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Short Communication

Sleep fragmentation and false memories during pregnancy and motherhood

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HIGHLIGHTS

- False memories were assessed using the Deese–Roediger–McDermott (DRM) paradigm.
- Sleep was monitored by actigraphy in home environment for seven consecutive nights.
- Pregnant women were tested during pregnancy and about 10 months after childbirth.
- Pregnant women produced more false memories and displayed more fragmented sleep.
- False memory generation was not correlated to sleep fragmentation.

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ABSTRACT

Pregnant women, both before and after childbirth, frequently experience memory deficits and disrupted sleep. In the present study we assessed the relationship between false memory generation and fragmented sleep during pregnancy and motherhood. We tested 178 pregnant women and 58 female non-pregnant childless controls, during pregnancy (15–35th week of gestation) and again after childbirth (8–13th month). False memories were defined as memories of gist words that were semantically related to studied word lists but were not presented during learning of these lists in the Deese–Roediger–McDermott (DRM) paradigm. Sleep was monitored by actigraphy in the home environment for seven consecutive nights. Compared to the controls, the group of pregnant women produced more false memories and displayed more fragmented sleep both during pregnancy and after childbirth. However, false memory generation was not correlated to measures of sleep fragmentation. These results show that pregnant women suffer from sleep fragmentation and a higher susceptibility to false memories, but leave open the question as to whether both phenomena are related.

Pregnant women, and those after childbirth, often subjectively report suffering from memory deficits in everyday life, such as increased forgetfulness [1]. Objective studies of memory impairments suggest that pregnant women show deficits in some measures of memory but not in others [1]. Memory functions that place high demands on prefrontal cognitive control processes [1], such as prospective memory [2,3] and working memory [4–6], seem to be particularly affected during pregnancy and after childbirth. Importantly, prefrontal cognitive control processes like retrieval monitoring are assumed to be necessary to determine whether or not a certain event has actually occurred [7,8]. These processes are essential to avoid false memories at retrieval [9,10]. Pregnant women and mothers after childbirth might be particularly susceptible to false memories given their impairments in prefrontal control. False memories are defined as events that are remembered despite never having happened [11]. To study false memories, the Deese–Roediger–McDermott (DRM) paradigm is most commonly applied as this procedure reliably induces high numbers of false memories [11,12]. In this paradigm, participants study lists of semantically associated words. The "gist" word of each list, the central theme, is not presented during learning. When tested on their memory of the word lists, participants

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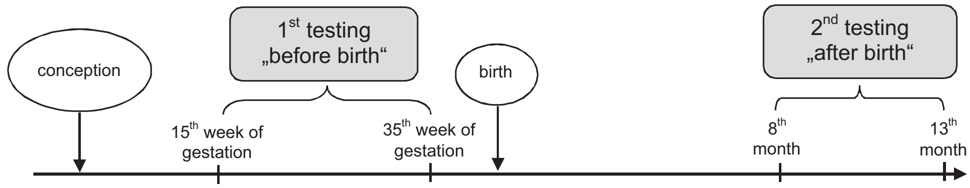

Fig. 1. Study design including two testing sessions, once before and a second time after childbirth for pregnant women and female controls. At both study time points, sleep was monitored in the home environment for seven consecutive days and nights using actigraphy and sleep diaries. During the week of sleep monitoring or a few days thereafter, testing on the false memory task took place in the laboratory.

frequently claim to remember the gist words that were never actually encountered.

Pregnant women also show pronounced changes and disruptions of sleep architecture [13]. During late pregnancy and the early postpartum period, i.e., shortly before and after childbirth, sleep is generally shorter, lighter, and less efficient [13]. During earlier stages of pregnancy and the late postpartum period, on the other hand, sleep is more often characterized by increased sleep fragmentation [14], i.e., repetitive short interruptions of sleep. Acute experimentally induced sleep fragmentation is not only known to increase daytime sleepiness and health complaints [15] but also has detrimental effects on daytime functioning [16,17] including memory recall [18]. For instance, memory recall of verbal material was impaired after a night of sleep fragmentation particularly if sleep fragmentation included disruptions of the naturally occurring NREM–REM sleep cycles [18]. Likewise, chronically fragmented sleep in patients suffering from obstructive sleep apnea (OSA) has been shown to contribute to observed impairments in memory functions, for example in verbal memory [19,20], procedural memory [20] and working memory [20, for an overview see 21]. However, whether sleep fragmentation also increases the risk of producing false memories is unclear. Previous studies found that normal sleep after learning as well as acute sleep deprivation before retrieval testing can increase the likelihood of false remembering [22–25].

In the present study, we sought to specify the role of chronic sleep fragmentation in pregnant women before and after childbirth for the generation of false memories. We hypothesized that women during pregnancy and in the late postpartum period would show pronounced sleep fragmentation and increased production of false memories compared to female controls. Furthermore, we expected increased false memory generation to be related to sleep fragmentation during pregnancy and motherhood.

178 pregnant women, who were expecting their first child, and 58 female non-pregnant, childless controls participated in the study. All subjects reported not to suffer from sleep disorders or irregular sleep habits (in the context of mental disorders or shift-work including night shifts). Fourteen subjects did not continue to participate in the study after childbirth and were excluded from data analysis. The pregnant women were slightly older (27.7 ± 4.0 vs. 26.1 ± 3.9 years; $p = 0.013$) and had a higher educational level than female controls ($p = 0.051$; see Supplementary Table S1). At the time of enrollment in the study, it was determined that none of the pregnancies displayed any clinically relevant conditions or complications. Pregnant women reported suffering from common mild pregnancy related complaints such as morning sickness, reflux, increased voiding, convulsions in legs and edema of the extremities, with low subjective distress caused by these complaints. Participation in the study was voluntary and participants received financial compensation. The study protocol was approved by the Ethics Committee of the Faculty of Medicine of the Technische Universität Dresden, Germany. Participants gave written informed consent.

Participants took part in the study at two time points: first during pregnancy (in the following called "before birth"; mean week of gestation: 22.2 ± 4.1, range = 15–35), and second, 10 months after birth (in the following called "after birth"; mean age of the child: 9.9 ± 0.6 months, range = 8.3–12.9, see Fig. 1). Control women participated in parallel with pregnant women before and after childbirth. At both study time points sleep was monitored for 7 days and nights continuously. Testing on the false memory task took place in the laboratory either during the week of sleep recording or a few days thereafter.

To assess false memories, we used the standard DRM paradigm in a German version comprising eight DRM lists [11,26] each containing 12 semantic associates that were strongly associated to a critical non-presented theme word. Two parallel versions were used in counterbalanced order at both study time points. During learning, participants were instructed to memorize the list words that were presented acoustically, one word every 3 s, in order of descending strength of association to the theme word. Recognition memory was tested after a 5-min retention interval. Forty-eight words were presented in random order on a computer screen, including 24 list words (actually presented words during learning, taken from list position 1, 5 and 10, respectively), eight theme words (not presented during learning, strongly semantically associated to the list words), and 16 distractors (not presented during learning, not semantically related to the list words). Participants had to indicate whether the presented word was "old" (=presented during learning) or "new" (=not presented during learning), without time limit for the judgments. The proportion of list words judged as old was defined as "correct memory rate", the proportion of theme words judged as old was defined as "false memory rate", and the proportion of distractors judged as old was defined as "false alarm rate". In addition to false memories, working memory performance was assessed with the German version of the Digit Span test of the Wechsler Adult Intelligence Scale, version 3 [27]. Within this task, participants have to repeat a series of digits in the given order (forward task) or in revised order (backward task). An additional digit is added to the series if at least one of two lists of the same length has been repeated successfully. Working memory performance refers to the sum of the longest series a person was able to remember in the forward and backward conditions. Furthermore, a subgroup of subjects performed a prospective memory task that is not reported here.

Objective sleep data were acquired using an accelerometer (Actiwatch 7®, CamNtech Ltd., Cambridge, UK) worn on the non-dominant wrist (epoch lengths of 15 s, sensitivity < 0.01 g, frequency of 32 Hz). Data were analyzed with Actiwatch Activity & Sleep Analysis 7, version 7.27, software (CamNtech Ltd., Cambridge, UK) using medium sensitivity threshold. Taken from sleep diaries, time points were (1) going to bed, (2) switching off the lights, (3) waking up, and (4) getting up. Fragmentation index (FragIndex), the percentage of wakefulness after sleep onset (WASO%), sleep efficiency (SE%) and total sleep time (TST) served as the main sleep parameters for analysis. FragIndex refers to the sum of time awake related to total sleep time and the percentage of very short sleep periods ($\leq$15 s) related to the total number of sleep periods. Therefore, FragIndex represents a marker of restless sleep. WASO% refers