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Immediate and delayed incorporations of events into dreams: further replication and implications for dream function

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SUMMARY The incorporation of memories into dreams is characterized by two types of temporal effects: the *day-residue effect*, involving immediate incorporations of events from the preceding day, and the *dream-lag effect*, involving incorporations delayed by about a week. This study was designed to replicate these two effects while controlling several prior methodological problems and to provide preliminary information about potential functions of delayed event incorporations. Introductory Psychology students were asked to recall dreams at home for 1 week. Subsequently, they were instructed to select a single dream and to retrieve past events related to it that arose from one of seven randomly determined days prior to the dream (days 1–7). They then rated both their confidence in recall of events and the extent of correspondence between events and dreams. Judges evaluated qualities of the reported events using scales derived from theories about the function of delayed incorporations. Average ratings of correspondences between dreams and events were high for predream days 1 and 2, low for days 3 and 4 and high again for days 5–7, but only for participants who rated their confidence in recall of events as high and only for females. Delayed incorporations were more likely than immediate incorporations to refer to events characterized by interpersonal interactions, spatial locations, resolved problems and positive emotions. The findings are consistent with the possibility that processes with circaseptan (about 7 days) morphology underlie dream incorporation and that these processes subserve the functions of socio-emotional adaptation and memory consolidation.

KEYWORDS circaseptan process, dream incorporation, dreaming, gender, memory, temporal factors

INTRODUCTION

Human memory researchers have begun to clarify how the temporal organization of awake- and sleep-related processes influences the consolidation of new learning (Born and Gais, 2003; Giuditta *et al.*, 2003; Smith, 2003; Stickgold *et al.*, 2000). Several types of research converge on the notion that the appearance of rapid eye movement (REM) and non-rapid eye movement (NREM) sleep at specific times is critical for the strengthening of memories. While most studies of such 'critical periods' have examined the hours immediately following new learning, some also implicate sleep occurring a few days later (for reviews see Smith, 1996, 2003). However, relatively little research has investigated postlearning critical periods a week or longer in duration. In addition, while a possible functional role for dreaming in memory consolidation has been suggested (Stickgold, 2003), there is a lack of research that clearly demonstrates a link between dreaming and memory.

A series of our previous studies has provided new clues to both the implication of delayed critical windows and the nature of a possible function for dreaming in memory

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consolidation. These studies are based on the assumption that incorporations of recent events into dreams reflect a form of additional memory processing during sleep. While our research has not employed the classical learning tasks employed in many other studies, our targeted measure – memories of emotionally salient, daytime experiences – has been linked to possible adaptive functions of dreaming (Cartwright, 1991; Kramer, 1993) and has been suggested to participate in a memory consolidation function as well (Stickgold, 2003).

Immediate and delayed references in dreams

Our research provides replicable evidence that two types of temporal delay characterize relationships between the occurrence of a daytime event and the reappearance of its features in a dream. We refer to these two delays as (1) the *day-residue effect*, or the reappearance of features from events occurring on the immediately preceding day, and (2) the *dream-lag effect*, or the reappearance of features from events occurring about a week prior to the dream. The two effects are curvilinear in nature such that, when plotted together over a time line of 1 week, they form a U-shaped curve.

The day-residue effect has been observed consistently in empirical studies (Nielsen and Powell, 1992), including studies using quantified presleep experimental stimuli, polysomnographic recordings, and sleep staging (Arkin and Antrobus, 1991). The proportion of dreams that contains residues varies considerably across studies, most likely because of differences in the methods used to identify them. The probability of observing the day-residue effect appears consistently to be about twice the probability of observing a reference to events occurring 2 days prior to the dream (Nielsen and Powell, 1992). For example, the relative proportions of dreams referring to events from the first and second days prior to target dreams were 64 and 36% in one study (Epstein, 1985), 65 and 35% in a second study (Jouvet, 1979), and 65 and 35% again in a third study (Nielsen and Powell, 1992).

Delayed references to daytime experiences (dream-lag effect) have been demonstrated in several experiments, five of which were conducted by our group (Nielsen and Powell, 1988, 1989, 1992; Powell *et al*., 1995) using within-subject designs. In these experiments, subjects were requested to write out reports of their dreams for durations of 7–12 days. Traceable memory sources, such as self-reported concerns or references to a disturbing film or a sleepover in the laboratory, were evaluated by blind judges for their degree of correspondence with the dreams. When correspondence ratings were plotted against days prior to the dream, sinusoidal U-shaped curves were observed, with peak scores occurring for dreams following the source by 1 day and 6–7 days. Randomization and other controls minimized the likelihood that these effects are attributable to confounding by the 7-day societal schedule, experimenter bias, subject anticipation, and other variables.

Delayed references to daytime experiences were also reported in a laboratory study of subjects who wore red-tinted goggles continuously over 5 days and who reported dreams after multiple REM period awakenings (Roffwarg *et al*., 1978). The proportion of red-tinted objects in the dreams ('goggle' incorporations) was most apparent for the first REM episode of each night, where it was sinusoidally distributed over nights; red-tinted objects increased (from a 37.8% pregoggle baseline) to a night 1 level of 56.7%, then decreased to 37.5% on goggle nights 2 and 3, increased again to 85.2% on nights 4 and 5, and decreased to 28.3% on postgoggle recovery. While it remains unknown whether the abrupt decrease on recovery was due to reintroduction of normal visual input or to a delayed incorporation effect, the marked decrease on days 2 and 3 and subsequent resurgence of incorporations on days 4 and 5 is clearly consistent with other findings for delayed incorporations. Two additional studies provide indirect evidence for delayed incorporations (Marquardt *et al*., 1996; Verdone, 1965).

Evidence consistent with the previous findings was also reported by Jouvet (1979). In an analysis of correspondences between 130 of his personal dreams and their preceding memory sources, Jouvet found a sinusoidal U-shaped curve with peak references occurring 1 day (34.6%) and 9 days (10%) prior to the dreams. In a second analysis of 270 dreams recorded during and after travel abroad, he found that spatial elements of the new environment were most apparent in his dreams on average 7.8 days after leaving on the trip, while his home environment was most apparent on average 6.5 days after returning from travel. Jouvet suggested that the delayed references reflected a mechanism responsible for delayed processing of spatial memory of environments; a possibility that we tested in the present study.

Together, these studies have fairly consistently shown that the dream-lag effect is similar in magnitude to that of the day-residue effect, but they have been less consistent in their identification of a precise temporal delay. Although our work and that of Roffwarg *et al*. (1978) demonstrated delays of 5–7 days, that of Jouvet implicated delays of 6.5–9 days. Overall, the findings converge on the possibility that incorporations of events into dream content are characterized by a circaseptan, or 7 ± 3 day (American Association of Medical Chronobiology and Chronotherapeutics, 2003) morphology.

Methodological problems

The present study improves upon four procedural problems with previous work. First, our previous reliance upon within-participant designs resulted in missing observations due to participant differences in dream recall that may reflect variations in memory ability, motivation, gender and other factors. Missing observations have necessitated dropping such participants from analyses, estimating their missing values statistically, and/or reducing df of the *F*-test with Geisser–Greenhouse corrections (Winer, 1971). Secondly, we have used judge, rather than participant, ratings of a dream's similarity to past events because participant ratings may be biased in repeated measurement designs. However, judge ratings are limited in validity and reliability; judges are not privy to the numerous, sometimes subtle, links between dreams and event memories, and they are further handicapped by participants' often sketchy descriptions of dreams and events. Thirdly, some previous work may have been confounded by recurrent temporal factors. The fact that some participants were exposed to a target stimulus, such as a film, at the same time on the same day may have led to a day-of-week confound. Similarly, it remains unknown to what extent results were confounded by incorporated memories of events that were recurrent in nature, e.g. weekly meetings. Fourthly, we have some evidence of important participant differences in the occurrence of delayed incorporation effects. In our 1995 (Powell *et al.*, 1995) study, we found that participants whose dreams clearly incorporated prior events (i.e. score of 10 on 0–10 scale on at least one dream) tended to manifest both temporal effects compared with participants whose dreams referred less clearly to such events. This difference could be due to differences in a dream's salience or impact, memory abilities or other factors. We also found some evidence of gender differences that could not be evaluated due to sample size limitations.

The present study responds to each of these problems in the use of a completely randomized between-group design in which participant ratings constitute the dependent variable and participant differences in gender and memory are considered. Further, the events selected by participants are evaluated to determine whether they refer to recurrent events such as the experiment and school activities or are inherently recurrent in some other way.

An additional advantage of the present study design – the evaluation of event qualities – is that we may explore competing hypotheses about the nature of delayed dream incorporations. We here consider three hypotheses that we derived from existing functional theories of dreaming, dream incorporation or learning.

(1) *Social adaptation hypothesis*: delayed incorporations reflect progressive adaptation to or resolution of interpersonal relationship problems (Cartwright, 1991).

(2) *Spatial memory hypothesis*: delayed incorporations reflect a separate memory system that processes spatial elements of the environment (Jouvet, 1979).

(3) *Zeigarnik effect hypothesis*: delayed incorporations reflect the lack of resolution of problems (Zeigarnik, 1927).

The goals of this study were therefore to (1) replicate the two temporal effects with a more highly controlled between-group design, and (2) assess the qualitative nature of events referred to in dream reports to exclude possible confounds and to compare hypotheses about the function of delayed incorporations. It was hypothesized that dream incorporation over successive days would be described by a U-shaped curve when self-reported memory for past events was high and that delayed incorporations would be more likely than either immediate or intermediate incorporations to implicate features of events indicative of social adaptation or spatial memory functions.

METHODS

Participants

A total of 470 students from four introductory psychology classes participated for course credit. This represents 73.2% of the 642 students enrolled in these classes. For the 432 (312 f, 120 m) who specified their age and gender, mean age was 20.2 ± 5.74, with no age difference between males (20.4 ± 7.39) and females (20.1 ± 5.03; $t_{430} = 0.362$, $P = 0.717$). Following the experiment, participants were given a written debriefing and, on a later date, an extended oral overview of the rationale for the research project. They received course credit for their participation.

Analysis 1: temporal effect replication

During class, the requirements of the study and the fundamentals of informed consent were explained, and students were made aware that they were free to decline participation for credit (alternate opportunities for research participation were available). If they consented, they were given a study package that contained instructions for recording and rating their dreams during the following week, as well as some personality questionnaires to complete at home. The results from the questionnaires are not reported here. They were instructed, first, to record a dream each morning for seven consecutive days and to rate it on several scales assessing clarity of recall, type and intensity of emotions, intensity of actions, and dream impact. Scale anchors were 0: 'not at all' and 9: 'very…' as appropriate. The results involving these ratings suggest that subjects whose dreams generally have high impact report both immediate and delayed types of incorporations (Alain *et al.*, 2003; Nielsen *et al.*, 2003). Participants were asked to bring their completed questionnaires and home logs to class 1 week later.

Target dream selection

The class period 1 week later was dedicated to the identification of references to target dreams and to the completion of additional questionnaires. Participants were asked first to select a target dream from their log ('please select from your diary the most recent dream that you can remember well'). If their recall of the most recent dream was poor or sketchy, they were asked to select the next most recent dream. If they had recorded no dreams in their logs, they were asked to proceed to a subsequent section containing questionnaires.

After selecting a target dream, they were asked to read through the dream, to imagine it as vividly as possible and to indicate from which of the 7 days in their logs they selected it ('dream log day'). Seventy of 470 participants (15%) failed to record a number, indicating either that they recalled no dreams or, possibly, that they did not bring their logs to class. Participants were then asked to consider correspondences between their selected dream and events occurring on a target day prior to the dream. This target day was selected separately using a constrained choice procedure.

Constrained choice procedure

Participants were asked to recall events ('everything that you did on this day') from one of seven randomly determined days prior to their dream. Randomization into the seven groups was achieved by randomly distributing seven parallel instruction sets which differed only in the target day (1–7) that was specified. A small calendar was provided to help in the identification of target days. Verbatim instructions are reproduced in Appendix 1.

Participants were then instructed to rate how well they could remember events from their target day on a scale where 0 signified *extremely poorly* and 9 signified *extremely well*. Memory confidence was defined as *low* when participants rated their confidence in recall as 0–4 on the scale and as *high* when they rated it as 5–9. Participants were also asked to write down the event from the target day that seemed most closely related to their dream. Finally, they were asked to rate the apparent correspondence between their chosen dream and this target event ('what is the extent of correspondence between your event and any part of your dream?'). Fourteen participants failed to evaluate either remembered events or event-dream correspondences correctly and were dropped from further analysis (final $n = 370$).

Analysis 2: event quality evaluation

Events recorded by participants in their logs were subsequently transcribed into text files, identifying information was removed, and two independent judges who were blind to experimental conditions evaluated them using 11 descriptors (Table 1). Each descriptor assessed the likelihood that it applied to the target event, where 1 = none, 2 = weak, 3 = average, 4 = high and 5 = certain. Descriptors were selected to permit evaluation of the following three functional hypotheses and a confound hypothesis.

- *Social adaptation hypothesis*. Our version of this hypothesis stipulates that delayed incorporations are implicated in the progressive adaptation of problematic social relationships. Items were developed that assess references to *interpersonal relationships*, *resolved problems* and *positive emotions*.
- *Spatial location hypothesis*. This hypothesis holds that delayed incorporations reflect the operation of a separate memory system that governs treatment of strictly spatial memory features. One item was developed that assesses direct references to *spatial locations* and another, control, item was developed that specifically does not refer to spatial locations, i.e. *self-actions*.
- *Zeigarnick effect hypothesis*. Our version of this hypothesis stipulates that delayed dream incorporations are analogous to memories that are better recalled because they remain in an incomplete or frustrated state. Thus, items were developed that assess references to *unresolved problems* and *negative emotions*.
- *Confound hypothesis*. This hypothesis states that delayed incorporations are artifactual, i.e. that weekly, recurrent events produce day residues and, about a week later, lagged

Table 1 Sample judge scoring of dream-related memory events for 11 event descriptors. Judges assessed the likelihood that each descriptor applied to the target event, where 1 = none, 2 = weak, 3 = average, 4 = high and 5 = certain. 'Day' indicates a participant's group membership, defined as the number of days prior to the dream that the event occurred

ID	*Sex*	*Age*	*Day*	*Event*	*Recurrent-weekly*	*Recurrent-other*	*Relationships*	*Unresolved Prob.*	*Resolved Prob.*	*Negative affect*	*Positive affect*	*Experiment*	*School*	*Spatial location*	*Self-actions*
53	F	19	7	That night my friends and I saw a person get hit by a car	1	1	4	3	3	4	1	1	1	4	3
363	F	19	1	There were lots of cops in the girls' washroom of my building checking for finger prints	1	1	3	2	3	4	1	1	5	5	3
485	F	18	6	The main guy in my dream was on the bus that day	1	3	4	1	1	3	3	1	1	5	1
617	F	18	1	At training I fell hard down the stairs and was nervous about it	1	1	1	4	1	5	1	1	1	5	3
631	M	19	3	Earlier during school I saw some peers studying with each other using flash cards	1	1	4	1	1	2	3	1	5	5	2
640	F	20	4	I got hit on at the bar and got a guy's phone number	1	1	5	3	3	5	2	1	1	5	3

dream incorporations. Once/week events, school-related events, and the 1-week experiment itself are all possible sources of such confounds. Items were developed to assess references to events that are *recurrent weekly*, *recurrent other than weekly*, and *school- and experiment-related.*

We calculated interjudge reliabilities with intraclass correlations (SPSS v10.0) and contrasted groups demonstrating immediate (days 1–2), intermediate (days 3–4) and delayed (days 5–7) incorporations on each of these scales using Kruskal–Wallis and Mann–Whitney tests.

RESULTS

All participants were studied within 15 days of each other and began the study at approximately the same time of the week: three of the four sessions (77% of participants) took place on a Tuesday; the fourth (23%) took place on a Wednesday. The distribution of participants who selected dreams from dream log days 1–7 was 15, 13, 8, 15, 12, 14, and 23% – less negatively skewed than we had intended with our instructions. The distribution of participants randomly assigned to temporal delay days 1–7 was 21, 15, 14, 11, 13, 14, and 13% ($n = 78, 56, 52, 38, 46, 53, 47$). The absence of confounding of day-of-week with the day of selected dreams (dream log days) was shown statistically in two ways. First, a 7×7 chi-square between temporal delay days (1–7) and dream log days (1–7) was non-significant (likelihood ratio = 33.07, $P = 0.609$), indicating that the number of participants choosing dreams from any given log day was not statistically different for all seven randomly assigned groups. Secondly, the Pearson correlation between temporal delay days and dream log days was non-significant ($r = 0.048$, $P = 0.349$), even for high ($r = 0.027$, $P = 0.701$) and low ($r = 0.135$, $P = 0.073$) memory confidence groups considered separately.

Analysis 1: replication of two temporal effects

As expected, an ANOVA with temporal delay (days 1–7) and memory confidence (low, high) as independent variables and extent of correspondence (0–9 score) as dependent variable revealed a significant main effect for memory confidence ($F_{1,372} = 19.87$; $P = 0.00001$) such that participants with low confidence ($n = 178$) gave lower correspondence ratings (3.45 ± 2.98) than did participants with high confidence ($n = 208$; 4.94 ± 3.03; see Fig. 1). No other main effects or interactions were significant.

The two memory confidence groups were therefore assessed separately. The high memory confidence group was 78.3% female and 21.7% male (10 participants not indicating gender were deleted). They were distributed among temporal delay days 1–7 as follows: 46, 36, 25, 23, 24, 25 and 19. This group demonstrated a clear U-shaped curve, as reflected in a significant main effect for temporal delay ($F_{6,191} = 2.167$; $P = 0.048$) that consisted exclusively of a quadratic polynomial trend ($F_{1,191} = 8.809$; $P = 0.003$).

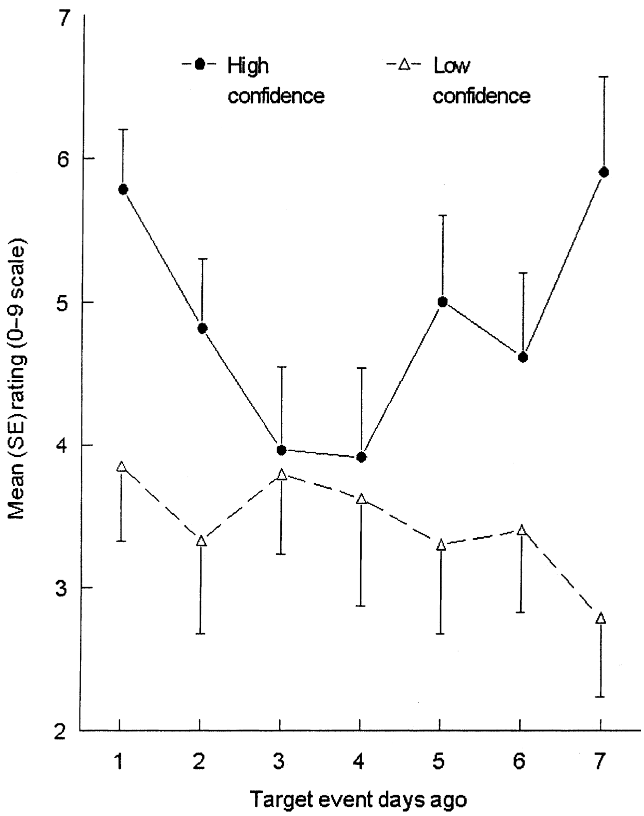

Figure 1. Mean (SE) dream incorporation ratings for each target day for low (triangles) and high memory confidence (circles) groups. The high confidence group displays the expected U-shaped curve with days 1 and 2 showing the immediate (day-residue) incorporation effect and days 5–7 showing the delayed (dream-lag) effect. No significant effects were observed for the low confidence group.

Contrasts between levels of the temporal delay variable for the high confidence group confirmed that incorporations were lower on days 3 and 4 than on days 1 and 7 (all $P < 0.05$).

The low confidence group was 67.6% female and 32.4% male (six participants not indicating gender were deleted) and participants were distributed among days 1–7 as follows: 32, 20, 27, 15, 22, 28 and 28. This group showed no main effect ($F_{6,163} = 0.453$; $P = 0.842$) and no polynomial trends (all $P =$ NS).

Because there was a predominance of female students in our sample, some levels of the temporal delay variable contained too few males to permit reliable gender comparisons. To maximize numbers for gender comparisons, we formed three aggregate temporal delay groups: an immediate group (days 1–2; $n = 62$ f, 20 m), an intermediate group (days 3–4; $n = 33$ f, 15 m) and a delayed group (days 5–7; $n = 60$ f, 8 m). Correspondence ratings were entered into a 3×2 ANOVA with temporal delay group (immediate, intermediate, delayed) and gender (male, female) as independent variables. An interaction effect revealed different patterns of correspondence over Delay groups for females and males ($F_{2,192} = 4.342$; $P = 0.014$; Fig. 2). A quadratic trend ($F_{1,152} = 8.293$; $P = 0.005$) described the pattern for females, whereas a

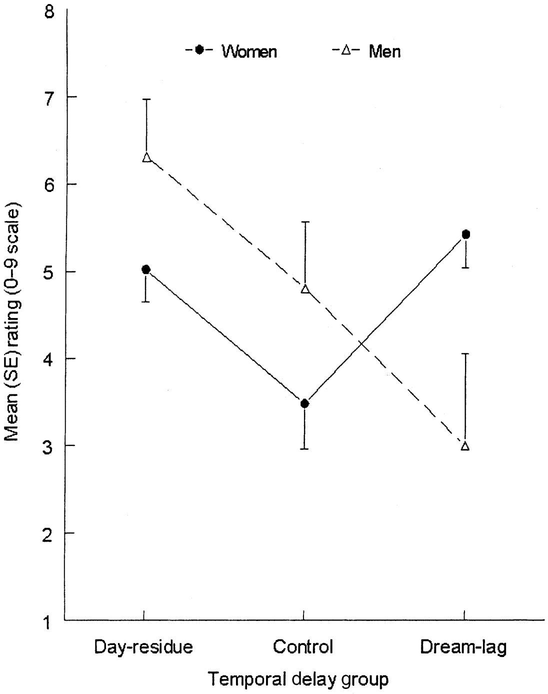

Figure 2. Mean (SE) subject ratings of correspondences between events and dreams for men (triangles) and women (circles) for three temporal delay groups. Temporal delay groups are aggregates of days 1 and 2 (immediate), days 3 and 4 (intermediate) and days 5–7 (delayed). Correspondence ratings for the delayed group were significantly higher for female than for male participants.

decreasing linear trend ($F_{1,40} = 9.780$; $P = 0.003$) described the pattern for males. Planned comparisons revealed that among females, only mean correspondence ratings for the immediate and delayed groups were higher than for the intermediate group ($P = 0.022$ and 0.004). Furthermore, ratings for the female delayed group were higher than for the male delayed group ($t_{66} = -2.165$, $P = 0.034$); small and statistically unreliable differences in the opposite direction were observed for the immediate ($t_{45.5} = 1.969$, $P = 0.055$) and intermediate ($t_{46} = 1.480$, $P = 0.146$) groups.

Analysis 2: differential event qualities for immediate and delayed incorporations

A total of 139 participants with high memory confidence supplied dreams for which correspondences with selected events was also high (≥4) and, thus, for which evaluations of event qualities were deemed appropriate. The mean age of these participants was 19.6 ± 2.10 years. The number of participants comprising each group was immediate ($n = 61$), intermediate ($n = 27$) and delayed ($n = 51$). Interjudge reliabilities for event quality descriptors for the dreams of these participants produced satisfactory intraclass correlations ($r = 0.511$–0.781).

Differences were found for descriptors assessing the social adaptation and spatial location hypotheses (Fig. 3, panels 1and 2) but not the Zeigarnick hypothesis (Fig. 3, panel 3). Contrasts between immediate and delayed conditions revealed significant differences for references to *interpersonal relationships* ($U = 707.5$; $P = 0.001$), *positive emotions* ($U = 782.0$; $P = 0.012$) and *problems resolved* ($U = 862.0$; $P = 0.046$) on the one hand, and *spatial locations* ($U = 745.0$; $P = 0.005$) but not *self-actions* ($U = 1067.0$; $P = 0.765$) on the other. The immediate group had significantly lower likelihood ratings than the delayed group on each of the four differentiating descriptors (Fig. 3). All contrasts involving the intermediate group were non-significant.

No differences were found for any descriptors pertinent to the confound hypothesis (Fig. 3, panel 4).

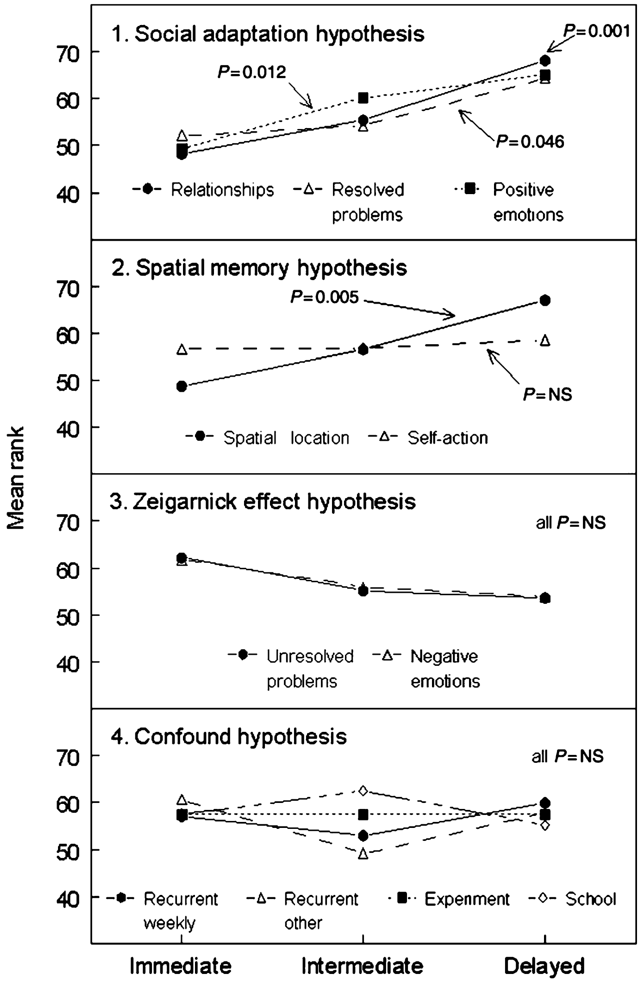

Figure 3. Kruskal–Wallis mean rank scores for judge ratings of event quality descriptors for immediate, intermediate and delayed incorporation groups. All *P*-values reflect contrasts between immediate and delayed groups. Delayed incorporations were more likely than immediate incorporations to be associated with *interpersonal relationships*, *resolved problems*, *positive emotions*, thus supporting the social adaptation hypotheses of dream incorporation function (panel 1), and with *spatial locations* but not *self-actions*, thus supporting the spatial memory hypotheses of dream incorporation function (panel 2). No support was found for the Zeigarnick effect hypothesis (panel 3) or for the confound hypothesis (panel 4).

Pearson correlations between the four differentiating descriptors revealed that *spatial locations* was positively correlated with *interpersonal relationships* ($r = 0.199$, $P = 0.021$) and (marginally) with *positive emotions* ($r = 0.145$, $P = 0.096$).

DISCUSSION

The results demonstrate the utility of a between-group design for assessing participants' own ratings of immediate and delayed dream incorporation effects. By replicating the familiar U-shaped pattern of event/dream correspondences, while simultaneously overcoming methodological shortcomings of previous repeated-measures studies, the results bolster our confidence in the existence of the two temporal effects and clarify the nature of previously unappreciated chronobiological processes that may contribute to the formation of dreams. The finding that delayed references are associated with qualitatively different features of remembered events than are recent references provides additional clues to the possible functions of delayed incorporations.

Evidence for a memory process with circaseptan morphology?

The consistency of the present findings with those of previous studies supports the possibility that some part of dream formation, namely, the selection of memories for incorporation into dream content, is governed by a process with circaseptan temporal morphology. Circaseptan morphology characterizes circaseptan rhythms, which are oscillatory processes with a periodicity of 7 ± 3 days (American Association of Medical Chronobiology and Chronotherapeutics, 2003). Such rhythms have been described for biological systems such as heart rate, blood pressure, and body weight (Cornelissen *et al.*, 2001), for cognitive phenomena such as reaction time (Beau *et al.*, 1999), and for psychopathological symptoms such as the timing of attempted suicides (De Maio *et al.*, 1982).

However, unlike circaseptan rhythms the processes postulated here are not necessarily recurrent; they are more likely to be hourglass processes (Hildebrandt, 1991) that are reactive to external stimulation and that 'count to 7' in some sense following the trigger (Cornelissen and Halberg, 2000). Reactive circaseptan processes have been identified for several adaptive and compensatory responses (De Maio *et al.*, 1982; Hildebrandt, 1991; Levi and Halberg, 1982; Pollmann, 1984). Work with animals (Leconte, 1983; Smith and Lapp, 1986) suggests that a circaseptan morphology affects changes in sleep architecture following some kinds of learning.

The hypothesized circaseptan morphology of dream incorporation processes appears to consist of a sequence of immediate and delayed memory retrievals, separated by an interval of relatively little retrieval – all apparently triggered by key daytime events. These triggers likely carry some affective, interpersonal or environmental importance, although our analyses of these features have only begun to assess their precise nature. When the triggering events are very arousing, some evidence (Nielsen and Powell, 1995; Sophie and Gross, 1994) suggests that the 7-day incorporation sequence may be delayed by several days (e.g. peaks on days 3 and 10). Such findings support the notion that the timing of dream incorporations may be influenced by a reactive circaseptan process the phase of which may be amenable to experimental manipulation by varying the intensity or salience of triggering events.

Although circaseptan rhythms and processes may be synchronized with the 7-day societal schedule, they are not necessarily artifacts of this schedule. Mounting evidence, including results from the present study, suggests that they are generated endogenously (Cornelissen *et al.*, 2001). That there was no day-of-week confound and, in particular, no consistent tendency for participants with delayed incorporations to select their dreams from particular days of the week, supports this point.

The fact that we observed delayed incorporations only for women needs replication but also has parallels in circaseptan rhythm research (Agrimonti *et al.*, 1982; De Maio *et al.*, 1982). For example, different circaseptan rhythms characterize the choice of different days for suicide attempts among women of different age groups but no effects at all are apparent for men (De Maio *et al.*, 1982). Some circaseptan rhythms are also known to be synchronized by the menstrual rhythm (Simpson *et al.*, 1990), which has an average periodicity of 28 days – an obvious harmonic of 7 days. In the case of dreaming, changes in dream content, such as portrayals of blood, have been observed for several different phases of the menstrual cycle (Van de Castle, 1994. See review in Nielsen, 2004). Although no systematic study of a circaseptan component in women's dreams has been reported, such changes in dream content may well reflect the influence of a circaseptan, in addition to a 28-day, rhythm or process.

Implications for dream function

The present design allowed us to test several exploratory hypotheses about possible functions of delayed dream incorporations. One hypothesis is based upon the notion that dreaming facilitates adaptation to the stresses and emotional difficulties of interpersonal relationships (Cartwright *et al.*, 1998; Greenberg *et al.*, 1972). In this respect, immediate and delayed incorporations of persons who are important in an individual's life may reflect processes dealing with different types of interpersonal information. Our finding that delayed incorporations were more likely to refer to situations of *interpersonal interactions, problem resolution* and *positive emotions* is consistent with the notion that the affected dreams may be implicated in the 'working through' of interpersonal difficulties. A related model has been proposed that describes variations in the quality of dreaming over time as due to different processes of adaptation to stressful events (Wright and Koulack, 1987).

A second hypothesis is that immediate and delayed dream incorporations reflect the operation of two different aspects of memory consolidation. We previously suggested (Powell and Nielsen, 1996; Powell *et al.*, 1995) that as the hippocampal role in memory formation changes over time, i.e. diminishes as the neocortex comes to maintain new memories (Squire, 1992; Wilson, 2002), dream incorporation processes change qualitatively in a parallel fashion. While the precise nature of hippocampal changes remains to be determined, one possibility suggested by Jouvet (1979) is that immediate incorporations are driven by a process barren of spatial memory elements that decays quickly across the week, while delayed incorporations are determined by a process dealing specifically with spatial elements that grows in importance across the week. Our finding that delayed incorporations had the highest likelihood of referring to *spatial locations* is consistent with this formulation. The fact that no difference was observed for attributes of *self-actions* suggests that the differential memory treatment may indeed be selective for spatial (and not motor) attributes. However, without more detailed assessments we cannot exclude the possibility that attributes of both person memories (as measured by *interpersonal interactions*) and spatial locations are processed similarly – perhaps by a common memory system involving episodic or autobiographical memories. The significant positive correlation observed between these two variables is consistent with this possibility, although the low shared variance between them ($R^2 = 0.04$) suggests that the link may not be strong.

A hypothesis linking delayed incorporations to unresolved problems (the Zeigarnick effect) received no support.

Finally, and perhaps most importantly, the results produced no evidence that delayed incorporations are due to experimental confounds. Specifically, the possibility that delayed incorporations are due to recurrent stimulus events was not supported. The latter stipulates that delayed incorporations are simply immediate incorporations of source events that either recur on the 7-day societal schedule (e.g. weekly sports events, weekly meetings, church attendance) (Freud, 1955) or that are a week in duration (e.g. the current experiment). Dreaming about such events may occur both at their onset and their conclusion simply because their temporal structure is known to the participants. However, our event quality ratings showed no evidence that delayed incorporations were any more likely than immediate or intermediate incorporations to be recurrent in nature or to refer to the experiment or to attributes of school routine. Such ratings are admittedly limited to an objective judge's ability to detect a participant's recurrent events and this finding therefore needs to be replicated using subjects' own ratings with similar scales. A related alternative explanation is that the difficulty of recalling temporally distant events (e.g. 7 days prior to the dream) leads to high-confidence confabulations which resemble recent events (e.g. 1 day prior) because the target days share more social cues with neighboring days than with other days of the week. While our failure to identify evidence that delayed incorporations are more recurrent in nature tends to repudiate this explanation, more information about confabulation effects as a function of days of the week is clearly needed to dispel it altogether.

We also found no evidence of a statistical dependence between the Dream Log and temporal delay days, i.e. participants assigned to different temporal delay conditions did not contravene instructions and select their dreams differentially from different days of the week. It is therefore unlikely that days synchronized with recurrent events (e.g. weekly meetings) were over-represented in any of the temporal delay conditions. Further evidence against experimental confound explanations for these temporal effects can be found in our previous publications.

Limits of the study

Participant and dream recall factors

Temporal links between memory processes and dream content were signaled in the present results only for participants who were confident in their memory of prior events. We suspect that participants with low memory confidence had either poorer memory abilities in general, or daily routines and experiences that were less memorable than those of participants with high confidence. However, without more objective measures of memory abilities, we can neither distinguish between such possibilities nor rule out other possible influences on the ratings of incorporated events, such as the systematic distortion of memory over time or the rating of memory confidence as low by participants who were unsuccessful at finding correspondences. Nor can we rule out participant factors such as differences in motivation, deception, and misunderstanding of our instructions or factors related to sleep stage and awakening conditions. As the latter factors were not measured, it is possible that the results were influenced either by variations in sleep stage physiology (e.g. REM versus NREM sleep awakenings) or by dream recall biases that affect home dream collection methods (e.g. preferential recall of visually or emotionally salient dreams; Foulkes, 1979). While we know of no such factors that could explain the sinusoidal variations in our findings, across-the-night assessments of dream content in relation to sleep stage are clearly desirable to more fully elucidate the temporal dynamics of dream formation that we have observed.

Another limit to the present design is that we were unable to determine whether individual participants manifested both immediate and delayed incorporations. Our previous studies using repeated-measures designs have established that most participants do display both effects (e.g. 66.7% of participants in our 1995 study) while some others fail to recall enough dreams to adequately assess both effects at once. However, this within-participants feature of the phenomenon was not strictly replicated in the present between-participants study.

Finally, because we assessed event qualities with custom scales, we have no norms that would inform us as to the distributions of these qualities for waking state, non-incorporated, memories in general. It is possible that, relative to immediate memories, delayed memories are also more likely to be characterized by high levels of interpersonal relationships, positive emotions, resolved problems, and spatial locations. Such findings would not necessarily be incompatible with our findings for dreaming, but would strongly suggest further avenues of research to determine whether our proposed model of dream formation processes is a specific instance of a more general system for processing memories, such as autobiographical memory (e.g. Rubin and Berntsen, 2003), the functioning of which during sleep has not yet been investigated in any detail.

Gender effects

Because of the importance of determining whether the incorporation effects we observed are linked to a circaseptan rhythm that is unique to women, our relative shortage of male participants imposes a limit in our confidence about the finding of a gender difference. Further assessment with larger groups of male participants is clearly required. Other gender differences in dreaming phenomena that have been observed should also be controlled in future studies: (1) women recall dreams more often than do men (Martinetti, 1989), at least for cohorts up to age 39 (Stenstrom *et al*., 2003); (2) women's dream recall following stress increases while men's recall decreases (Blagrove and Akehurst, 2000); (3) the content of women's dreams differs systematically from that of men's (Hall, 1984); and (4) women describe their dreams as more vivid, meaningful, and impactful (Levin, 1994). Control of such variables is all the more critical given evidence that delayed incorporations are associated with measures of dream impact (Nielsen *et al*., 2003).

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APPENDIX 1

Instructions for recall of events prior to target dream

We want you to try to find some of the sources of the dream you have chosen; we want you to focus on events that occurred on a specific day prior to this dream. To do this, we would like you first to think about what happened to you on exactly X* days before this dream. That is, if the dream occurred on a Wednesday, we want you to look for sources from X* days prior to Wednesday. It is very important that you think only about this day and no others, even though other days might seem more pertinent to your dream…

Please think carefully about everything that you did on this day; the calendar may help you with this. Start from early in the morning and try to retrieve what you did throughout the day: who you saw at breakfast, at school or work, what you did in the evening, etc. If you saw a movie, what was it? If you saw friends, what did you do or talk about? If you watched TV, what did you see? and so forth. Please note anything that may have stood out on that specific day.

*The symbol 'X' corresponds to a randomly assigned value between 1 and 7.