MEMORY RECONSOLIDATION IN THE PRESENCE AND ABSENSE OF SLEEP

By

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Abstract

This study explores the connection between sleep and reconsolidation of memory. Previously, memory was thought to be static after information is initially coded. However, recent research suggests that memories can be reactivated and reconsolidated using a simple reminder (Hupbach et al. 2007).

The present study explores the occurrence of the reconsolidation effect in presence or absence of sleep, based on Hupbach et al. (2007). Regardless of sleep, there was no significant reconsolidation found in this experiment. This suggests that memory updating needs more than 12 hours to develop.

Introduction

Traditionally, the memory consolidation hypothesis has held most support in the scientific community. It suggests that memory remains static after information is initially coded (McGaugh 2000). There are two distinct phases of this consolidation effect. The first is a daytime stabilization phase in which the memory becomes encoded despite daytime interference. The second stage, memory enhancement, has been shown to occur exclusively during sleep. This phase has been shown to both improve on and retain the previously encoded information (Walker 2004).

Recent research contradicts strict consolidation theory and suggests that memory is in fact dynamic (Nader, 2003, Hupbach et al., 2007; Walker et al., 2003). Memories that are reactivated can be manipulated using a simple reminder of the previously encoded information. New information presented at the time of the reminder can either interfere with or be incorporated into the previous memory, which then undergoes a process of reconsolidation. This process is important for understanding how memories are updated.

Walker et al. (2003) were the first to show reconsolidation in humans. Using a finger tapping apparatus, participants were initially taught a sequence (Sequence 1) on Day 1. Twenty-Four hours later (Day 2) participant's memory was reactivated by rehearsing the original sequence immediately before learning a new sequence (Sequence 2). On Day 3, participants who practiced sequence 1 before learning sequence 2 performed poorly in comparison to those subjects that simply learned sequence 2 with no reactivation of sequence 1. This implies that the procedural memory can be returned to a liable state during which new information interferes with it.

Hupbach et al. (2007) became the first to show memory reconsolidation in human episodic memory. This form of memory is more complex because it requires a conscious recollection of objects or events. In their study, adults learned a list of twenty objects on Day 1. On Day 2, they received a reminder or not, and then learned a second list of unrelated objects. Memory for List 1 was tested on Day 3. Subjects who received a reminder recalled not only items from the first list, but also intruded items from the second list when recalling List 1 on Day 3–they had updated their original memory.

No studies to date have explored the effect of sleep on reconsolidation of episodic memory. My study replicated the procedure used by Hupbach et al. (2007) in a shorter time frame in order to incorporate a sleep and non-sleep group. All subjects were taught a

list of twenty objects (List 1) during Session 1. Next, they were presented with a subtle reminder 24 hours later during Session 2 and then immediately taught a new list of twenty unrelated objects (List 2). Session 3 recall of List 1 occurred 12 hours after initially learning List 2. The sleep group learned List 2 at night and was asked to recall List 1 the next morning, after a full night's sleep. The non-sleep group learned List 2 in the morning of Day 2, and was asked to recall the List 1 items the same night after a day which was spent awake.

There were no significant intrusions in either group, which suggests that there may be a time requirement for successful reconsolidation, more than 12 hours. Hupbach et al. (2007) showed that reconsolidation does not occur immediately after reactivation; however, more research is needed to define the specific time frame needed for memory updating.

Please note: There was a tendency for sleep group subjects to recall on average less List 1 objects than the non sleep group on Day 3. This may be interpreted as sleep causing interference and beginning reconsolidation; however more significant data is needed to draw this conclusion.

Materials and Methods

Design and participants

The independent variable that was varied between subjects was the presence or absence of sleep between the learning List 2 and the final recall of List 1. All subjects were provided with a reminder in effort to obtain the reconsolidation effect. In both groups, recall of List 1 occurred 12 hours following the List 2 learning trials. The sleep group's Session 2 was scheduled at night and they were asked to recall List 1 (Session 3) the next morning, after a full night's sleep. The non-sleep group's Session 2 was scheduled in the morning, and they were asked to recall the List 1 items that night.

Participants included 17 undergraduate students from the University of Arizona (sleep [n=9] and non-sleep [n=8] group respectively). They received monetary compensation for their participation and were randomly assigned to either the sleep or non-sleep group.

Materials

List 1 and List 2 materials consisted of 20 unrelated objects (Table 1). List 1 objects were presented in a yellow basket while List 2 objects were presented in a small cardboard box.

Table 1. Lists of objects presented on Day 1 and Day 2

List 1	*List 2*
Balloon	Apple
Bow	Band-Aid
Calculator	Battery
Crayon	Book

Cup	Cassette Tape
Dice	Cellular Phone
Feather	Comb
Flashlight	Dollar Bill
Flower	Elephant
Glue	Envelope
Key	Paper Clip
Sock	Puzzle Piece
Sponge	Rock
Spoon	Shovel
Sunglasses	Straw
Teabag	Thread
Tennis ball	Tissue
Toothbrush	Toy Pot
Toy Car	Watch
Whistle	Zipper

Procedure

The three sessions took place on Monday and Wednesday (non sleep group) or Monday, Wednesday and Thursday (sleep group) of the same week (see Tables 2 and 3). Each subject participated one at a time and was informed that they would be memorizing different lists on different days. Aside from the time/day of the sessions, all procedures were identical for both groups. Experimenter, location, and time between trials were kept constant between subjects.

Table 2. Sample Schedule for participant in Sleep Group

Monday	**Wednesday**	**Thursday**
8:00 pm – Session 1 (Learn List 1)	8:00 pm – Session 2 (Learn List 2)	8:00 am – Session 3 (Recall List 1)

Table 3. Sample Schedule for participant in Non-Sleep Group

Monday	**Wednesday**
8:00 am – Session 1 (Learn List 1)	8:00 am – Session 2 (Learn List 2) 8:00 pm – Session 3 (Recall List 1)

During Session 1, the participants were told that they would be learning 20 random objects (List 1). The experimenter pulled each object from a box and placed them into a yellow basket. Participants were asked to name each object as it was shown to them. After all 20 objects were placed into the basket the experimenter hid the basket and asked the participants to recall as many objects as possible. The procedure was repeated until the participant remembered 17 of 20 objects or until he or she completed four learning trials.

During Session 2, the experimenter showed the participant the empty yellow basket and asked "Do you remember this basket? Can you describe what we did with it?" Participants were limited to describing the procedure and were stopped from naming objects from List 1 if they attempted to do so. Participants were told that they would be learning 20 new objects (List 2). All objects were placed in front of the participants. The experimenter instructed the participants to name each one and then allowed 30 seconds of study time. The objects were removed and hidden after 30 seconds and the participants were asked to recall as many objects as possible. The procedure was repeated until the participant remembered 17 of 20 objects or until he or she completed four learning trials.

During Session 3, the experimenter asked the participants to recall as many objects from Session 1 (List 1) as possible. All objects recalled were noted and no questions from the participants about the objects were answered. When participants indicated they could not remember anymore objects, the experimenter engaged the participant in conversation for 30 seconds and then asked them to recall the objects from Session 1 again. This procedure was repeated for a total of four consecutive trials.

Results

Performance during Session 1: Acquisition of List 1

I recorded the number of learning trials required to recall at least 17 of the 20 objects. Participants took an average of 2.41 (SD = 0.806) learning trials reach criterion.

Performance during Session 2: Acquisition of List 2

Participants took an average of 2.12 (SD = 0.697) learning trials to reach criterion.

Performance during Session 3: Recall of List 1

One subject in each group had to be discarded because they remembered only on average one or less items during the four retrieval attempts. The mean percent objects recalled (List 1 items, averaged over all four recall trials) and the mean percent of intrusions (List 2 items, averaged over all four recall trials) is displayed in Figure 1.

List 1 Recall

The sleep group recalled an average of 5.22 (SD = 2.96) objects from List 1. The non sleep group recalled an average of 7.34 (SD = 1.79) objects. The number of objects recalled from List 1 were averaged within each group and analyzed between the groups using a t-test. This revealed that there is no statistical significant difference between the

two groups. However, there was a tendency [t(15)=1.76, p=.10] showing that the sleep group recalled slightly fewer objects than the non-sleep group.

List 2 Intrusions

The sleep group showed an average of 0.389 (SD = 0.532) intrusions. The no sleep group showed an average of 0.833 (SD = 0.799) intrusions. The number of objects incorrectly recalled from List 2 (Intrusions) was averaged across participants and analyzed within each group using a z test. This revealed that there were no statistically significant levels of intrusions in the sleep or in the non-sleep groups.

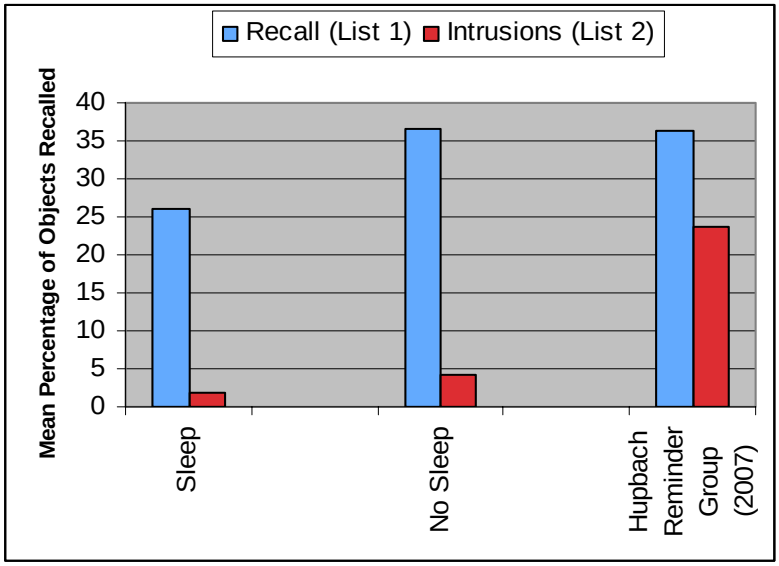

Figure 1: Mean percentage of recalls and intrusions on Day 3 in the sleep and no sleep groups. Data on Hupbach original reminder group indicates presence of reconsolidation effect. Note: Participants were asked to recall objects from List 1. Objects that were falsely recalled from List 2 were labeled as intrusions.

Discussion

Neither experimental group showed a significant intrusion of List 2 objects during recall of List 1. The absence of intrusions suggests that the reconsolidation effect did not occur regardless of the sleep manipulations. Previous results suggest that in the presence of a reminder, reconsolidation should occur (Hupbach et al. 2007). However, in this follow-up of Hupbach et al.'s study, we only allowed 12 hours between Session 2 learning and Session 3 recall. This vital difference between the two experiments suggests a time requirement for successful reconsolidation, namely, more than 12 hours.

Although no intrusions were present, the sleep group recalled, on average, less objects than the no sleep group. The sleep group correctly recalled an average of 5.22 objects in Session 3 and the no sleep group correctly recalled an average of 7.34 objects. This tendency, though not statistically significant, may imply the reconsolidation effect in

the sleep group. Sleepers might have had difficulty recalling more objects from List 1 because reconsolidation had begun after their night of sleep. The effect may have manifested itself in making recall more difficult by clouding judgment about the original objects.

Follow up experiments are needed to further test length of time necessary for successful reconsolidation.

References

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