

The effect of dream report collection and dream incorporation on memory consolidation during sleep

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Abstract

Collecting dream reports typically requires waking subjects up from their sleep—a method that has been used to study the relationship between dreams and memory consolidation. However, it is unclear whether these awakenings influence sleep-associated memory consolidation processes. Furthermore, it is unclear how the incorporation of the learning task into dreams is related to memory consolidation. In this study we compared memory performance in a word–picture association learning task after a night with and without awakenings in 22 young and healthy participants. We then examined if the stimuli from the learning task are successfully incorporated into dreams, and if this incorporation is related to the task performance the next morning. We show that while the awakenings impaired both subjective and objective sleep quality, they did not affect sleep-associated memory consolidation. When dreams were collected during the night by awakenings, memories of the learning task were successfully incorporated into dreams. When dreams were collected in the morning, no incorporations were detected. Task incorporation into non-rapid eye movement sleep dreams, but not rapid eye movement sleep dreams positively predicted memory performance the next morning. We conclude that the method of awakenings to collect dream reports is suitable and necessary for dream and memory studies. Furthermore, our study suggests that dreams in non-rapid eye movement rather than rapid eye movement sleep might be related to processes of memory consolidation during sleep.

KEYWORDS

awakenings, non-rapid eye movement, rapid eye movement, sleep quality

1 | INTRODUCTION

Current theories assume that sleep plays an active role in the process of memory consolidation. The active system consolidation hypothesis states that memories are spontaneously reactivated during sleep, resulting in a redistribution between hippocampal and cortical storage sites (Born & Wilhelm, 2012). On the neural level, hippocampal reactivations occur mainly during slow-wave sleep (SWS) in rodents, and only to a lesser extent in rapid eye movement

(REM) sleep (Girardeau, Inema, & Buzsáki, 2017; Kudrimoti, Barnes, & McNaughton, 1999; Louie & Wilson, 2001). Consequently, hippocampus-dependent declarative memories profit more from early sleep periods with high amounts of SWS (Marshall & Born, 2007). In addition, inducing memory reactivations by re-exposure to memory cues during sleep (targeted memory reactivations, TMR), consistently benefits memories when cues are presented during non-rapid eye movement (NREM) sleep, but not REM sleep (Rasch, Buechel, Gais,

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& Born, 2007; Rudoy, Voss, Westerberg, & Paller, 2009; Schreiner, Lehmann, & Rasch, 2015).

At first glance, memory reactivations might provide an obvious link to dreaming activity (Schredl, 2017; Stickgold, Hobson, Fosse, & Fosse, 2001). The incorporation rate of autobiographical memories in later dreams is relatively high (Malinowski & Horton, 2014; Stickgold, Malia, Maguire, Roddenberry, & O'Connor, M., 2000; Wamsley, Perry, Djonlagic, Reaven, & Stickgold, 2010). Dreaming occurs during both NREM and REM sleep stages, although NREM dreams are less frequent (38%–67% versus 75%–83% in REM), shorter, less emotional and less vivid (McNamara et al., 2010; Montangero, 2018; Stickgold, Paceschott, & Hobson, 1994). Baylor and Cavallero (2001) reported that the amount of episodic memories was higher in NREM compared with REM dream reports, while there was no sleep stage dependency for semantic memories.

While waking events are clearly incorporated into dreams (Schredl & Hofmann, 2003), it is still unclear whether incorporations are related to memory consolidation. To our knowledge, only two (non-pilot) studies have examined this question using awakenings and an episodic task. Cipolli, Fagioli, Mazzetti, and Tuozi (2004) showed that sentences presented before sleep were incorporated more often during dream reports collected from REM sleep than non-presented sentences. However, memory recall in the morning was not related to incorporation of the stimuli. In contrast, Wamsley, Tucker, Payne, Benavides, and Stickgold (2010) reported that incorporation rate during dreams collected from NREM sleep during a nap positively predicts later memory performance in a spatial memory task. However, only four participants reported task-related dreams, and these four participants differed in task performance already at baseline before the nap. In addition to these inconsistent findings, a more general problem is that the acquisition of dreams requires repeated awakenings from sleep. So far it is unknown if and how repeated collection of dream reports affects ongoing memory consolidation. Without knowing this basic effect, studies using dream collection techniques cannot be compared with most sleep and memory studies that typically examine undisturbed sleep periods.

The major aim of the current study was to examine the effect of dream report collection during sleep on memory consolidation. Additionally, we examined whether a word-picture association learning task was incorporated into dreams and if this was related to memory performance the next day. We hypothesised that repeated dream collection will disturb ongoing memory consolidation. In addition, we expected incorporations in NREM and REM sleep, but that only NREM dream incorporation would be positively related to next day memory performance.

2 | MATERIALS AND METHODS

2.1 | Participants

Twenty-two healthy participants aged between 19 and 35 years ($M = 23.32$, $SD \pm 4.2$) completed the whole study (12 female). They met

our inclusion criteria as defined in the supplementary material (Data S1), and received 200 CHF as reimbursement. All participants gave written informed consent. The study was approved by the ethics committee of the Department of Psychology, University of Zurich.

2.2 | Polysomnographic setup

The polysomnographic recording consisted of electroencephalography (EEG), electrooculography (EOG), electromyography (EMG) and electrocardiography (ECG). EEG and EOG were measured with a 128-channel high-density geodesic sensor net from EGI. EMG was measured with two single electrodes. ECG was measured with a singular recording from two electrodes placed on the thorax. The data went through Net Amps 300 series amplifier of EGI, and were recorded and presented on the screen with the program Netstation (Version 4.5.4). Impedances were kept below 50 k Ω .

Participants were woken up through an intercom system from Monacor, which allowed the experimenter to hear and talk to the participants.

2.3 | Procedures

After an adaptation night, the participants completed two experimental nights for which they arrived at 20:00 hours. First, polysomnography was applied. At about 21:00 hours, participants started with the word-picture association learning task. After the first five blocks, they filled in two questionnaires (mood and sleep quality of the previous night), allowing for a short pause between learning and recall. Then they completed the recall blocks of the task before going to bed at about 23:00 hours. During the experimental condition of awakenings (Session A), the participants were woken up between three and six times during the night. Awakenings were based on sleep stage determined visually from the EEG. Up to three awakenings were prompted from both NREM and REM sleep. Participants were immediately asked: "What went through your mind before you woke up?" They were then asked to rate the emotionality of the dream on a positive and negative scale. The participants got up at 07:00 hours, and filled in a mood and a sleep quality questionnaire. At the end of the session they completed the same two recall blocks of the word-picture association learning task as before sleep. In the other experimental night (non-awakening condition, Session B), participants were not woken up during sleep and were instructed to memorise as many dreams as possible and write them down after completing the questionnaires and memory task in the morning. Every participant remembered at least one dream. The order of awakening and non-awakening condition was counterbalanced. An overview of the procedure is depicted in Figure 1. More details on the procedure can be found in the supplementary material (Data S1).

2.4 | Word-picture association learning task

Memory performance was measured with a word-picture association learning task adapted from Lehmann, Seifritz, and Rasch (2016). In

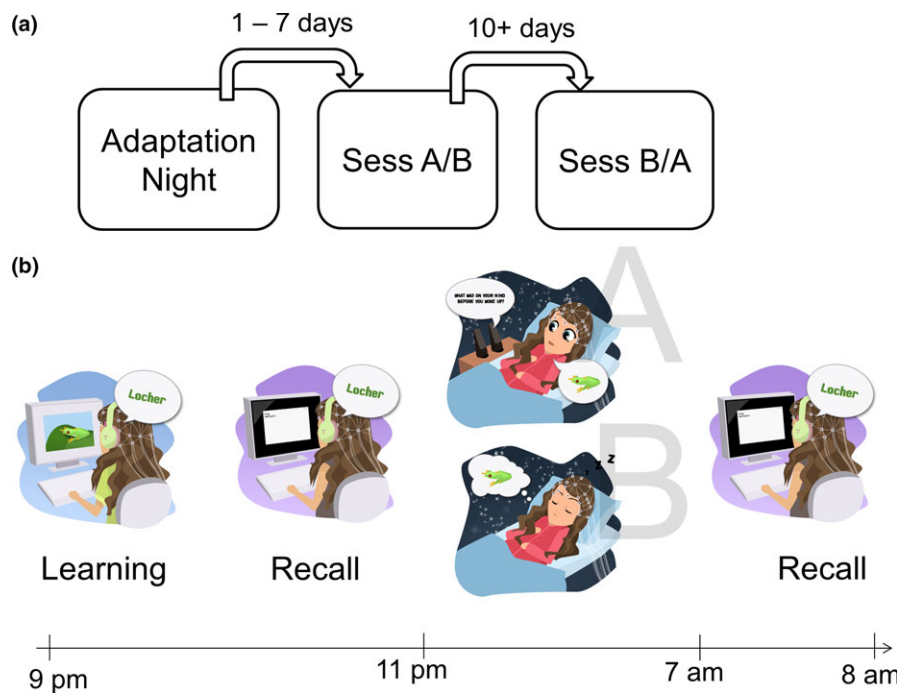


FIGURE 1 Procedure of the study. (a) The experiment consisted of three sessions. Participants completed an adaptation night to get used to the sleep environment. The two experimental sessions were counterbalanced. (b) Detailed procedure of an experimental night. Participants first completed the learning task with an immediate recall. Then participants had a sleep opportunity from 23:00 hours to 07:00 hours. In Session A, participants were repeatedly woken up for dream report collection, while in Session B dream reports were collected in the morning. After getting up, participants completed another recall

this task, participants learned two different sets of 100 neutral words, which were paired with 50 neutral and 50 positive images from three categories (Set 1: children, sports, animals versus Set 2: water, transportation and food). After rating both the words and the pictures on valence and arousal, the participants tried to learn as many word-picture pairs as possible in three blocks. After a short pause, during which the participants filled in two questionnaires, subjects were confronted with two recall blocks: the first consisted of valence ratings of the pictures associated with the word; and the second block was a cued recall. The percentage of the correctly remembered word-picture pairs was used as a measure for memory performance, with learning performance before sleep set to 100% (retention performance).

2.5 | Sleep and dream analysis

The sleep stages were scored manually using the computer software SchlafAus 1.0 (Gais, unpublished). Raters followed the rules of the *Manual for the Scoring of Sleep and Associated Events* from the American Academy of Sleep Medicine (Iber, Ancoli-Israel, Chesson, & Quan, 2007).

Each dream was rated by two blind raters on appearance of the six possible categories (children, sports, animals, water, transportation and food). Additionally, the dreams were rated on their realism, positive and negative feelings, number of mentioned people, acoustic perceptions, occurrences of content related to the laboratory or experiment, and incorporation of the words used in the word-picture task (results for the dream characteristics are reported in the supplementary material [Data S1]). The inter-rater reliability was moderate to good ($r_s = .56-.74$, $\kappa = 0.53-0.91$). To operationalise to

which degree the categories of the memory task were incorporated into the dreams, an incorporation score was generated for both nights and picture sets, respectively. The congruent score reflects the number of categories that had appeared in the picture set that the participants had seen in the task before sleep. The incongruent score reflects how many categories of pictures not used in the evening before were incorporated into the dream. The number of incongruent incorporations represents an estimate of the number of task-related categories that appeared in the dreams by chance. For each reported dream, the number of congruent and incongruent incorporations was counted (0–3) and then summed up per night. Scores could range from 0 to 18, indicating 0–3 categories in 0–6 dreams in the awakening condition. For the non-awakening condition, all dreams reported in the morning were counted as one dream (scores ranging from 0 to 3). For the sleep stage-dependent analysis, only the sum of dreams that occurred in the respective sleep stage was taken into account. For our correlational analysis, the number of congruent incorporations of picture categories in dreams was corrected by the number of incongruent incorporations to account for spontaneous occurrence of certain picture categories in dreams. Thus, our corrected incorporation score is calculated as follows: congruent incorporation score minus incongruent incorporation score.

2.6 | Statistical analysis

The data were analysed using IBM SPSS Statistics 22 (Statistical Product and Service Solutions, IBM, Armonk, New York) and RStudio (R version 3.1.3; R Core Team, 2015). Statistical analysis was performed

with repeated-measures analysis of variance (ANOVA) and one-way ANOVAs. Post hoc analyses were corrected with Tukey's HSD. Pairwise differences were examined using paired *t*-tests. For correlations, Pearson coefficients were used. Differences between the nights were examined using paired *t*-tests with Bonferroni corrected *p*-values. Significance level was set to $p = 0.05$.

3 | RESULTS

3.1 | The effect of dream report collection on memory performance

As expected, collecting dream reports during the night strongly affected sleep quality. Compared with the night without awakenings, dream report collections during the night significantly reduced the amount of N2 and REM sleep, while it increased time spent awake after sleep onset, N1 sleep and SWS latency (Table 1). Overall sleep efficiency was significantly reduced from $94.19\% \pm 1.06\%$ (mean \pm standard error of the mean, SEM) in non-awakening nights to $87.34\% \pm 1.71\%$ in nights with awakenings ($p < 0.001$, $d = 0.82$; Figure 2).

In contrast to our hypothesis and despite the strong impairment of sleep, we did not observe any significant differences between the awakening and non-awakening night on memory performance ($t_{21} = 1.08$, $p = 0.29$, $d = 0.23$). In the non-awakening nights, $93.19\% \pm 3.39\%$ of the images remembered in the evening were retained, with the number of images remembered in the evening before sleep set to 100%. In the night with awakenings, participants remembered descriptively even more images ($97.18\% \pm 1.61\%$; Figure 2). Given our sample size of $n = 22$ and our alpha threshold of $p = 0.05$, we can exclude an effect size for independent samples with $d_z = 0.81$ or higher of the influence of awakenings on memory consolidation during sleep with a probability of 95%.

TABLE 1 Comparison of objective sleep characteristics of the experimental nights

	Awakening		Non-awakening		<i>p</i>
	M	SEM	M	SEM	
Total (min)	468.67	± 4.74	454.29	± 8.88	0.124
Awake (%)	10.43	± 1.53	2.10	± 0.73	$<0.001^*$
N1 (%)	7.08	± 0.9	4.61	± 0.7	$<0.001^*$
N2 (%)	52.84	± 1.55	54.72	± 1.22	0.27
N3 (%)	13.75	± 0.89	16.93	± 0.64	0.007
REM (%)	15.9	± 0.88	21.61	± 1.15	$<0.001^*$
Sleep latency (min)	12.19	± 2.63	17.36	± 4.03	0.21
SWS latency (min)	34.43	± 3.88	16.24	± 1.1	$<0.001^*$
REM latency (min)	123.76	± 13.64	95.5	± 11.68	0.073
Sleep efficiency	87.34	± 1.71	94.19	± 1.06	$<0.001^*$

Notes. REM: rapid eye movement; SWS: slow-wave sleep.

Standard error of the means are reported.

*Significant after Bonferroni correction.

3.2 | Dream characteristics

In the night with awakenings, participants were awakened 121 times (5.5 ± 0.18 awakenings), of which 106 lead to dream reports (4.82 ± 0.22). Fifty (2.27 ± 0.16) of these dream reports were obtained in NREM sleep (63 awakenings, 2.86 ± 0.07 , 79% dream recall rate) and 56 (2.55 ± 0.15) in REM sleep (57 awakenings, 2.59 ± 0.15 , 97% dream recall rate). In the night without awakenings, one morning dream diary report per participant was collected ($n = 22$). Additional details on dream characteristics are reported in the supplementary material (Data S1).

3.3 | Incorporation of task into dreams

Participants learned one of two image sets before each experimental night. Images in Set 1 showed children, sports and animals, whereas images of Set 2 showed water, transportation and food (Materials and methods; Figure 1). To test incorporation rates of images into dreams, we compared "congruent" (i.e. dreaming of a child when the learning set before sleep included images of children) with "incongruent" incorporations (i.e. dreaming of a child when the learning set did not include children). We analysed our data using a 2×2 repeated-measures ANOVA with the within-subject factors night (awakening versus non-awakening) and set congruency (congruent versus incongruent). While we did not observe a main effect of set congruency ($p > 0.20$), we observed a significant interaction between set congruency and night ($F_{1,21} = 7.9$, $p = 0.01$, $\eta_p^2 = 0.27$). Follow-up analysis confirmed that in the night with awakenings, dream reports contained significantly more incorporations of the congruent set of categories learned before sleep (2.59 ± 0.3 incorporations, mean \pm SEM) as compared with the incongruent set (1.82 ± 0.26 incorporations; $t_{21} = 2.63$, $p = 0.016$, $d = 0.56$; Figure 3). In contrast, in the nights with no awakenings, dream reports collected in the morning did not differ in the number of congruent versus incongruent incorporations ($t_{21} = -1.70$, $p = 0.10$, $d = 0.36$; Figure 3). We also observed a main effect of night ($F_{1,21} = 25.36$, $p < 0.001$, $\eta_p^2 = 0.55$) with more incorporations in the night with awakenings, because more dreams were collected in the night with awakenings as compared with the non-awakening night. When dividing the incorporation score by the number of dream reports, the main effect of night was no longer significant ($p > 0.15$). Importantly, the interaction remained significant ($F_{1,21} = 5.03$, $p = 0.036$, $\eta_p^2 = 0.19$), as did the follow-up *t*-tests.

Daily events are mainly incorporated up to 6 days after an event ("dream-lag effect"; Nielsen & Powell, 1989). Although our two sessions were a minimum of 10 days apart to exclude delayed incorporations, we additionally tested whether incorporation of the picture set from the first session in night 2 ($0.55\% \pm 0.13\%$) was more likely than incorporations of the picture set from the second session in night 1 ($0.71\% \pm 0.16\%$, corrected by amount of dream reports). The difference was not significant ($p > 0.51$) and descriptively even in the opposite direction. Thus, our incongruent incorporation score is not significantly affected by delayed incorporations, and rather represents spontaneous incorporations into dreams unrelated to any learning set.

FIGURE 2 Influences of awakenings to collect dream reports on sleep efficiency and overnight memory retention. (a) Awakenings significantly reduced sleep efficiency. (b) In spite of the differences in sleep efficiency, no significant difference in retention performance was observed between nights with and without awakenings. Memory performance is shown as relative retention score with the amount of images recalled before sleep set to 100%. Means ± SEM are indicated. *** $p < 0.001$

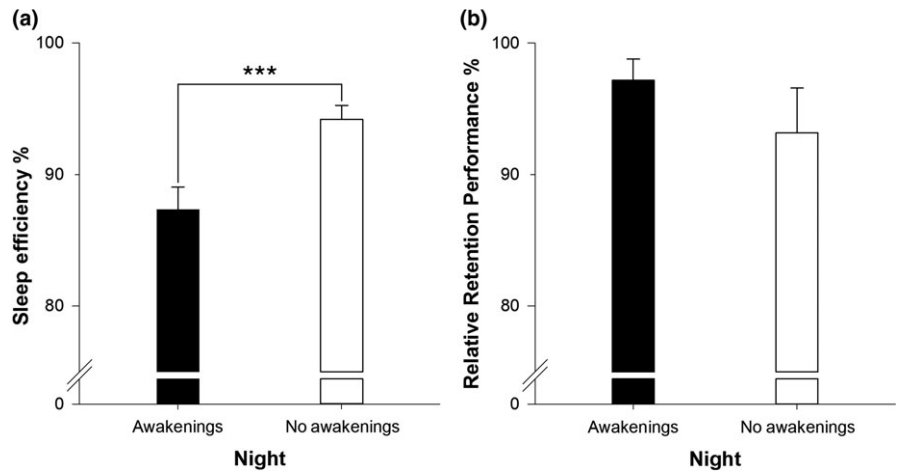
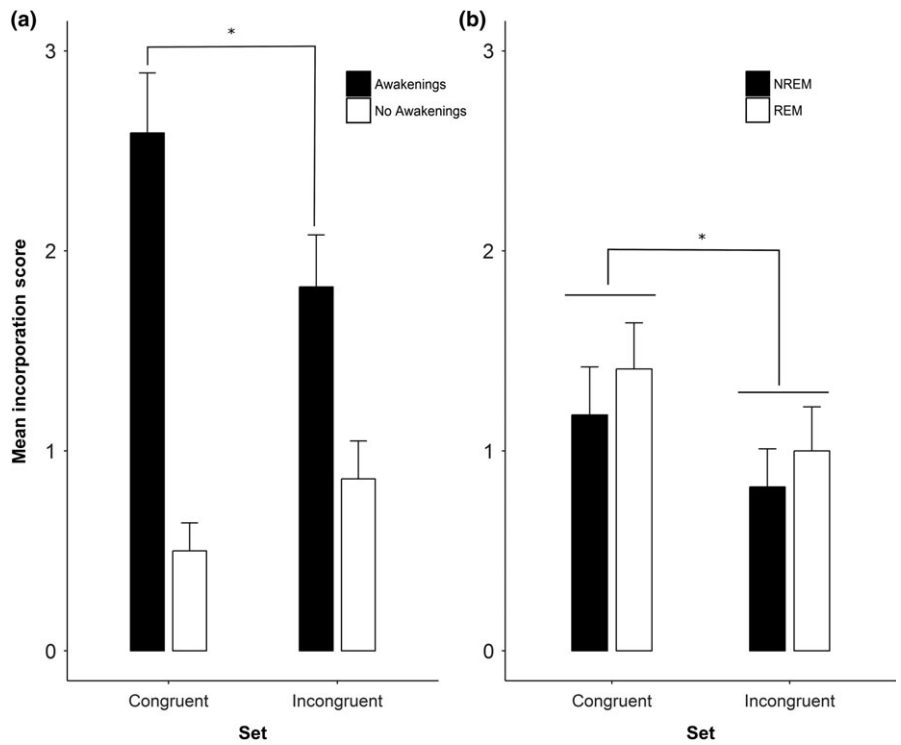


FIGURE 3 Incorporation of the task content into dreams depending on the appearance in the picture set learned before sleep. (a) The rate of incorporations of congruent set categories into dreams was significantly higher as compared with incongruent set categories in the night with awakenings. In contrast, in the night without awakenings, no difference in incorporation rates was observed between congruent and incongruent picture categories. (b) During nights with awakenings, the higher incorporation rate for congruent set categories was similar for dream reports collected during non-rapid eye movement (NREM) versus rapid eye movement (REM) sleep. Means ± SEM are indicated. * $p < 0.05$



We further split the night with awakenings into awakenings from NREM and REM sleep stage. However, we only found a main effect of set congruency with more incorporation of the congruent set ($F_{1,21} = 6.92, p = 0.016, \eta_p^2 = 0.25$), but no main effect of sleep stage or interaction between sleep stage and set congruency (all $p \geq 0.48$). Thus, in both NREM and REM sleep, congruent incorporations were similarly higher as compared with incongruent incorporations.

3.4 | Relationship between dream incorporation and retention performance

Finally, we tested the predictive value of the number of task-related incorporation into dreams for memory performance after sleep. As predictor, we used the number of congruent incorporations

corrected by the number of incongruent incorporations into dreams (corrected incorporation score; Materials and methods). Memory retention across sleep was indicated by the relative retention scores, with performance before sleep set to 100%. To account for the higher chance of incorporations with more dream reports during REM as compared with NREM sleep, we included the amount of dream reports as covariates in a partial correlation. In accordance with our hypothesis, we observed a significant positive correlation between the corrected incorporation score and overnight memory retention ($r_{19} = .49, p = 0.026$). In contrast, during REM sleep the correlation was not significant ($r_{19} = 0.00, p > 0.99$; Figure 4). The difference between the two correlation coefficients for NREM and REM sleep was on a trend level ($z = 1.65, p = 0.098$). When dreams were collected only in the morning in the no awakening condition, the

correlation was not significant ($r_{22} = 0.06$, $p = 0.78$). When using the uncorrected incorporation score (i.e. the amount of correct incorporations), the strength of the association was slightly reduced and failed to reach the significance threshold during NREM sleep ($r_{19} = .36$, $p = 0.11$). In contrast, the number of incongruent incorporations (estimating spontaneous incorporations of certain picture categories) was clearly not associated with memory performance ($r_{19} = -0.07$, $p = 0.76$). Correlation coefficients between congruent versus incongruent incorporations in REM sleep and memory performance remained both close to zero ($r_{19} = 0.02$, $p = 0.94$ versus $r_{19} = 0.02$, $p = 0.94$, respectively).

4 | DISCUSSION

Our results indicate that dream report collection during sleep does not generally disturb overnight memory retention, despite impairments in sleep efficiency. Thus, memory consolidation might be comparable between nights with and without awakenings. In addition, we show that incorporation of learning stimuli into dreams only is reliably detected during dreams collected by awakenings from sleep. Finally, higher incorporation ratios of learning stimuli in NREM dreams, but not REM dreams, predicted better overnight memory retention. Our results suggest that processes of memory consolidation and reactivation during sleep might be related to dreaming during NREM sleep.

4.1 | The effect of the nocturnal awakenings on sleep-associated memory consolidation

While the awakenings impaired the objective and subjective sleep quality of the participants, they did not impair memory consolidation. Relative reductions of SWS using procedures like the night-half paradigm (Plihal & Born, 1997) have shown that the amount of SWS might be particularly important for consolidation of declarative information during sleep. Furthermore, some studies reported positive correlations between the amount of SWS and declarative memory consolidation across sleep (Backhaus et al., 2007), although this has not been consistently observed (Ackermann, Hartmann, Papanicolaou, Quervain, & Rasch, 2015). As the amount of SWS was significantly lower in nights with awakenings, we expected an impairment of sleep-associated memory consolidation. However, memory performance was descriptively even better in nights with awakenings. It is possible that recalling dreams during the night represented additional processing of the task stimuli, thereby compensating for possible sleep quality impairments. Generally, sleep-associated memory benefits have been reported from Lehmann, Seifritz, et al., (2016) using a very similar version of the word–picture association task. However, inclusion of an additional waking control group using exactly the same picture sets would have been ideal to estimate relative contributions of sleep and awakenings to memory consolidation.

In summary, our study suggests that using up to six awakenings per night to collect dream reports does not significantly impair

memory consolidation during sleep, and can be used as a method to study dreams and their relationship with memory performance. However, it is unclear whether there is an influence of task-related processing by repeatedly reporting dreams that might be related to the memory task.

4.2 | Incorporation of the task into dreams

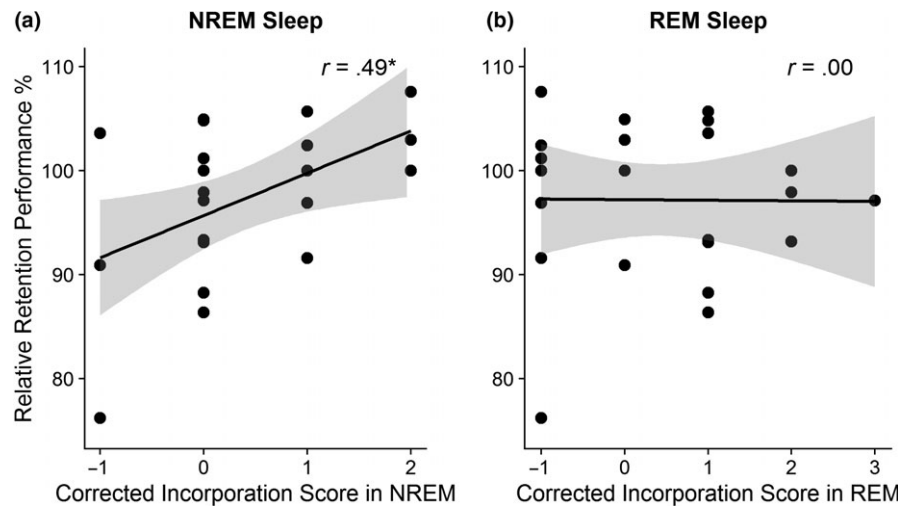
We found that the picture set used in the task before sleep was incorporated significantly more often than the other picture set, but only if dream reports were collected by awakenings. This is an important methodological finding, as it underlines the importance of collecting dream reports via awakenings. Possibly, the remembered subset of dreams in the morning might not be representative of the whole night, as those dream reports only reflect a small part of the dreams that were experienced during the whole night. A case study with one volunteer showed that both recency and intensity influenced which reported dream was recalled again in the morning (Meier, Ruef, Ziegler, & Hall, 1968). In addition, because REM sleep is more prominent in the morning, it is also likely that dream reports collected in the morning reflect REM rather than NREM dreams.

While increased incorporation of the task stimuli appeared in dream reports collected via awakenings, we found no significant differences in the incorporation rate between NREM and REM dreams. According to the active system consolidation hypothesis, declarative memories are mainly reactivated during NREM sleep, while evidence for hippocampal reactivation during REM sleep is rather scarce, but has been reported by Louie and Wilson (2001) in rats following a memory task (see Rasch & Born, 2013 for an overview). A recent study examining pattern replay in hippocampo-amygdala cell assemblies even reports no signs of reactivations in REM sleep, in contrast to robust replay events during NREM sleep (Girardeau et al., 2017). Along similar lines, TMR during REM sleep did neither improve emotional nor neutral declarative memories, while TMR during NREM sleep improved memory for pictures (Lehmann, Schreiner, Seifritz, & Rasch, 2016). Note that we used an almost identical word–picture association task in the current study as Lehmann, Schreiner, et al., (2016).

4.3 | Dream incorporation and relationship with task performance

Although incorporation rates were similar between REM and NREM sleep, we found that only NREM incorporations had a positive relationship with task performance in the next morning. This was only significant when corrected for spontaneous incorporations, suggesting that this correction successfully accounted for some residual variation. Furthermore, the number of chance incorporations did not predict memory performance. This is in line with the two previous studies, reporting no relation between performance and REM incorporations (Cipolli et al., 2004) and a strong association between performance and NREM incorporations (Wamsley, Tucker, et al., 2010). It is possible that NREM and REM dreams reflect different

FIGURE 4 Correlations between the incorporation ratio of the stimulus material into dreams and the overnight memory retention performance for non-rapid eye movement (NREM) and rapid eye movement (REM) sleep. (a) In dreams collected during NREM sleep, the ratio of incorporation scores for congruent versus incongruent learning stimuli significantly predicted the overnight memory retention score. (b) For dreams collected during REM sleep, no such correlation was observed. * $p < 0.05$



mechanisms, and that only NREM dreams are indicative of memory processes that take place during sleep. This also fits with the assumption of the active system consolidation hypothesis that replay mainly takes place in NREM sleep, and therefore the subjective reflection of this process also appears in this sleep stage. Our findings suggest that the association between mechanism of memory replay and dreaming might be stronger during NREM as compared with REM sleep. However, further studies are necessary to examine this notion more systematically.

4.4 | Limitations

A major limitation of our study is that we examined only dreams occurring during the first night after the memory task. According to the dream-lag effect, daily experiences get incorporated into dreams with a lag of several days (Nielsen & Powell, 1989), which might be specific to REM dreams (van Rijn et al., 2015). It is possible that incorporation into REM sleep was higher the days following the experiment, and that these incorporations would reflect ongoing memory processes. However, it is also methodologically challenging to disentangle the contributions of several nights of sleep, forgetting over time and incorporations into dreams during multiple nights to processes of memory consolidation. Another limiting factor is our sample size. While the sample size was clearly sufficient to detect differences in our within-subject design, it is not sufficient to analyse differences and associations between participants in detail (e.g. examine single items and categories in detail). Finally, dream reports were collected directly after awakenings in the awakening nights, but only after memory recall in the non-awakening nights, which might have resulted in loss of content. Following this order was crucial to avoid effects of dream recall on memory processes, and to make the study comparable to other studies in the sleep and memory field.

4.5 | Conclusion and future research

Here we showed that the awakenings used in dream research do not impair memory performance in an overnight task and are crucial

to uncover incorporations of tasks into dreams. Our results support the notion that only NREM dreams might reflect ongoing memory processes, suggesting possible links between processes of memory reactivation/consolidation and dreams during NREM sleep. One might speculate that incorporation of memories during REM sleep dreams might rather support some sort of emotional processing and re-evaluation. However, the relation between processes of memory consolidation and NREM versus REM sleep dreams clearly warrants further systematic examination.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

SFS, MS and BR designed the study; SFS collected the data; SFS and MJC analysed the data; SFS, MJC, MS and BR wrote the article.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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