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Promotion and Suppression of Autobiographical Thinking During Wakeful Rest:

An Online Replication of Varma et al. (2018)

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Abstract

Memory consolidation is the process in which memory traces are strengthened over time for later retrieval. Although some theories hold that consolidation can only occur during sleep, accumulating evidence suggests that brief periods of wakeful rest may also facilitate consolidation. Interestingly, however, Varma et al. (2018) reported that a demanding 2-Back task following encoding produced similar performance to a wakeful rest condition. We tested whether participants' recall would be best following a wakeful rest condition as compared to other distractor conditions, consistent with the extant wakeful rest literature, or whether we would replicate the finding from Varma et al. (2018) such that participants' memory benefitted from both a Rest and 2-Back task following encoding. Across two experiments, we used similar (Experiment 1) and the same (Experiment 2) encoding material as Varma et al. (2018), employed a wakeful rest condition adapted for online testing, and compared participants' recall across post-encoding conditions. In the first experiment, we used a between-subjects design and compared participants' cued recall performance following a period of wakeful rest, a 2-Back task, or a Rest + Sounds condition. The second experiment more closely replicated the experimental design used in Varma et al. (2018) using a within-subjects manipulation. Ultimately, our findings more consistently aligned with the canonical wakeful rest finding such that recall was better following the Rest condition as compared to all other post-encoding conditions. These results support the notion that wakeful rest may allow for consolidation by protecting recently encoded information from interference and thereby improving memory performance.

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**Promotion and Suppression of Autobiographical Thinking During Wakeful Rest:
An Online Replication of Varma et al. (2018)**

Memory consolidation is broadly defined as the process in which memory traces become less susceptible to interference and are strengthened across time for later retrieval (Wixted & Cai, 2004). Although some theories hold that consolidation occurs exclusively during sleep, accumulating evidence suggests that brief periods of wakeful rest following encoding may similarly facilitate consolidation of new memories (Wamsley, 2019).

The typical wakeful rest paradigm consists of an incidental encoding phase, an immediate retrieval phase, a wakeful rest or distractor phase, and a final delayed retrieval phase. The critical manipulation occurs after the immediate retrieval phase: participants either undergo ~10 minutes of wakeful rest, where they rest alone in a quiet room without access to distracting materials, or perform a simple distractor task, such as a passive listening task or visual search task (e.g., Dewar et al., 2012). Finally, participants complete a delayed retrieval test for the initially encoded stimuli. Performance following the wakeful rest period is typically better than performance following the distractor task (see Wamsley, 2019 for a review). It has been suggested that wakeful rest may reduce forgetting by affording an opportunity for memory consolidation processes to take place (Dewar et al., 2009; Dewar et al., 2010; Dewar et al., 2012; Tambini et al., 2010; Wixted, 2004).

However, there has been some inconsistency in the literature across different post-encoding tasks and stimuli (Varma et al., 2018; Dewar et al., 2012). Studies using distractor tasks such as spot the difference, picture naming, and facial recognition tasks have shown wakeful rest effects (Dewar et al., 2012; Dewar et al., 2009; Mercer, 2015), whereas others using a cognitively demanding n-back task did not show a wakeful rest effect (Varma et al., 2017 &

2018). Thus, it is clear that further investigation is necessary to better understand the mechanisms and circumstances under which a wakeful rest effect is obtained.

Several potential mechanisms have been proposed to account for the wakeful rest effect, including protection against retroactive interference (Dewar et al., 2009), rehearsal (Millar & Balota, 2018.), and reduced/suppressed autobiographical thinking (Varma et al., 2018). For example, consider the initial study by Dewar et al. (2009) which investigated the effect of wakeful rest in a sample of amnesic patients to better understand how wakeful rest may protect memories from retroactive interference. Participants studied a list of 15 standardized, aurally presented words (Snodgrass & Vanderwaart, 1980) before a 9-minute post-encoding block which included either an interference or wakeful rest condition. The interference condition (i.e., picture-naming task where the participant was instructed to name the picture rather than the word superimposed on the picture) was introduced either early on, in the middle, or at the end of the 9-minute block. The wakeful rest condition included no interference and participants simply rested alone in the quiet testing room, free of any potentially interfering material with the lights dimmed. Dewar et al. (2009) found that, overall, participants recalled more material from encoding in the wakeful rest condition than the interference conditions. Moreover, within the interference conditions, participants' performance was better when the interference was introduced at the end of the post-encoding block than when it was introduced early on or in the middle. These results suggest that not only did participants' memory benefit from the post-encoding wakeful rest period, but also that delaying interference allowed for more consolidation to occur. Thus, Dewar et al. (2009) concluded that the wakeful rest period allowed for consolidation by protecting recently encoded information from interference, boosted the strength of the memory traces, and ultimately improved memory performance.

An alternative account of this pattern is that wakeful rest paradigms afford an opportunity for individuals to intentionally rehearse recently learned information (Millar & Balota, 2018; Wamsley, 2019). Specifically, it is possible that participants simply choose to explicitly rehearse encoded information in preparation for an upcoming retrieval task (even though participants often undergo incidental encoding tasks and are not informed about the final retrieval task in many wakeful rest studies). There are two major arguments against this rehearsal account. First, several studies have shown that wakeful rest elicits an equivalent benefit for “difficult-to-rehearse materials” including non-words and non-English words (Dewar et al., 2014; Humiston & Wamsley, 2018). Second, although many wakeful rest studies include post-experiment questionnaires aimed at identifying participants who may have tried to prepare for the final memory test (Craig et al., 2014; Dewar et al., 2014), it appears that exclusion of these individuals does not change the results. Although wakeful rest researchers have attempted to account for potential rehearsal confounds, further steps are necessary to determine which aspects of wakeful rest (explicit rehearsal, or otherwise) may influence subsequent memory performance.

Varma et al. (2018) proposed an alternate explanation for the retroactive interference argument proposed by Dewar et al. (2009). Specifically, Varma et al. (2018) argue that studied materials are susceptible to being forgotten when consolidation is interrupted by “novel memory encoding or retrieval, associated with sensory stimulation from the environment or from autobiographical thinking.” Drawing upon work by Mednick and colleagues (2011) and Wixted (2004), the authors suggest that retroactive interference occurs specifically when novel encoding usurps limited hippocampal resources that would otherwise be engaged in consolidation processes. Furthermore, they suggest that a tradeoff may take place between resources allocated towards memory consolidation and novel encoding processes (such as attending to the current

environment/stimuli and maintaining a logical stream of thought). Under this assumption, Varma et al. (2018) argued that consolidation only suffers whenever the post-encoding period is filled with *novel episodic memory processing*, such as autobiographical thinking, and that limiting such thoughts during a period of wakeful rest could “free up” episodic memory resources for consolidation and thereby reduce interference effects.

Varma et al. (2018) investigated this possibility by comparing the efficacy of a standard wakeful rest period to a 2-Back condition, where participants performed a 2-Back working memory task, and to a Rest + Sounds condition including sound cues (e.g., a sound of a dog barking causes one to think of their childhood pet) meant to trigger autobiographical thoughts (memories of personal events or experiences and future scenarios). Varma et al. (2018) hypothesized that the promotion of autobiographical thinking during the Rest + Sounds condition would be detrimental to memory consolidation, and therefore final memory performance, compared to both the Rest (wakeful rest) condition and the 2-Back condition, while performing the 2-Back task would suppress these autobiographical thoughts, benefitting memory performance. They compared participants’ recognition memory performance for information encoded prior to either the Rest, 2-Back, or Rest + Sounds post-encoding conditions. Remarkably, their results indicated that memory performance in the Rest and 2-Back condition did not differ while performance in the Rest + Sounds condition was significantly lower. Thus, memory consolidation appeared to occur in the demanding 2-Back condition while being blunted in the other conditions. The authors suggested that only the promotion of autobiographical thoughts (i.e., in the Rest + Sounds condition) disrupted the consolidation process and that the 2-back task shielded participants’ from incurring autobiographical thoughts. However, the results of Varma et al. (2018) clearly contradict other wakeful rest studies which have shown that doing

any demanding task (e.g., spot the difference task, picture naming, facial recognition) post-encoding may disrupt consolidation as compared to wakeful rest. Thus, an exploration of the mechanisms involved in a successful wakeful rest condition is necessary.

The Current Study

The present set of studies tested whether participants' recall would be best following a wakeful rest condition as compared to the other distractor conditions, consistent with the extant wakeful rest literature, or the Varma et al. (2018) finding of a memory benefit in both the Rest and 2-Back conditions, compared to the Rest + Sounds condition. Across two experiments, we used similar (Experiment 1) and the same (Experiment 2) encoding material as Varma et al. (2018), employed a wakeful rest condition adapted for online testing, and compared participants' recall across post-encoding conditions. In the first experiment, we used a between-subjects design and compared participants' cued recall performance following a period of wakeful rest, a 2-Back task, or a Rest + Sounds condition. The second experiment more closely replicated the experimental design used in Varma et al. (2018) such that we employed a within-subjects manipulation and used the exact stimuli (translated to English) as reported in Varma et al. (2018). To foreshadow our findings, although we were ultimately unable to replicate the exact results of Varma et al. (2018), we did find a similar general pattern with the within-subjects design (Experiment 2) such that memory performance was worse when encoding was followed by the Rest + Sounds condition as compared to the Rest and 2-Back conditions. Interestingly, however, results from the between-subjects experiment (Experiment 1) were more consistent with the canonical wakeful rest finding such that recall was better following the Rest condition as compared to all other conditions (i.e., 2-Back, Rest + Sounds).

Experiment 1

In our first experiment, we aimed to conceptually replicate the Varma et al. (2018) study using a between-subjects design and a wakeful rest paradigm adapted for online testing. Specifically, participants first performed an incidental encoding task where they studied picture-word pairs followed by a 9-minute post-encoding period filled with either (1) a wakeful rest period, (2) a 2-Back task, or (3) a Rest + Sounds condition which played sound cues to trigger autobiographical memories. All participants, except for those in the 2-Back condition, performed a brief 1-minute “washout” period following the post-encoding task where they performed the Stroop task. The 2-Back task was not followed by a Stroop washout period because the purpose of the washout period was to negate any potential refreshing effects of the Rest and Rest + Sounds conditions. Given that the 2-Back task was attentionally demanding (similar to the Stroop task), we chose not to include a Stroop washout period after. Finally, participants received a cued recall test at the end of the experiment. The cued recall test included pictures from encoding which were the cues to recall the words that the pictures were paired with. A between-subjects design was used such that participants would only undergo one final retrieval period rather than four, as done in Varma et al. (2018) where participants underwent an immediate recall task after each encoding period as well as a final recall task. In this way, compared to Varma et al. (2018), the participants in the present Experiment 1 should be less likely to rehearse the items in anticipation of an upcoming unexpected final test. We hypothesized that, consistent with the extant wakeful rest literature, participants’ recall would be best following the wakeful rest condition as compared to the other conditions. The important issue is whether we would replicate the Varma et al. (2018) finding of a memory benefit in the 2-Back task compared to the Rest + Sounds condition.

Methods

Participants

Participants were recruited from the Younger Adult Subject Pool at Washington University in St. Louis and compensated at a rate of 1 credit/hour. Inclusion criteria included native English-speaking ability, normal or corrected-to-normal vision, and access to a computer with the Google Chrome web browser. Participants were not allowed to participate in more than one of the present studies. Studies were posted to Washington University in St. Louis' Sona System one at a time and run sequentially. Because different numbers of participants randomly signed up per condition, each condition had a slightly different numbers of participants: Rest ($N = 52$), 2-Back ($N = 52$), and Rest + Sounds ($N = 50$).

Materials

Stimuli consisted of a set of 52 picture-word pairs with pictures drawn from Oudiette et al. (2013) and words drawn from Varma et al. (2019). Pictures were of everyday, concrete objects. The word stimuli consisted of adjectives that ranged from three to nine letters in length ($M = 6.06$ letters) and ranged in subtitle word frequency (SUBTL frequency norms, a word frequency measure based on American English television and film subtitles; Brysbaert & New, 2009, from 0.22 to 545.18 ($M = 49.12$)). Autobiographical sounds used during the Rest + Sounds conditions were drawn from Hall et al. (2014) and deliberately selected to avoid semantic similarity to the picture-word pairs.

All experimental programs were written in PsychoPy (Pierce et al., 2019), hosted on Pavlovia (pavlovia.org), and posted on the Washington University in St. Louis' Sona System (wupsych.sona-systems.com) for recruitment.

Procedure

A general overview of the experimental procedure is provided in Figure 1. In the Rest + Sounds condition, participants received an auditory check to confirm that the sound was working and that they could adequately hear and comprehend auditorily presented sounds/instructions. During the auditory check, participants were visually presented the following directions: “This is an audio check. Please follow the instructions being presented auditorily. If you cannot hear the audio check, you will not be able to complete this experiment. Please close the tab.” Participants then received auditory instructions stating: “This is an audio check. Please take a moment to adjust the volume to a comfortable setting. Once the experiment begins, please refrain from adjusting the volume. This is critical for the experiment. If you can hear this message at a comfortable volume, please press the ‘Q’ key on your keyboard to move on.” These instructions repeated (up to three times) until the participant responded with the correct key response (pressing Q). If the participant pressed Q, the experiment would commence. If the participant did not press Q before the auditory instructions had repeated three times, the experiment would end (Nicosia, 2021).

Figure 1. Experiment 1 procedure. The Rest task is displayed as the post-encoding task in this figure, and its variable interval was 3-42 seconds.

As described earlier and shown in Figure 1, each participant performed three tasks during the course of the experiment. First, participants performed an incidental encoding task. During each encoding trial, participants were asked to create an imaginative association between the word (e.g., “colorful”) and the picture (e.g., sheep). The word was presented on the screen for a fixed duration of 1000 ms before the picture was presented along with the word for a fixed duration of 4000 ms. Then, participants were asked to rate the vividness of their imagined association on a scale from 1-5 (i.e., not vivid-very vivid) by using the mouse to click along the scale within the next 5000 ms. After 5000 ms had elapsed, the next trial began with a fixation cross displayed for 500 ms. This was kept constant regardless of when participants responded.

Next, participants performed one of three post-encoding conditions which each lasted for ~9 minutes: Rest, 2-Back, or Rest + Sounds. In the Rest condition, participants performed a modified version of the Shapes task adapted from O’Callaghan et al. (2015). Participants were presented with instructions that read: “This portion of the study is looking at relaxation. Please look at the computer screen and try to relax with your eyes open while attending to the shapes.” This screen was displayed until participants pressed the spacebar to advance. Shapes were used in the Rest condition to provide minimally-demanding stimuli for participants to attend to. Because of the online nature of the present study, we wanted to ensure that participants were at least looking at the screen, rather than possibly-interfering material, during the wakeful rest period.

In the 2-Back condition, participants were instructed: “In this portion of the experiment you will see a digit (1-5) presented on the screen. If this number is the same as the one displayed two trials earlier, press the “j” key, otherwise press the “f” key. Please do the task as quickly AND accurately as possible. Press SPACE to continue.” For each trial, a random number

(between 1–5) was displayed in the middle of the screen for 3000 ms or until the participant responded. Also displayed on the screen was a reminder of the correct key-mapping: “Press ‘j’ if digit same as 2 trials ago, otherwise press ‘f’.” After response or 3000 ms had elapsed, whichever came first, the next trial began with a fixation cross displayed for 500 ms. During this condition, participants engaged in 680 trials, half of which were the same as 2 trials earlier while the other half of the trials were different. Participants were not given trial-by-trial feedback in order to minimize disruption in the continuous 2-Back task.

The design of the Rest + Sounds condition was adapted from Varma et al. (2018). In this condition, participants received the same instructions as the Rest condition and performed the Rest task. Additionally, however, 19 sounds (each 4 seconds in duration) were presented throughout the duration of the post-encoding condition. These stimuli consisted of sounds encountered in everyday life (e.g., “alarm clock”, “ducks”, “camera shutter”, etc.) that may trigger memories from one’s personal past or the imagination of a future scenario but did not share any semantic content with the encoding stimuli. Participants were instructed to rest quietly while sounds would be played. No instructions were given to identify the sounds nor engage in any autobiographical thinking during this period.

After the post-encoding task, participants in all conditions completed a questionnaire aimed at assessing their thought contents during the post-encoding task. First, participants were asked how demanding they found the post-encoding task they participated in. Participants responded on a scale from 1-5 with 1 representing “not at all demanding” and 5 representing “very demanding.” Next, participants were presented with the following questions, one at a time: “What percentage (%) of your thoughts during the [post-encoding task specified here] were related to the [post-encoding task specified here]?” “What percentage (%) of your thoughts

during the [post-encoding task specified here] were related to past/future events?” “What percentage (%) of your thoughts during the [post-encoding task specified here] were related to the picture-word pairs you rated earlier?” “What percentage (%) of your thoughts during the [post-encoding task specified here] were related to something else not mentioned?” Participants responded on a scale from 0% of the time to 100% of the time.

As mentioned previously, all participants (except those in the 2-Back condition) then completed a 1-minute round of the Stroop task. This task served to minimize any refreshing or carry-over effects which may differ between the conditions (e.g., Dewar et al., 2014; Millar & Balota, 2018). Any benefit of wakeful rest on memory consolidation should be present after this 1-minute washout period. Participants were presented with instructions that read: “In this portion of the experiment you will see words (“RED”, “GREEN”, “BLUE”) presented in different colored ink. The ink color may be the same or different from the color word. Please press the key which corresponds to the INK COLOR and do your best to IGNORE the word. Press SPACE to continue.” This screen was presented until participants pressed the spacebar to advance. Participants performed 72 trials consisting of red, blue, and green word and color stimuli, 36 of which were congruent (i.e., color and word matching) and 36 were incongruent (i.e., color and word not matching). Each trial was presented for 4000 ms, or until participants pressed a key response. Participants were not provided any feedback on their response. After pressing a key response or 4000 ms had passed, the next trial began with a 200 ms fixation cross.

After the post-encoding period, participants performed a cued recall task of the initially encoded picture-word pairs. Participants were presented with instructions that read: “Now, you will be presented with a picture from earlier in the experiment. Please recall the WORD that was paired with the picture from earlier in the experiment. Please type your response using the

keyboard and press ENTER after you are done to move on. Please press SPACE to begin.” This screen was presented until participants pressed the spacebar to advance. After typing their response and pressing the return key, or 10,000 ms had expired, whichever came first, the next trial began with a fixation cross displayed for 500 ms. Once the cued recall task was finished, participants were then thanked for their participation and prompted to press the spacebar to complete the experiment.

Results

For all results reported, statistical significance was set at $p < .05$, two-tailed test, unless otherwise noted. Effect sizes of eta squared (η^2 , Olejnik & Algina, 2003) are reported for significant F tests and Cohen’s d (d , Cohen, 1988) for significant t -tests. Adjusted degrees of freedom are reported such that unequal variances were assumed and the Welch approximation was applied.

First, analyses on recall accuracy are presented to test the main hypothesis that participants’ recall would be best following the wakeful rest condition as compared to the other conditions. Second, participants’ self-reported difficulty ratings are examined to test whether the demanding nature of the task performed during the retention interval could explain the difference in wakeful rest effects found across conditions. As mentioned, we hypothesized that, consistent with the extant wakeful rest literature, participants’ recall would be best following the wakeful rest condition as compared to the other conditions. The important issue is whether we would replicate the Varma et al. (2018) finding of a memory benefit in the 2-Back task compared to the Rest + Sounds condition.

Recall Accuracy. Percent correct recall accuracy as a function of post-encoding task for Experiment 1 are displayed in Figure 2. Overall, participants in the Rest (wakeful rest) condition

correctly recalled more words than participants in the other conditions. These patterns were confirmed by a one-way analysis of variance (ANOVA) which yielded an effect of post-encoding condition, $F(2, 1151) = 3.83, p = 0.02, \eta^2 = 0.05$. Planned t -tests confirmed that recall was significantly better in the Rest condition as compared to the 2-Back condition, $t(101.64) = 2.54, p = 0.01, d = 0.50$, and the Rest + Sounds condition, $t(97.95) = 2.30, p = 0.02, d = 0.46$. Recall in the 2-Back and Rest + Sounds conditions did not significantly differ from one another, $ps = 0.88$.

Figure 2. Recall accuracy as a function of post-encoding condition for Experiment 1. Error bars represent confidence intervals.

Difficulty Ratings. Participants' self-reported difficulty ratings of the post-encoding condition tasks as a function of post-encoding task for Experiment 1 are displayed in Figure 3. Overall, participants rated the 2-Back condition as the most difficult followed by the Rest + Sounds condition, and the Rest condition as least demanding. These patterns were confirmed by

a one-way analysis of variance (ANOVA) which yielded an effect of post-encoding condition, $F(2, 151) = 75.02$, $p < 0.001$, $\eta^2 = 0.50$. Follow-up t -tests confirmed that participants found the Rest condition less difficult than the both 2-Back condition, $t(98.44) = 11.97$, $p < 0.001$, $d = 2.35$, and the Rest + Sounds condition, $t(99.97) = 2.54$, $p = 0.01$, $d = 0.50$. Additionally, participants reported the 2-Back condition to be more difficult than the Rest + Sounds, $t(95.90) = 9.22$, $p < 0.001$, $d = 1.83$.

Figure 3. Participants' self-reported difficulty ratings of the post-encoding condition tasks as a function of post-encoding task for Experiment 1. Error bars represent confidence intervals.

Discussion

To summarize the results of Experiment 1, using a between-subjects version of the Varma et al. (2018) paradigm adapted for online testing, we found the canonical wakeful rest effect such that participants in the Rest condition recalled more information than participants in either the 2-Back or Rest + Sounds conditions. Additionally, consistent with the hypothesis put

forth in the extant wakeful rest literature, participants rated all of the “distractor” conditions as more demanding than the Rest condition, suggesting that when any additional cognitive demand or potentially interfering information follows encoding, there is minimal-to-no benefit as in the wakeful rest condition.

It is important to note, however, that in contrast to simply presenting a fixation cross on the screen and asking participants (who completed the experiment on their personal computers outside of the controlled laboratory setting) to focus on the fixation for ~9 minutes, the Shapes condition provided a minimally demanding stimulus to maintain participants’ attention. Indeed, in earlier pilot studies, we found this manipulation to be critical for maintaining participants’ engagement in the experiment. Pilot analyses corroborated the notion that the Rest + Sounds condition used here did not significantly differ in either recall accuracy, $t(86.26) = 1.73, p = 0.088$, or difficulty ratings, $t(81.42) = 1.22, p = 0.23$, from a Fixation + Sounds condition (where participants simply stared at a blank fixation cross), indicating that using the Shapes task as an online version of the wakeful rest condition was similarly minimally demanding as if participants were simply staring at a blank fixation cross. Thus, it seems that it is possible to achieve wakeful rest effects in online studies, though simple modifications should be made to maintain participants’ engagement in the task.

In contrast to Varma et al. (2018), participants’ recall was worse following the 2-Back condition as compared to following the Rest condition. However, there were several critical differences between Varma et al. (2018) and the design used in Experiment 1. First, we used a between-subjects design to reduce the number of retrieval periods that participants would complete so that participants would be less likely to expect the final recall task. Second, participants incidentally encoded picture-word pairs and performed a cued recall task instead of

intentionally encoding a word list and performing a free recall task. Third, with the exception of the 2-Back task, participants received a Stroop task for a washout period. Finally, to make the task more suitable for the online testing format, we used the Shapes task instead of having participants stare at a blank screen (as discussed in the previous paragraph). Thus, because of these potentially critical differences in our experimental design, in Experiment 2, we sought to test a more directly comparable experimental design to Varma et al. (2018).

Experiment 2

Methods

Participants

Forty-two participants were recruited from the Younger Adult Subject Pool at Washington University in St. Louis and compensated at a rate of 1 credit/hour. Inclusion criteria were the same as Experiment 1. Because of the within-groups nature of the present study, six different counterbalancing orders were used for the post-encoding tasks.

Materials

Stimuli consisted of 45 words used in Varma et al. (2018). The word stimuli were translated from Dutch to English and consisted of commonly used nouns. As described by Varma et al. (2018), these words were chosen to have minimal semantic relatedness but similar word frequency and concreteness (see Varma et al., 2018 for additional information on the word stimuli). Autobiographical sounds used during the Rest + Sounds condition were drawn from Hall et al. (2014) and selected to avoid semantic similarity to the words used. From the 45 words, 3 lists of 15 words were created for use in each section of the experiment.

All experimental programs were written in PsychoPy (Pierce et al., 2019), hosted on Pavlovia (pavlovia.org), and posted on the Washington University in St. Louis' Sona System (wupsych.sona-systems.com) for recruitment.

Procedure

An overview of the Experiment 2 procedure is displayed in Figure 4. As in Experiment 1, all participants received an auditory check to confirm that the sound was audible at an appropriate level.

Figure 4. Experiment 2 procedure.

Following Varma et al. (2018), the experiment was divided into three blocks, one for each condition (see Figure 4). Each block consisted of an encoding session, followed by an immediate recall test and a 9-minute post-encoding period. Across the three blocks, the 9-minute post-encoding period was filled with either a wakeful rest (Rest task, as described in Experiment 1), a rest period interspersed with familiar sounds (Rest + Sounds condition, as described in Experiment 1), or a 2-Back task (2-Back condition, as described in Experiment 1), in a counterbalanced order across participants. There were no breaks between successive blocks. At the end of the third block, a surprise (delayed) free-recall task was administered. During both the

immediate and delayed recall tests, participants were asked to recall as many words as possible in any order. Participants typed in their responses and clicked a button on the screen to advance to the next portion of the experiment when they felt they had recalled as many words as they could.

During the encoding sessions, a list of 15 words was presented visually, one word every 5000 ms. Participants were instructed to memorize the upcoming word list and told to expect a memory test immediately following the presentation. Instructions read: “You will be shown a short list of words presented one at a time. Please do your best to memorize the list of words. You will be tested on your ability to recall these words immediately following their presentation. Please press SPACE to continue.” After all 15 words had been presented, the immediate recall test was conducted to obtain a score of initial memory retention. Next, the 9-minute post-encoding interval began. One of the three post-encoding conditions was filled with the Rest task, one was filled with the 2-Back task, and one was filled with the Rest + Sounds condition (all described earlier). After undergoing three encoding, immediate recall, and post-encoding condition blocks, participants completed a surprise delayed recall task. Instructions read: “Lastly, you will recall as many words from the ENTIRE EXPERIMENT as you can. Please type your response using the keyboard and press ENTER after you are done to move on. Click the blue button at the bottom of the screen when you feel you have recalled as many words as possible to end this portion of the experiment. Please press SPACE to begin.”

Results

Immediate Recall Accuracy. Following Varma et al. (2018), we first examined whether immediate recall scores (number of items correctly recalled during the immediate recall tasks) differed as a function of post-encoding condition. Consistent with Varma et al. (2018), there

were no differences in immediate recall across post-encoding conditions. This pattern was confirmed by a one-way analysis of variance (ANOVA) which indicated that immediate recall scores (Rest: $M = 9.86$ items correctly recalled, $SD = 3.24$; 2-Back: $M = 8.86$, $SD = 3.75$; Rest + Sounds: $M = 9.42$, $SD = 3.72$) did not differ significantly between the three encoding blocks, $F(2, 111) = 0.79$, $p = 0.45$, $\eta^2 = 0.01$, although recall for the 2-Back condition items was numerically lower.

Delayed Recall Accuracy. We next examined whether delayed recall scores (number of items correctly recalled during the delayed recall task) differed as a function of post-encoding condition. There were no differences in delayed recall across post-encoding conditions. This pattern was confirmed by a one-way ANOVA which indicated that delayed recall scores (Rest: $M = 6.65$ items correctly recalled, $SD = 3.55$; 2-Back: $M = 5.42$, $SD = 4.01$; Rest + Sounds: $M = 5.33$, $SD = 4.22$) did not differ significantly between the three encoding blocks, $F(2, 111) = 1.51$, $p = 0.22$, $\eta^2 = 0.02$, although the performance on the Rest condition items was numerically higher.

Proportional Retention Score. Following Varma et al. (2018), we calculated the “proportional retention score” for each condition. The number of words recalled during the delayed recall test was divided by the number originally recalled during the immediate recall test, yielding the proportional retention score. Additionally, consistent with Varma et al. (2018), in cases where the delayed recall score exceeded the immediate recall score (which was true for 4 participants, 3 in the Rest condition and 1 in the 2-Back condition), the proportional retention score was capped at 1 (as done in Varma et al., 2018).

Proportional retention scores as a function of post-encoding task for Experiment 2 are displayed in Figure 5. Overall, participants in the Rest (wakeful rest) condition correctly recalled

more words than participants in the other conditions. However, consistent with Varma et al. (2018), participants showed a benefit in both the Rest and 2-Back conditions as compared to the Rest + Sounds condition. These patterns were confirmed by a two-way Condition (Rest, 2-Back, Rest + Sounds) by Order (counterbalance 1-6) mixed-factor ANOVA which yielded a main effect of Condition, $F(2, 108) = 3.03, p = 0.04, \eta^2 = 0.05$. Follow-up t -tests confirmed that the proportional retention score was significantly better in the Rest condition as compared to the Rest + Sounds condition, $t(80.32) = 2.54, p = 0.01, d = 0.50$, but that scores did not differ across the Rest and 2-Back conditions, $t(80.75) = 1.54, p = 0.13$. There was also a Condition by Order interaction, $F(10, 108) = 2.50, p = 0.01, \eta^2 = 0.17$, which indicated that the proportional retention score was better for the Rest condition in the counterbalance orders when the Rest condition occurred last. Consistent with that reported by Varma et al. (2018), this seems to indicate that there may be a slight advantage to memory retention in conditions that occur either at the beginning or at the end, compared to the delay condition that occurs in the middle. However, the interaction results should be interpreted cautiously such that there were only seven participants within each counterbalance order.

Figure 5. Participants’ proportional retention scores as a function of post-encoding task for Experiment 2. Error bars represent confidence intervals.

Discussion

The results indicated that participants’ proportional retention scores were better for words that were encoded prior to the Rest and 2-Back conditions as compared to the Rest + Sounds condition. However, also consistent with that reported by Varma et al. (2018), there were counterbalance order effects which showed that the effect was most robust when the Rest condition was presented last. This somewhat complicates reconciling the results of Experiments 1 and 2 with each having their unique experimental design advantages. While Experiment 2 controls for individual differences in participants’ baseline memory performance because of the within-subjects design and proportional retention score, Experiment 1 better controls for potential rehearsal effects.

It is important to note that although there was a significant difference between the mean proportional retention score of the Rest and the Rest + Sounds stimuli, the proportional retention score for the 2-Back items was not significantly different from either the Rest or the Rest + Sounds words. In comparison to Varma et al. (2018) who found a significant difference between the 2-Back and Rest + Sounds conditions, we did not replicate this finding. In this sense, we were able to replicate the general pattern of results of Varma et al. (2018), although the pairwise comparisons did not reach significance. In accordance with our initial hypothesis, we found a significant wakeful rest effect such that participants showed a higher proportional retention score for the Rest condition as compared to the Rest + Sounds condition, although the difference between the Rest and 2-Back conditions did not reach significance.

There were a few critical differences in our conceptual replication of Varma et al. (2018), the first of which being that we used the Shapes task during the Rest and Rest + Sounds conditions rather than a fixation cross in order to make the experiment more suitable for the online layout (see Experiment 1 discussion for further explanation). Additionally, during the 2-Back task, participants were not given trial-by-trial feedback and there was no performance threshold set, as done in Varma et al. (2018). Thus, it is possible that the lack of feedback on the 2-Back task may have contributed to participants slightly lower memory performance in that condition. Nevertheless, we aimed to more closely replicate the experimental design of Varma et al. (2018) in Experiment 2 and indeed yielded results more closely in line with their hypothesis regarding the suppression of autobiographical thoughts to promote consolidation.

General Discussion

The results from the present study support findings consistent with the wakeful rest literature such that participants' recall was best following a wakeful rest condition as compared

to other distractor conditions. We compared participants' recall following a wakeful rest condition to their recall following distractor conditions. The goal of this study was to test whether, consistent with the extant wakeful rest literature, participants' recall would be better following wakeful rest only, or whether we would replicate the Varma et al. (2018) finding of a memory benefit in both the Rest and 2-Back conditions compared to the Rest + Sounds condition. Across two experiments, we employed a wakeful rest condition adapted for online testing, and compared participants' recall across post-encoding conditions. In the first experiment, we used a between-subjects design and compared participants' cued recall performance following a period of wakeful rest, a 2-Back task, or a Rest + Sounds condition. The second experiment more closely replicated the experimental design used in Varma et al. (2018) such that we employed a within-subjects manipulation and used the exact stimuli (translated to English) as reported in Varma et al. (2018).

The results from Experiment 1 supported the canonical wakeful rest finding such that participants in the Rest condition recalled more information from encoding than participants in either the 2-Back or Rest + Sounds conditions. Indeed, consistent with the hypothesis commonly described in the wakeful rest literature, participants rated both of the "distractor" conditions as being more demanding than the Rest condition. Taken together with the recall accuracy data, the results of Experiment 1 suggest that any additional cognitive demand or potentially interfering information which follows encoding, may prohibit the beneficial effects of wakeful rest.

There were, however, several critical differences between Varma et al. (2018) and Experiment 1. First, in an attempt to reduce participants' anticipation of a final recall test, we used a between-subjects design which (1) reduced the number of retrieval periods that participants would complete and (2) had participants incidentally (rather than intentionally)

encode picture-word pairs. Second, participants performed a cued recall task instead of a free recall task. Finally, to make the task more suitable for the online testing format, we used the Shapes task instead of having participants stare at a blank screen. Thus, in Experiment 2, we sought to test a within-subjects design more comparable to Varma et al. (2018).

The results of Experiment 2, although *closer* to the findings of Varma et al. (2018), still did not directly replicate the results of Varma et al. (2018). Specifically, the results indicated that participants' proportional retention scores were better for words that were encoded prior to the Rest and 2-Back conditions as compared to the Rest + Sounds condition. Although there was a significant difference between the mean proportional retention score of the Rest and the Rest + Sounds stimuli, the proportional retention score for the 2-Back items was not significantly different from either the Rest or the Rest + Sounds words.

Taken together, both Experiment 1 and 2 provide support more in favor of the canonical wakeful rest effect though each have their unique advantages and limitations. Specifically, while Experiment 2 controls for individual differences in participants' baseline memory performance because of the within-subjects design and proportional retention score, Experiment 1 better controls for potential rehearsal effects. There were, however still several critical differences between Experiment 2 and Varma et al. (2018). First, as discussed, we used the Shapes task during the Rest and Rest + Sounds conditions rather than a fixation cross in order to make the experiment more suitable for the online testing environment. Second, during the 2-Back task, participants were not given trial-by-trial feedback and there was no performance threshold set, as done in Varma et al. (2018). Nevertheless, we aimed to more closely replicate the experimental design of Varma et al. (2018) in Experiment 2 and indeed yielded results more closely in line with their hypothesis (at least compared to Experiment 1) regarding the suppression of

autobiographical thoughts to promote consolidation. Of course, additional work is necessary to fully understand the boundary conditions under which one can produce a wakeful rest effect.

The present study affords several key conclusions: First, we replicated the canonical wakeful rest effect in an online testing format. This may be useful for future studies or applications seeking to boost memory consolidation for individuals from the comfort of their own home. Second, these results suggest that, contrary to some theories of memory consolidation, it is possible for memory consolidation to occur during brief periods of wakeful rest when other demanding processes are not presently engaged. Although additional investigations are certainly warranted, the results of the present study provide support for the hypothesis that interference reduction rather than the suppression of autobiographical memories may be one of the critical mechanisms through which wakeful rest effects are observed.

Word Count: 6705

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