)　　　　　　　　→ *n.* occúrrence
41. column [káləm] *n.*
44. supleméntary *a.*　　　　　　← súpplement *n.*
45. hatch *v.* 孵化する／(斜めの)平行線で塗りつぶす
46. in the absence of
46. módify *v.*　　　　　　　　→ *n.* modificátion