Good morning creativity: task reactivation during sleep enhances beneficial effect of sleep on creative performance

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SUMMARY

Both scientists and artists have suggested that sleep facilitates creativity, and this idea has received substantial empirical support. In the current study, we investigate whether one can actively enhance the beneficial effect of sleep on creativity by covertly reactivating the creativity task during sleep. Individuals' creative performance was compared after three different conditions: sleep-with-conditioned-odor; sleep-with-control-odor; or sleep-with-no-odor. In the evening prior to sleep, all participants were presented with a problem that required a creative solution. In the two odor conditions, a hidden scent-diffuser spread an odor while the problem was presented. In the sleep-with-conditioned-odor condition, task reactivation during sleep was induced by means of the odor that was also presented while participants were informed about the problem. In the sleep-with-control-odor condition, participants were exposed to a different odor during sleep than the one diffused during problem presentation. In the no odor condition, no odor was presented. After a night of sleep with the conditioned odor, participants were found to be: (i) more creative; and (ii) better able to select their most creative idea than participants who had been exposed to a control odor or no odor while sleeping. These findings suggest that we do not have to passively wait until we are hit by our creative muse while sleeping. Task reactivation during sleep can actively trigger creativity-related processes during sleep and thereby boost the beneficial effect of sleep on creativity.

INTRODUCTION

From the world's first wheel to the latest microprocessor, creative ideas have continuously enriched our lives. Several famous anecdotes suggest that sleep facilitates creativity, ranging from musical compositions to scientific insights (Mazzarello, 2000), and the idea that sleep fosters creativity has also received empirical support. Research has demonstrated that sleep enhances important aspects of creativity, including cognitive flexibility (Walker *et al.*, 2002) and the ability to find remote associations (Cai *et al.*, 2009). Moreover, sleep has been shown to inspire creative insight (Wagner *et al.*, 2004). One critical question, though, is whether one can actively enhance the beneficial effects of sleep on creativity. Do we have to wait passively until we are hit by a creative muse while sleeping, or can we actively trigger creative thought processes during sleep, thereby boosting the positive effects of sleep on creativity?

Previous research has shown that a night of sleep more than doubled the likelihood of acquiring insight into a hidden rule (Wagner *et al.*, 2004). Subjects completed a number reduction task, and each numerical sequence could be completed in a slow, stepwise way, but the trials could also be completed according to a hidden, more abstract rule that would significantly speed up participants' responses. The initial training was followed by 8 h of night-time sleep, night-time wakefulness or daytime wakefulness. Of the people who slept before they resumed, almost 60% discovered the rule, as opposed to 23% of the people in the two groups that did not sleep. Recent research has increased our understanding of what happens while we sleep. Rapid eye movement (REM) sleep enhances the formation of

associative networks and the integration of unassociated information for creative problem solving (Cai *et al.*, 2009). The aim of the present experiment is to test whether one can actively trigger creativity-related processes during sleep, thereby enhancing the beneficial effects of sleep on creativity.

Prior studies have shown that one can manipulate sleep, for example, by transcranial magnetic stimulation during sleep (Massimini *et al.*, 2009) or napping at different times of the day (Mednick *et al.*, 2003). Moreover, it has been shown that covertly reactivating newly acquired memories during sleep by presenting a conditioned odor improves memory performance the next day (Rasch *et al.*, 2007). While learning object locations in a memory task during the evening before sleep, participants were repetitively exposed to an odor to establish a robust association between learning stimuli and odor. During sleep, the conditioned odor was presented again to reactivate the newly acquired memories. Compared with a night of sleep with a control odor, it was found that memory reactivation during sleep significantly enhanced individuals' memory performance. The creative process, which entails the formation of associative elements into new combinations, is more complex than memory reactivation (Dietrich, 2004; Ward *et al.*, 1999); however, given that an odor cue can reactivate information, it is very possible that an odor cue can foster creativity by reactivating the creative problem. It may be possible that reactivation of a creativity task during sleep activates concepts related to the task, and that these pre-activated concepts provide a broader network of possible answers the next morning.

In our experiment, we aimed to trigger creativity-related processes during sleep by re-exposing participants to an odor that had also been presented while the participants were being informed about the problem that required a creative solution. An odor was used because odors are known for their usefulness as contextual retrieval cues (Chu and Downes, 2002), and can be presented without disturbing the continuity of sleep (Zelano and Sobel, 2005). To investigate whether one can actively boost the beneficial effect of sleep on creativity by covertly reactivating the creativity task during sleep, we compared individuals' creative performance after three different conditions: sleep-with-conditioned-odor; sleep-with-control-odor (i.e. an odor not presented previously); and sleep-with-no-odor. It was hypothesized that participants would be more creative after sleeping with the conditioned odor than after a night of sleep with the control odor or no odor.

MATERIALS AND METHODS

Participants

A total of 49 (43 female) Dutch-speaking participants between the ages of 18 and 29 years (M = 21.31, SD = 2.28) gave informed consent to participate in the study, which was approved by a member of the local Ethics Commitee.

Procedure

Participants arrived at the laboratory in the evening (between 07:00 and 22:00 h), and were randomly assigned to one of three sleeping conditions: sleep-with-conditioned-odor; sleep-with-control-odor; or sleep-with-no-odor. In individual cubicles, all participants watched a 10-min video about voluntary work and were presented with a problem (i.e. how to motivate people to do voluntary work) that required a creative solution the next morning. Moreover, they were informed that they had to perform this creativity task the next morning immediately after waking up (no later than 10:00 h) by logging onto an online version of the creativity task. In the two odor conditions, i.e. sleep-with-conditioned-odor (n = 17) and sleep-with-control-odor (n = 13), a hidden scent-diffuser (SmartNose®) spread an orange-vanilla odor while participants watched the movie and were informed about the creativity task. Also, participants in these two conditions received an envelope that they were asked to open 1 h before going to bed. The envelope contained a scent-diffuser and a flyer instructing them to open the scent-diffuser when going to bed, and to place the scent-diffuser at 3 m from their pillow. In the sleep-with-conditioned-odor condition, the scent diffuser to which participants were exposed during sleep spread an odor identical to the one presented in the laboratory (i.e. orange-vanilla). In the sleep-with-control-odor condition, the scent diffuser spread a different odor (i.e. fresh tonic) to the odor diffused at the lab.

In the sleep-with-no-odor condition (n = 19), participants also received an envelope that they were asked to open when going to bed, in order to keep memory re-activation directly before sleep constant across conditions. This envelope contained instructions to place a sticky Post-it note at a visible location in their bedroom, supposedly to remind them of the creativity task the next morning. A schematic overview of the experimental design can be found in Table 1.

The next morning, participants completed the online creativity task. They were given 2 min to list creative ideas and, thereafter, had to select their most creative idea from all the ideas they generated. Furthermore, they had to answer several odor-related questions, for example, whether and where the scent-diffuser was placed.

Materials

Creativity task

Participants completed a version of the Unusual Uses Task (Guilford, 1967), which is a widely used measure of creativity. Participants were given 2 min to generate and list creative solutions for a problem, that is, how to motivate people to participate in volunteer work. As an additional measure of

Table 1 Overview of the experimental design

Conditions	*Evening*	*Sleep*	*Morning*
Sleep – conditioned odor	Task presentation + vanilla scent	Vanilla scent	Creativity task
Sleep – control odor	Task presentation + vanilla scent	Tonic scent	Creativity task
Sleep – no odor	Task presentation		Creativity task

creativity, we asked the participants to select their most creative idea from all the ideas they generated. We included this measure, as in real-life settings most creative processes entail both idea generation and idea selection. For example, when trying to find creative solutions for a problem, one-first has to generate ideas and, thereafter, one has to select the one that is most promising. For the idea generation phase, the measure of interest was the participant's average creativity score. Concerning the idea selection phase, we were interested in whether a participant's selection of the most creative idea was in accordance with judgment of trained raters.

Training of raters

Training consisted of an elaborate explanation of the concept of creativity (i.e. that a creative idea has to be both useful and novel; e.g. Hennessey and Amabile, 2010), and the raters were provided with information about the scoring system. Afterward, the raters performed a 10-min practice phase in which they assessed the creativity of various ideas and received detailed feedback on their ratings.

Scoring procedure

To receive an average creativity score, two raters had to score the creativity of each idea on a five-point scale (1 = 'not at all creative' to 5 = 'extremely creative'). For each idea, a mean of the two scores was calculated (inter-rater reliability $\alpha = 0.84$), and per participant these mean scores were added. To make sure that a participant's creativity score was independent of the number of ideas generated (i.e. verbal fluency), this sum score was divided by the number of ideas that the participant listed. To investigate whether a participant's selection of the most creative idea was in accordance with the selection of the trained raters, participants as well as three trained raters had to make a forced decision: they were instructed to select one idea only, the one they considered to be their most creative. To receive an objective external judgment, it was required that at least two of the three raters agreed on a participant's most creative idea. This requirement was fulfilled in 84% of the cases, and the agreement between the three raters was equally distributed across the three conditions ($F_{2,49} = 0.45$, $P = 0.64$), indicating that it was not easier in any of the three conditions to select the most creative idea out of all ideas.

RESULTS

Average creativity

An ANOVA with average creativity as the dependent variable and sleeping condition as the between-subject factor revealed a main effect of sleeping condition ($F_{2,46} = 3.65$, $P = 0.034$, $\eta^2 = 0.14$). As shown in Fig. 1, participants' average creativity score was higher in the sleep-with-conditioned-odor condition than in the sleep-with-control-odor condition ($t_{28} = 2.27$, $P = 0.031$) and the sleep-with-no-odor condition ($t_{34} = 2.11$, $P = 0.042$). Performance in the latter two conditions did not differ ($t_{30} = 0.26$, $P = 0.797$). Additional analyses showed similar results ($P < 0.05$) when including gender as a factor.

Selection of most creative idea

We examined whether participants' selection of their most creative idea was in accordance with the selection made by trained judges. To compare whether participants' selection ability differed between the sleeping conditions, a Chi-square test was conducted. This revealed a main effect of sleeping condition [$\chi^2(2) = 6.04$, $P = 0.049$]. As shown in Fig. 2, the percentage of participants who successfully selected their most creative idea was significantly higher in the sleep-with-conditioned-odor condition than in the sleep-with-control-odor condition [$\chi^2(1) = 5.13$, $P = 0.024$] and the sleep-with-no-odor condition [$\chi^2(1) = 4.03$, $P = 0.045$]. Performance in the latter two conditions did not differ [$\chi^2(1) = 0.03$, $P = 0.954$].

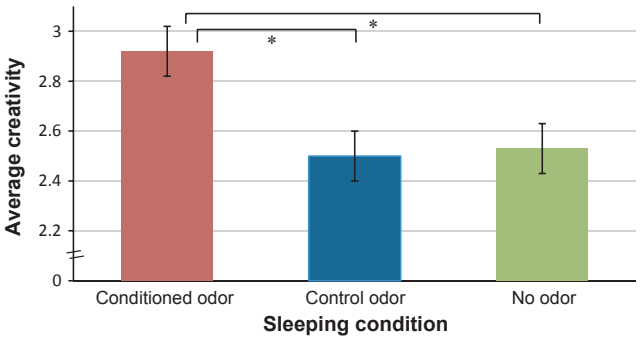

Figure 1. Average creativity as a function of sleeping condition. Error bars represent standard errors (SEM). *$P < 0.05$.

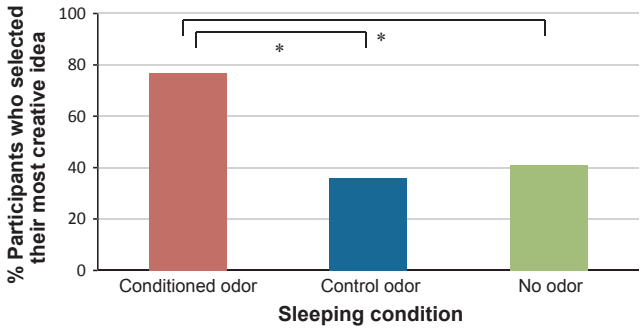

Figure 2. Percentage of participants who selected their most creative idea as a function of sleeping condition *$P < 0.05$.

Odor-related questions

The two odor conditions did not differ on liking of the odor ($t_{27} = 1.11$, $P = 0.28$) and on aspects that may have influenced odor intensity, such as distance between the location of the scent-diffuser and the pillow ($t_{27} = 0.20$, $P = 0.84$), duration of odor presentation during sleep ($t_{27} = 1.63$, $P = 0.11$), size of the bedroom ($t_{27} = 1.34$, $P = 0.19$), and whether subjects slept with open window or open door ($t_{27} = 0.39$, $P = 0.70$).

DISCUSSION

The idea that sleep can improve creative performance has been suggested by anecdotal reports of famous scientists and artists, and has received substantial empirical support (Cai *et al.*, 2009; Wagner *et al.*, 2004). For a long time, however, it has remained unclear whether one can actively influence creative processes during sleep. In our experiment, we covertly reactivated a creativity task during sleep by means of a conditioned odor, that is, the odor that was also presented during task presentation. After a night of sleep with the conditioned odor, participants were found to be: (i) more creative; and (ii) better able to select their most creative idea than participants who had been exposed to a control odor or no odor while sleeping. These findings suggest that we do not have to passively wait until we are hit by our creative muse while sleeping. By applying the right means, we may be able to actively trigger creativity-related processes during sleep, and thereby enhance the beneficial effect of sleep on creativity.

The current research does not allow firm conclusions about underlying mechanisms. However, previous research has shown that sleep inspires insightful behavior as new memory representations are restructured (Wagner *et al.*, 2004), and links are created between pieces of information that otherwise might remain unrelated (Paller and Voss, 2004). Creative thought, like insightful behavior, often considers a mental restructuring of information, which in turn leads to the generation of novel associations between concepts (Guilford, 1967). Moreover, prior research has demonstrated that the integration of unassociated information for creative problem solving can be enhanced by REM sleep (Cai *et al.*, 2009). We propose that reactivation of a creativity task during sleep activates task-related concepts. This may include both strongly associated concepts, as well as remotely associated concepts. For example, in the task 'what can you do with a brick', a strongly associated concept could be 'house', whereas a remotely associated concept could be 'penholder'. These pre-activated concepts may provide a bigger network of possible answers when performing the creativity task the next morning.

As the focus of the current experiment was to investigate whether one can actively enhance the beneficial effect of sleep on creativity, we included two control conditions. Some participants were exposed to a control odor during sleep, while others were not exposed to an odor at all. Although the beneficial effect of sleep on creative performance has been described in previous studies (Cai *et al.*, 2009; Wagner *et al.*, 2004; Walker *et al.*, 2002), a limitation of the current study is that we did not include a wakefulness condition to assess whether sleep itself increases creativity in the task applied in the current study. Furthermore, the majority of participants in the current study were female. However, in line with previous studies that have demonstrated that there are no gender differences in scores on creativity tests (for a review, see Baer and Kaufman, 2008), gender probably did not confound the results of the current creativity task. In the current study the participants smelled the odor before they went to sleep and the odor was continuously presented during sleep. Previous research has demonstrated that, compared with quiet rest and non-REM sleep, REM enhanced the formation of associative networks and the integration of unassociated information (Cai *et al.*, 2009). Therefore, future studies should assess the beneficial role of a task-associated odor during the different sleep stages.

To our knowledge, this is the first study that has investigated whether one can actively facilitate the beneficial effect of sleep on creativity. In addition to its scientific contribution, the current study may have practical implications for various settings where a creative thinking style and innovation are needed. Reactivating a problem by means of a conditioned odor may be a means to actively stimulate creativity-related processes and thereby facilitate creative performance, both for individuals and on the level of organizations.

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CONFLICT OF INTERESTS

None of the authors have any conflicts of interest.

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