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The dream-lag effect: Selective processing of personally significant events during rapid eye movement sleep, but not during slow wave sleep

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ABSTRACT

Incorporation of details from waking life events into Rapid Eye Movement (REM) sleep dreams has been found to be highest on the night after, and then 5–7 nights after events (termed, respectively, the day-residue and dream-lag effects). In experiment 1, 44 participants kept a daily log for 10 days, reporting major daily activities (MDAs), personally significant events (PSEs), and major concerns (MCs). Dream reports were collected from REM and Slow Wave Sleep (SWS) in the laboratory, or from REM sleep at home. The dream-lag effect was found for the incorporation of PSEs into REM dreams collected at home, but not for MDAs or MCs. No dream-lag effect was found for SWS dreams, or for REM dreams collected in the lab after SWS awakenings earlier in the night. In experiment 2, the 44 participants recorded reports of their spontaneously recalled home dreams over the 10 nights following the instrumental awakenings night, which thus acted as a controlled stimulus with two salience levels, high (sleep lab) and low (home awakenings). The dream-lag effect was found for the incorporation into home dreams of references to the experience of being in the sleep laboratory, but only for participants who had reported concerns beforehand about being in the sleep laboratory. The delayed incorporation of events from daily life into dreams has been proposed to reflect REM sleep-dependent memory consolidation. However, an alternative emotion processing or emotional impact of events account, distinct from memory consolidation, is supported by the finding that SWS dreams do not evidence the dream-lag effect.

1. Introduction

Rapid-eye movement (REM) and non-REM sleep stages Slow Wave Sleep (SWS) and stage 2 sleep (N2), are believed to play a role in the consolidation of memories (e.g., Diekelmann & Born, 2010; Gais & Born, 2004; Smith, 2001). Several researchers have proposed a sequential two-step model for memory consolidation during sleep (Gais & Born, 2004; Giuditta et al., 1995; Stickgold, James, & Hobson, 2000). In the first step, events from the day are processed during SWS, with non-adaptive memories being weakened while adaptive memories and responses are strengthened. The second step takes place during REM sleep, in which adaptive memories are processed for better storage and integration with previous memories (Giuditta et al., 1995; Walker & Stickgold, 2010). A process of memory triage for consolidation has also been proposed (Stickgold & Walker, 2013), in which there is a differential processing of memories based on factors such as salience and future relevance. This discriminatory selection serves multiple forms of memory, such as emotional memory, episodic memory and procedural memory, is facilitated by different sleep stages and by the reactivation of new memories during sleep, and is necessary for rapid and effective adaptation to changes in the environment (Stickgold & Walker, 2013).

Dreaming has been proposed to reflect this reactivation and consolidation of memories during sleep (Wamsley, Perry,

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Djonlagic, Babkes Reaven, & Stickgold, 2010; Wamsley & Stickgold, 2011). For example, Wamsley, Tucker, Payne, Benavides, and Stickgold (2010) demonstrate that improved performance on a virtual navigation task is associated with task-related dreams during an intervening nap, but not with task-related daydreams during an intervening period of wake. Regarding longer timescales, findings of a 7-day U-shaped function of incorporation of waking life events into dreams has led to speculation by Nielsen and Stenstrom (2005) that this indexes a process of memory consolidation across several nights, during which recently acquired memories shift from the hippocampus to neocortical structures.

The 7-day U-shaped timescale comprises the appearance in dreams of memory details from one or two days before, known as immediate incorporations or the day-residue effect, and a delayed incorporation of daily events into dreams 5–7 days after the event took place, known as the dream-lag effect (Nielsen, Kuiken, Alain, Stenstrom, & Powell, 2004). Naturalistic designs used to study this have involved the completion of daily diaries and dream diaries over periods of one to two weeks, with the incorporation of waking life events into dream reports then being identified (Blagrove, Fouquet, et al., 2011; Blagrove, Henley-Einion, Barnett, Edwards, & Seage, 2011; Nielsen et al., 2004). In two of these studies (Blagrove, Henley-Einion, et al., 2011; Nielsen et al., 2004) account is taken of any putative recurring weekly events confound. Standardized stimulus designs have also been used, with a night sleeping in the sleep laboratory (Nielsen & Powell, 1989, second experiment) or the watching of a videotape of the ceremonial slaughter of a water buffalo (Powell, Nielsen, Cheung, & Cervenka, 1995) as the stimulus: In both these studies the dream-lag effect was found.

The dream-lag effect holds for REM sleep dreams but not N2 dreams (Blagrove, Fouquet, et al., 2011). In that study participants kept a daily diary for nine days and dream reports were then collected in the sleep laboratory from REM and N2 sleep, with interruptions from both sleep stages occurring across the night. Participants rated the correspondence between each of their daily diary records and each dream report collected in the sleep laboratory. Experiment 1 in the present paper similarly investigates the dream-lag effect for the incorporation of naturalistic events and occurrences into dreams where the sleep stage at awakening is known. Experiment 1 extends the work of Blagrove, Fouquet, et al. (2011) by having one condition where awakenings occur from REM sleep and from SWS. Of necessity data collection has to occur in the sleep laboratory and with SWS awakenings occurring early in the night, when SWS predominates, before the REM awakenings. The question of whether SWS dreams evidence the dream-lag effect arises because SWS is held to be involved in system consolidation for declarative memory (Diekelmann & Born, 2010), and in the integration of newly learned memories into existing schemas, and the formation of new schemas (Lewis & Durrant, 2011). However, whether such processing is reflected in dream content, and with the timescale of delayed incorporation found for REM sleep dreams, is currently unknown.

Experiment 1 also extends Blagrove, Fouquet, et al. (2011) by having another condition where participants are woken for dream reporting solely from REM sleep, at home using the Nightcap sleep monitoring device (Ajilore, Stickgold, Rittenhouse, & Hobson, 1995). Although the results of Blagrove, Fouquet, et al. (2011) regarding the dream-lag effect being specific to REM rather than N2 dreams were clear, and understandable in terms of REM specific emotional memory consolidation, dream reports were collected over two non-consecutive nights (separated by one night at home), as necessitated by the need to sample each of REM and N2 across the night. The advantage of the current study is that dream reports are collected solely from one night: with either SWS awakenings early and REM sleep awakenings later in the night, or solely REM sleep awakenings across one night. This removes any confounds of having two nights of awakenings, such as dream content on the second dream collection night referring to the sleep experiment on the first night, which could increase apparent correspondences for the 2 and 3 day periods between a diary day and a dream report.

Experiment 1 also extends previous studies on the dream-lag by investigating which types of naturalistic occurrences are subject to delayed incorporation. In order that categories of waking life occurrence can be assessed separately, participants keep a structured daily log, taken from Fosse, Fosse, Hobson, and Stickgold (2003), that differentiates three categories of waking life occurrences: major daily activities (MDAs), personally significant events (PSEs), and major concerns (MCs). We hypothesize that PSEs are incorporated into dreams according to the 5–7 day dream-lag timescale. MDAs are not expected to demonstrate the dream-lag effect, as they are less salient than personally significant events, and because they might not be temporally exact or distinctive enough (Hartmann, 2000) to show the dream-lag. Major concerns also might not be temporally exact, and so likewise are not expected to evidence the dream-lag.

All studies reviewed above on the dream-lag effect allowed for one overall correspondence score to summarize the comparison of a dream report with an event or a diary record of a day's events. Importantly, in experiment 1, in order to allow for the identification of incorporations of the three different types of waking life sources into dream reports, participants are allowed to score multiple correspondences between each daily log record and each dream report. However, Henley-Einion and Blagrove (2014), using such a multiple correspondences method, found that there are individual differences in overall number of correspondences identified between diary records and dream reports. This individual difference in tendency to find connections between daily life records and dreams reports was found to result in a dilution or eradication of timecourse relationships for individuals who identify high numbers of such incorporations across the study. The authors thus recommend dividing participants in such studies into two groups, using a median split based on the total number of correspondences identified by each participant across the whole study. Following this, Blagrove et al. (2014) used a multiple correspondences method for comparisons of daily logs and dream reports, just as in the current study, with the Fosse et al. (2003) daily log, but with spontaneous home dream recall. 38 participants kept a daily log and a dream diary for 14 days. Participants later compared all daily log records to all dream reports and identified any correspondences between items on the logs and the contents of each dream report. As above, participants were divided into above and below median total number of incorporations and the two groups were then analyzed separately. Comparing mean number of incorporations per dream, a significant dream-lag effect was found for incorporations of personally significant events, but only for the below-median total correspondences participants. A dream-lag effect was not found for MDAs and MCs. In experiment 1 here the same method of analysis is performed, with low and high incorporators analyzed separately, but with sleep stage of the dream being known. It is hypothesized that the REM sleep dream-lag effect will only be present in the low incorporator subsample, and only for PSEs.

Although many studies have demonstrated the dream-lag effect using naturalistic diary keeping, this has been despite the variability in types and salience of events across the days during which the diary is kept. The effect of this error variance can be reduced by having many diary records, each of which is compared to dream reports collected over several days, resulting in a matrix of comparisons, as in Blagrove, Fouquet, et al. (2011) and Blagrove, Henley-Einion et al. (2011). The naturalistic variance can, however,

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