

Oberlin

Digital Commons at Oberlin

Honors Papers

Student Work

2013

Post-Learning Activities and Memory Consolidation: the Effect of Physical and Cognitive Activities on Memory Consolidation

Yue Tang
Oberlin College

Follow this and additional works at: <https://digitalcommons.oberlin.edu/honors>



Part of the [Psychology Commons](#)

Repository Citation

Tang, Yue, "Post-Learning Activities and Memory Consolidation: the Effect of Physical and Cognitive Activities on Memory Consolidation" (2013). *Honors Papers*. 344.

<https://digitalcommons.oberlin.edu/honors/344>

This Thesis is brought to you for free and open access by the Student Work at Digital Commons at Oberlin. It has been accepted for inclusion in Honors Papers by an authorized administrator of Digital Commons at Oberlin. For more information, please contact megan.mitchell@oberlin.edu.

Post-Learning Activities and Memory Consolidation: the Effect of Physical and
Cognitive Activities on Memory Consolidation

Yue Tang

Oberlin College

This research project is supported by Oberlin College Psychology Department and Jerome Davis Research Award. Special thanks to Prof. Nancy Darling, Prof. Patty deWinstandley and Prof. Albert Porterfield for being on my honors committee, and Prof. Karen Sutton for helping with my writing. I would also like to thank Marissa Cross, Jolie DeFies, Sela Miller and Lingyu (Mini) Zhang for their assistance in running the study.

Abstract

Memory consolidation is the process during which short-term memory is stabilized and long-term memory is formed. This study aims at investigating how physical and cognitive activities affect memory consolidation during wakefulness. There were four conditions: sit, sit-puzzle, walk and walk-puzzle and a repeated measure, within subject design was adopted. Participants engage in each condition for ten minutes immediately following a learning session, and this process was repeated for four times. Word recall was collected twice, both immediately after engaging in the task, and in the second day. Results revealed that engaging in physical activity alone (walk) led to the best recall performance. Recall score was diminished when physical activity was coupled with cognitive activity (walk-puzzle), and there was no difference between the two physically inactive conditions (sit and sit-puzzle). In addition, it was shown that physical activity provided favorable condition for memory consolidation especially when participants' were fatigue. Based on the results of this study, suggestions can be made to students that engagement in moderate exercise such as walking immediately following learning is beneficial to memorization.

Post-Learning Activities and Memory Consolidation: the Effect of Physical and Cognitive Activities on Memory Consolidation

Over the past years studies about memory consolidation have identified sleep as the primary state during which memory consolidation takes place (Ellenbogen, Payne, & Stickgold, 2006; García, 2012). Recent studies, however, are showing accumulating evidence of memory consolidation during wakefulness (Carr, Jadhav, & Frank, 2011; Foster & Wilson, 2006; Cowan, Beschin, & Della, 2004). While the conditions which enhance wakeful memory consolidation have not been fully explored, a recent study by Dewar and colleagues found that a ten minute wakeful rest immediately following learning significantly improved memory performance over 7 day period (Dewar, Alber, Butler, Cowan, & Sala, 2012). However, Dewar and colleagues failed to recognize that her two conditions also contained a physical inactivity component. Thus their results cannot address the contribution of physical activity to memory consolidation. Furthermore, the generalizability of their findings was also limited by the age of her participants. In response, through a replication and expansion of Dewar et al.'s study, the current study seeks to explore the physical activity conditions that enhance memory consolidation in wakefulness. The larger purpose of this study is in an effort to identify potential strategies that students can adopt to improve their memorization.

The process during which newly formed, labile, short-term memory is transformed into stable and accessible longer-term memory is called memory consolidation (Anastasio, Ehrenberger, Watson, & Zhang, 2012). During memory consolidation, longer-term memory is formed through synaptic rescaling that strengthens selective neural traces and integrates new information into existing knowledge stores (Nadel, Hupbach, Gomez, & Newman-Smith,

2012). Research has shown reactivation of newly encoded memory traces in the hippocampus using fMRIs, revealing that memory traces are stabilized and their neural representation is changed during sleep memory consolidation (Rasch & Born, 2008).

Despite the compelling evidence for sleep memory consolidation, recent studies have shown memory consolidation during wakefulness under various situations. A study with auditory identification learning showed that a single intensive training session led to significant performance gains 4-6 hours following the learning session, suggesting a latent consolidation phase during wakefulness ((Roth, Kishon-Rabin, Hildesheimer, & Karni, 2005). Another study found similar results in word retention. Amnesia patients showed significant higher retention of new verbal material when there was a 9 minute delay between learning and interference (Dewar, Garcia, Cowan, & Sala, 2009). Both studies suggested a memory consolidation phase following learning. Evidence in neuroscience suggests awake memory replay, which is the sequential reactivation of hippocampal place cells that represent previous experience, as a potential contributor to memory consolidation (Carr, et al., 2011; Foster, et al., 2006). In fact, studies with animals have shown reactivation of spatial memory representations during wakefulness independent of sensory input (Karlsson & Frank, 2009). Therefore, taken together these findings, memory consolidation during wakefulness is evident.

While evidence is accumulating for memory consolidation during wakefulness, the immediate post-learning conditions during which wakeful memory consolidation can be optimized remain unknown. Dewar and colleagues compared the effect of a ten-minute wakeful rest task to a ten minute cognitive task, on facilitation of memory consolidation of

details from a newly learned story. In Dewar et al.'s study, participants engaged in two story learning phases; following which they either rested with their eyes closed for ten minutes, or engaged in a cognitive task involving "spot-the-difference" puzzles for ten minutes (Dewar, et al., 2012). Results indicated significantly better recall for the story details when it was followed by the ten minute closed eye rest, compared to the cognitive task, both immediately following the study and seven days later. The authors concluded that newly encoded memories underwent a consolidation process that was initiated after encoding, and that the wakeful rest provided a more favorable condition for memory consolidation than the non-verbal cognitive task.

Dewar et al. argued that the effect of wakeful rest was the result of superior memory consolidation that occurred automatically due to minimal interference. Although the spot-the-difference task was not verbal, thus there was no retrieval competition at recall, the task divided participants' attention from memory consolidation of the story (Dewar et al., 2012). Past studies had demonstrated a limited central pool of working memory (Baddeley & Hitch, 1974; Vergauwe, Dewaele, Langerock, & Barrouilet, 2012), and reduction in attentional resource was proven the key factor for the relational memory deficit observed in aging (Sun, 2010).

The ability to learn and memorize information, and recall it over long period of time is essential to students in school, thus Dewar's findings bear important practical implications for students (Al-Ahmadi & Oraif, 2009; Kyllonen & Christal, 1990). However, two questions arise from Dewar et al.'s study. First, while Dewar may have assumed her findings could be generalized to the population as a whole, their sample, which was restricted to people aged 61

and older, raises the question of the generalizability of their findings. Age differences in cognitive ability have been well established in the field of aging. Many studies in aging and cognitive performance have shown age differences in memory ability, including working memory capacity, automatic encoding process, and ability to keep out interference (Lovelace, 1990; Clapp, & Gazzaley, 2012; Ishihara, Gondo, & Poon, 2002). For example, one study showed fMRI evidence of reduction of hippocampal activation, suggesting a lessened ability to form relational memory when older participants' attention was divided (Kim, 2010). In Dewar's study, the constitution of the sample limits the generalizability of the findings.

Additionally, Dewar et al.'s conclusion raises the question of whether one has to be engaged in both physical and cognitive rest to permit wakeful memory consolidation. Wakeful rest consisted of both physical rest and cognitive rest, and whether physical restfulness is necessary for memory consolidation cannot be determined from their study. Physical activity is one factor that was not examined. From a practical perspective, the closed-eye rest is not practical for most people in learning situation. For example, students do not have access to a dark room after every learning session, or the time to take such a rest. As a result, it is worth investigating the impact of physical activity upon wakeful memory consolidation.

The purpose of this study is to better understand the conditions that enhance memory consolidation in the state of wakefulness. This study sought to address the two problems of Dewar's study: the generalizability of the results and the untested contribution of physical activity to memory consolidation. The goal was to identify practical suggestions for college students about methods that they can adopt post-learning to improve their memory

performance.

Methods

Overview

This study was consisted of two parts. The first part was conducted in the lab and consisted of a memorization and recall task interrupted by one of four unrelated conditions. Each participant repeated the memorization and recall task four times to include one of the four unrelated tasks. The second part was completion of an email survey sent out the day after the lab session.

Participants

Participants were recruited from the Introduction to Psychology course and compensated with partial course credits for participating in the study. A total of 61 students were recruited (24 male, 37 female).

Design

The study used a 2 (physical activity level) x 2 (cognitive activity level) within subject design for a total of four conditions as follows:

1) Low physical activity level, low cognitive activity level

This was the wakeful rest condition. For this condition, participants rested quietly in their seat for ten minutes. They were told to close their eyes and not think about anything in a darkened room.

2) Low physical activity level, high cognitive activity level

This was the spot-the-difference condition. For this condition, participant spent ten minutes doing a spot-the-difference task, circling the difference between two

similar pictures using a pencil.

3) High physical activity level, low cognitive activity level

This was the walk in place condition. For this condition, participants were asked to stand and walk around the room for ten minutes.

4) Low physical activity level, low cognitive activity level

This was the walk and spot-the-difference condition. For this condition, participants walked around the room for ten minutes while working on the spot-the-difference task using a clip board.

The order of conditions varied. There were four orders of conditions; any condition could be first. Thereafter, conditions were blocked such that a low physical activity level condition was followed by the other physically inactive condition, and a high physical activity level condition was followed by the other physically active condition. There was a five minute break between the 2 sets of conditions. Conditions were organized in this manner in order to minimize an effect due to condition order, and to minimize the possibility of either the inactive or the active conditions affecting the other.

Although conditions were counterbalanced as above, the order of the word lists remained the same so that each condition had an equal chance of being paired with any of the four word lists.

Participants were tested in groups no larger than six, and each group was randomly assigned to a condition order.

Materials

Word lists The word lists students were required to memorize were four sets of English

words, 24 each, from the Toronto Word Pool (Friendly, Franklin, Hoffman, & Rubin, 1982; See Appendix A). Imagery level was equated across each list. Each word was displayed for seven seconds on the wall by a projector. The total display lasted 2.5 minutes.

Puzzle package Puzzle material was obtained from Google Image. Images were black-and-white, spot-the-difference puzzles with number of differences indicated on the page. (Google Images; see Appendix B).

Lab questionnaire The questionnaire consisted of four open-ended questions concerning students' state of wakefulness and mental activity during the lab. For example, Question 1 asked, "How were you feeling during wakeful rest? Were you thinking about anything?" (See Appendix C).

Email questionnaire Participants were asked to recall as many words as they could from the prior day, in addition to several demographic information questions (See Appendix D).

Procedure

Upon arrival at the lab, participants were informed about the tasks involved in this study. The consent form was signed before proceeding, and students under age 18 were either excluded or had obtained parental consent. Clipboards were distributed to students to write with.

Participants were seated in front of a projector screen. Participants were told to memorize as many words as possible without writing them down. With one word on each slide, 24 words were shown to participants. Immediately following the learning, participants were timed for 10 minutes to complete one of the four conditions. They then were asked to write down as many words as they remembered from the word lists. Following this, they were

shown a second word list, which was followed by another task, and a second recall of words from the second word list. This process was repeated for the third and fourth conditions. Each group of participants went through all four conditions in a designated order.

Upon completion of the first two conditions, there was a 5-minute break. Participants were asked not to leave the room, but talking, moving, or listening to music was allowed. After the break, participants completed the second two conditions following the same procedure as the first half of the session.

Before leaving the laboratory, participants filled-out a questionnaire.

The next day, all participants were emailed a link to an online questionnaire. Participants were asked to write down any words they remembered from the four word lists. Demographic information, including gender and year in college, was collected at that time (See Appendix B).

Once email questionnaires were received, a debriefing email was sent out explaining the research question and design of the study.

Measures

The primary dependent variables were the number of correct words immediately recalled ($M = 22.59$, $SD = 11.59$) and recalled the next day ($M = 13.57$, $SD = 9.26$). The immediate recall was collected during the laboratory session, and the delayed recall was collected through the email questionnaire.

The scores on the two recalls were highly correlated (Sit: $r(61) = .742$, $p < .001$; Sit-puzzle: $r(61) = .639$, $p < .001$; Walk: $r(61) = .713$, $p < .001$; Walk-puzzle: $r(61) = .464$, $p < .001$).

Data handling

Scoring There were 24 words in each word list to start with. Due to an operational mistake, one word was omitted from list three. Recall score was computed by dividing the number of correct words in each recall session by the number of words on the list. Words with recognizable spelling and plurals mistakes were considered correct. Words from a different word list were ignored (See Table 1 for descriptive statistics).

Normalizing the data Descriptive statistics showed that the data were significantly positively skewed for both the immediate recall (*Skewness* = 1.03, *Std. Error* = 0.156), and the delayed recall (*Skewness* = 1.00, *Std. Error* = 0.156). To correct for skewness, data points with *Z*-score higher than 95% were truncated (For immediate recall, 13 cases out of 244 were truncated; for delayed recall, 15 cases out of 244 were truncated). After truncating, skewness of both recalls was lowered. (Immediate recall: *Skewness* = 0.309, *Std. Error* = 0.156; Delayed recall: *Skewness* = 0.479, *Std. Error* = 0.156).

Statistical Analyses Repeated measure ANOVA could not be used since the four conditions had unequal variances ($p < 0.05$ for the sphericity test). Instead, a HLM (hierarchical linear model) was adopted. In the model, a diagonal covariance type was chosen, and equivalent variance groups were no longer assumed. Baseline model showed significant residual variance to be explained for both the immediate recall (Wald $Z = 9.566$, $p < 0.001$), and the delayed recall (Wald $Z = 9.566$, $p < 0.001$).

Confounds A potential confounding factor, order, which was the order of conditions, was tested. The confound was detected for both the immediate recall ($F(1,3) = 4.$, $p < 0.01$), and the delayed recall ($F(1,3) = 15.897$, $p < 0.01$). As a result, order was included as a control

variable in the model.

Other potential confounds, including gender and year in college (for immediate recall), and gender, year, and hours of sleep (for delayed recall), all failed to reach significance ($p > 0.05$). Thus no other confounds were included in later analyses.

An additional analysis was run to find out if prior learning contributed to the results for delayed learning. There was no significant change in the results, immediate recall was excluded for the delayed recall model.

Results

Generalization of Dewar et al.'s Findings

To examine whether the findings from Dewar's study can be generalized to college students, a mixed model was run predicting recall from the sit and sit-puzzle conditions. Order was included as a control variable and treated categorically. Results showed no significant difference between sit and sit-puzzle during the immediate recall ($F(1,51.112) = 0.001, p = 0.974$), or delayed recall ($F(1,55.440) = 2.202, p = 0.144$; See Figure 1 & Table 2 for results). Dewar's finding that wakeful rest led to better memory enhancement than engaging in a cognitive task was not replicated with college students.

Main Effects

Immediate Recall A hierarchical linear mixed model was run to answer the question of whether recall scores differed between the four conditions. Order was included as a control variable. Results showed significant main effect of condition ($F(3,57.061) = 3.453, p = 0.022$), order ($F(3,61.39) = 4.795, p = 0.005$). However, there was no significant interaction between order and condition ($F(9,58.605) = 1.086, p = 0.387$; See Figure 2 for main effects,

Model A in Table 2 for results).

Delayed Recall A second mixed model was run to find out if the difference between conditions remained in the delayed recall. Results showed a significant main effect of conditions ($F(3,68.75) = 4.906, p = 0.022$) and order ($F(3,64.412) = 24.355, p < 0.001$), and a significant interaction between order and condition ($F(9,64.815) = 4.617, p < 0.001$; See Figure 2 for main effects, Figure 3 for the interactions, and Model B in Table 2 for results).

Interaction The significant interaction during delayed recall led to further inspection, which suggested that physically inactive conditions (sit and sit-puzzle) and physically active conditions (walk and walk-puzzle) had respective trends of change over time (order of conditions). As it appeared on the graph, physically inactive conditions showed a decrease of memory performance when encountered in the second half of the laboratory session, while physically active conditions, in contrast, showed an increase of memory performance in the second half of the session. To test this hypothesis, HLM was run to find out first, the difference between sit and sit-puzzle conditions; second, the difference between walk and walk-puzzle conditions; and last, the difference between the two sets of conditions. Results showed no significant difference in recall scores from the sit and sit-puzzle conditions ($F(1,55.440) = 2.202, p = 0.144$). However, recall from the walk condition was significantly higher than that of the walk-puzzle condition ($F(1,58.136) = 8.061, p = 0.006$).

In order to understand the difference between the physically inactive set of conditions and the walk and walk-puzzle condition, the two physically inactive conditions were grouped together (sit and sit-puzzle), and two HLMs were run comparing it with the walk and walk-puzzle conditions respectively. Results showed no significant differences between the

physically inactive conditions and walk-puzzle ($F(1,74.700) = 0.196, p = 0.660$). However, recall from the walk condition was significantly greater than the physically inactive condition set ($F(1,66.19) = 11.964, p = 0.001$; See Figure 3 for interaction and Model C – F in Table 2 for results).

Discussion

The questions posed by this study were two-fold. First, we asked whether Dewar's findings generalize to a sample of college students. Second, we asked under what conditions was memory consolidation enhanced. To investigate the first question, recall scores of the sit and sit-puzzle conditions were compared. To investigate the second question, recall scores of the four conditions were compared. A mixed model was used to test these questions. The significant interaction between order and conditions was also tested using a mixed model.

Generalizability of Dewar et al.'s findings

Dewar and colleagues found that sit provided better recall than the sit-puzzle. She argued that relative to sit-puzzle, sit provided conditions of minimal interference, which allowed for superior memory consolidation (Dewar et al., 2012). Inconsistent with their findings, results of the current study showed no significant difference in recall scores between the sit and sit-puzzle conditions, either in the immediate recall or delayed recall. Therefore Dewar et al.'s findings were not replicated with college students. There are two possible explanations for this failure to replicate Dewar et al.'s results. First, it may have been that the spot-the-difference task was not cognitively challenging for college students. In that case, the interference of the cognitive task was not strong enough to diminish recall performance. In their study, because of the participants' age, the cognitive task may have provided a stronger

interference that led to worse recall performance. Studies of aging and cognition have shown not only significant attenuation in the attentional-related neural activities for older adults, but also a significant reduction in hippocampal activation when attentional resource was divided. However, the same reduction was not observed with younger adults (Kim, 2011). In addition, studies have shown decreased working memory capacity as well as negative impact of interfering on memory formation exacerbated by age (Lovelace, 1990; Class & Gazzaley, 2012).

The second possible explanation for the failure to replicate involves participants' mental activities during wakeful rest. Qualitative analysis of the post-lab questionnaire showed that compared to the empty minded state Dewar's participants reported, students reported they were generally not able to empty their minds during wakeful rest. They reported that their minds were engaged in other activities and thoughts. This may be because students are used to sitting and engaging in active thinking. Therefore the full rest component of Dewar's study may not have occurred in this study with student participants. This may suggest the need for a different strategy for a different population. For example, students may need training in how to empty their minds while sitting.

Conditions which enhance memory consolidation

The results demonstrated significant differences in recall performance among the four conditions. In both immediate and delayed recalls, walk, which was physically active and cognitively inactive, led to significantly better recall performance than all other conditions. There were no differences in the recall performances among the walk-puzzle, sit, and sit-puzzle conditions. Based on these results, physical activity coupled with cognitive

inactivity led to the best recall performances. When physical activity was coupled with cognitive activity, it diminished recall performances. A similar result was not observed when participants were physically inactive – there was no significant difference between sit and sit-puzzle.

Further analyses with the interaction between order and condition revealed different patterns of performance over time. Generally, with the progress of the laboratory trial, participants would show lower recall performance in later conditions (order = 3 and 4) due to fatigue. Results from the sit and sit-puzzle conditions followed this pattern. However, as shown in Figure 3, the two physically active conditions showed opposite results. When participants encountered a physically active condition at order 3 or 4, their recall performances were likely to be better than those who encountered these conditions in the beginning of the study. Results from HLM showed no significant difference between the two physically inactive conditions (sit and sit-puzzle). Although the difference between walk-puzzle and the physically inactive conditions did not attain statistical significance, the graph demonstrated performance pattern more similar to the walk condition than to the physically inactive conditions. In conclusion, physical activity appeared to have shielded the negative effect of tiredness on memory consolidation.

The positive effect of physical activity could be explained with sympathetic nervous system activity due to a moderate level of exercise. A study has shown positive association between sympathetic nervous activities and cognitive performances (Murray & Russoniello, 2012). Although participants' physiological changes were not measured in the laboratory, walking was considered a moderate exercise (Egli, Bland, Melton, & Czech, 2011).

When considering the overall recall scores, there was a significant difference in recall performance between the walk and walk-puzzle conditions. The negative effect of the cognitive component in the walk-puzzle condition can be explained by a limited central pool of working memory (Baddeley & Hitch, 1974; Vergauwe, et al., 2012). As argued by Dewar, a spot-the-difference task is a cognitive task that interferes with neural replay of newly formed memory (Dewar, et al., 2012). When coupled with walking, it is possible that more attentional resources were occupied, and the replay of neural activation was further interfered. As for the sit and sit-puzzle condition, the difference was not detected due to the low cognitive intensity of a spot-the-difference puzzle for participants of this study. Future studies would have to control for the difficulty of the cognitive task to better understand the influence of the cognitive component.

Results of this study suggests that engaging in moderate physical activity such as walking leads participants to overcome the negative influence of fatigue due to long study time.

Implications for future studies

This study showed the advantages of using two recall periods, an immediate and a delayed recall. The delayed recall allowed us to access the prolonged effects of memory consolidation. Since one of the purpose of this study was to make suggestions for students in school who need to recall information over a long period of time, the delayed recall, even though it was only one day, was closer to a real world application. To be able to determine memory retention over longer term, future studies of awake memory consolidation should include a delayed recall with a longer period of time.

The methodological implication to analyze the order effect has implications for future studies. One of the most interesting findings of the study was that recall appeared to be affected by the order in which conditions were encountered differently for different conditions. When participants got tired, engaging in a physically inactive condition led to worse performance, while a physically active condition showed the opposite effect. This result was identified when order effect was analyzed. In other studies, order is counterbalanced and thus not analyzed. Results from this study suggest that future studies of awake memory consolidation take into consideration the order in which conditions occur.

Limitations

The statistical power of this study is limited by a small sample size (61 participants), and unequal group size (13 participants in one order and 16 in each of the other three). In addition, because the imagery level of each word lists were equated, the word lists were assumed to be equally easy to memorize. The analyses were carried out under the assumption of no word list effect.

This study did not include a quantitative measure of participants' fatigue. Thus no quantitative association can be built to address the question how participants' fatigue interacted with conditions and affected participants' memory performances.

Considering the age difference between participants in the current study and in Dewar's study, the spot-the-difference task might not be challenging enough for college students. For future studies, a more cognitively demanding task should be used to further investigate the interference of cognitive tasks on wakeful memory consolidation.

Finally, due to restriction in the developmental and education level of participants in the

current study, the generalizability of this study is limited to college students only.

Conclusion

This study is the first attempt to comprehensively understand the conditions that enhance memory consolidation during wakeful state. Memorization plays an important role in college students' success at school, and findings from this study provide practical oriented strategies that students can adopt. Based on findings of the current study, students are strongly encouraged to engage in some physical activities immediately following learning to allow for wakeful memory consolidation.

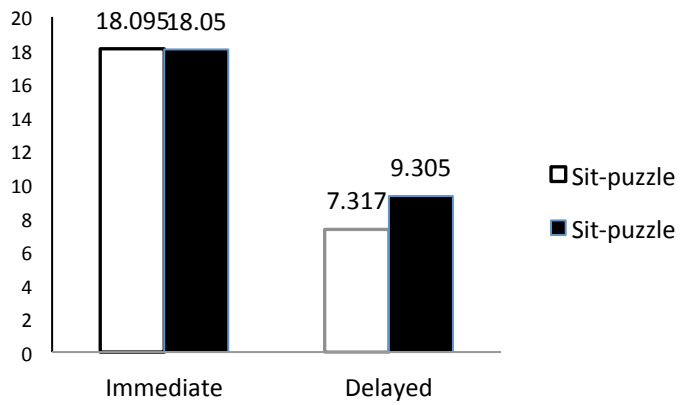
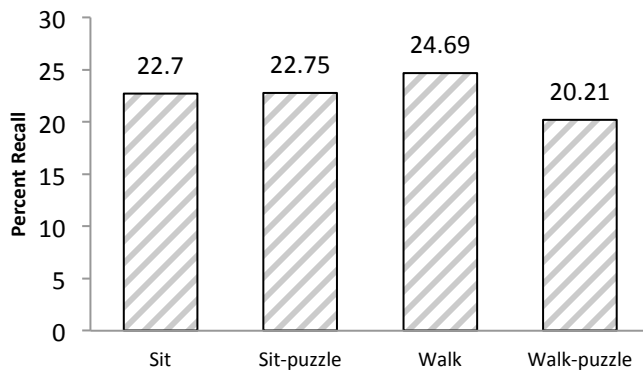


Figure 1 Recall score means from the sit and sit-puzzle conditions.

(a)



(b)

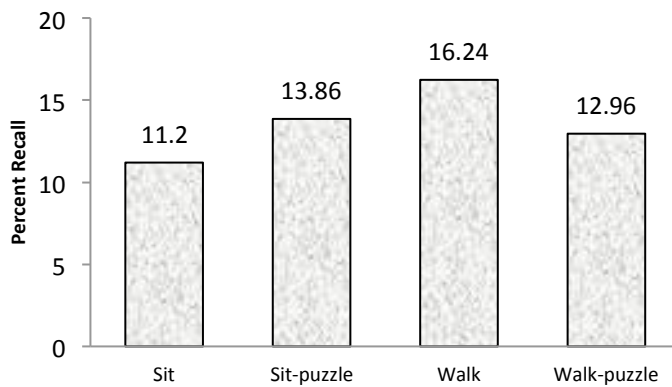


Figure 2 (a) Means of percentage recall from four conditions in immediate recall. (b) Means of percentage recall from four conditions in delayed recall.

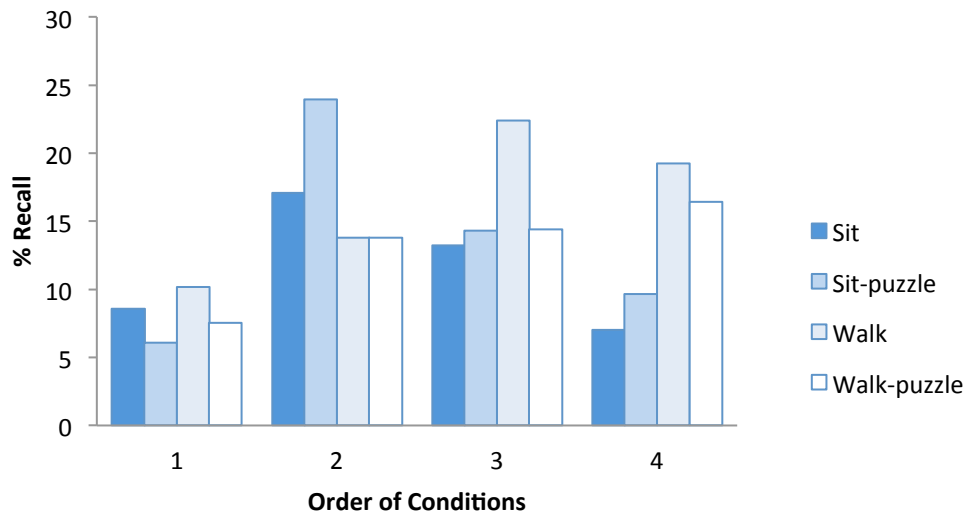


Figure 3 Means of percentage recall from four conditions in each order in delayed recall are presented.

Table 1 Raw means of percentage recall from each condition in both recalls, after skewness is fixed.

	Mean	SD	Minimum	Maximum
<u>Immediate recall</u>				
Sit	22.70	11.85	.00	45.83
SitPuz	22.75	11.85	.00	45.83
Walk	24.69	12.56	4.17	45.83
WalkPuz	20.21	9.76	4.17	41.67
<u>Delayed recall</u>				
Sit	11.20	9.44	.00	33.33
SitPuz	13.86	10.53	.00	33.33
Walk	16.24	10.12	.00	33.33
WalkPuz	12.96	7.68	.00	33.33

(N = 61)

Table 2 Results of HLM analyses predicting immediate and delayed recall from conditions and order. Parameters are *F* scores.

	Immediate Recall	Delayed Recall
<u>A Sit and sit-puzzle</u>		
Condition	0.001	2.202
Order	4.794**	22.41***
<u>B Sit, sit-puzzle, walk and walk-puzzle</u>		
Condition	4.282**	4.906**
Order	5.334**	24.355***
Order x condition	--	4.617***
<u>C Walk and walk-puzzle</u>		
Condition	8.326**	8.061**
Order	--	8.118***
<u>D Sit-puzzle and walk-puzzle</u>		
Condition	3.507	0.177
Order	3.107*	18.321***
Order x condition	--	4.581**
<u>E Physically inactive and walk-puzzle</u>		
Condition	--	0.196
Order	--	15.774***
Order x condition	--	4.753**
<u>F Physically inactive and walk</u>		
Condition	--	11.964***
Order	--	12.579***
Order x condition	--	7.674***

(N = 61)

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

References

- Al-Ahmadi, F., & Oraif, F. (2009). Working memory capacity, confidence and scientific thinking. *Research in Science & Technological Education*, 27(2), 225-243. doi:10.1080/02635140902853673
- Baddeley, A. D., & Hitch, G. J. (1974). Working memory. *The psychology of learning and motivation*, 8, 47-89.
- Carr, M. F., Jadhav, S. P., & Frank, L. M. (2011). Hippocampal replay in the awake state: A potential substrate for memory consolidation and retrieval. *Nature Neuroscience*, 14(2), 147-153. doi:10.1038/nn.2732
- Clapp, W. C., & Gazzaley, A. (2012). Distinct mechanisms for the impact of distraction and interruption on working memory in aging. *Neurobiology of Aging*, 33(1), 134-148. doi:10.1016/j.neurobiolaging.2010.01.012
- Cowan, N., Beschin, N., & Sala, S. D. (2004). Verbal recall in amnesiacs under conditions of diminished retroactive interference. *Brain: A Journal of Neurology*, 127(4), 825-834. doi:10.1093/brain/awh107
- Dewar, M., Alber, J., Butler, C., Cowan, N., , & Della Sala, S. (2012). Brief wakeful resting boosts new memories over the long term. *Psychological Science*, 23(9), 955-960. doi:10.1177/0956797612441220
- Dewar, M. T., Cowan, N., , & Della Sala, S. (2007). Forgetting due to retroactive interference: A fusion of Müller and Pilzecker's (1900) early insights into everyday forgetting and recent research on anterograde amnesia. *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior*, 43(5), 616-634.

doi:10.1016/S0010-9452(08)70492-1

Dewar, M., Garcia, Y. F., Cowan, N., , & Sala, S. D. (2009). Delaying interference enhances memory consolidation in amnesic patients. *Neuropsychology*, *23*(5), 627-634.

doi:10.1037/a0015568

Diekelmann, S., & Born, J. (2010). The memory function of sleep. *Nature Reviews Neuroscience*, *11*(2), 114-126.

Egli, Bland, Melton, Czech, T. (2011). Influence of Age, Sex, and Race on College Students' Exercise Motivation of Physical Activity. *Journal of American College Health*, *59*(5), 399. doi:10.1080/07448481.2010.513074

Eichenbaum, H. (2001). The hippocampus and declarative memory: Cognitive mechanisms and neural codes. *Behavioural Brain Research*, *127*(1-2), 199-207.

doi:10.1016/S0166-4328(01)00365-5

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., ...Kramer, A. F. (2011). Exercise training increases size of hippocampus and improves memory. *PNAS Proceedings of the National Academy of Sciences of the United States of America*, *108*(7), 3017-3022. doi:10.1073/pnas.1015950108

Friendly, M., Franklin, P. E., Hoffman, D., & Rubin, D. C. (1982). The Toronto Word Pool: Norms for imagery, concreteness, orthographic variables, and grammatical usage for 1,080 words. *Behavior Research Methods & Instrumentation*, *14*(4), 375-399.

doi:10.3758/BF03203275

Foster, D. J., & Wilson, M. A. (2006). Reverse replay of behavioural sequences in hippocampal place cells during the awake state. *Nature*, *440*(7084), 680-683.

- doi:10.1038/nature04587 Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience*, 9(1), 58-65. doi:10.1038/nrn2298
- Ishihara, O., Gondo, Y., & Poon, L. W. (2002). The influence of aging on short-term and long-term memory in the continuous recognition paradigm. *Japanese Journal of Psychology*, 72(6), 516-521. doi:10.4992/jjpsy.72.516
- Karlsson, M. P., & Frank, L. M. (2009). Awake replay of remote experiences in the hippocampus. *Nature Neuroscience*, 12(7), 913-918. doi:10.1038/nn.2344
- Kim, S. (2011). The source of the associative deficit in aging: The role of attentional resources for processing relational information. *Dissertation Abstracts International: Section B: The Sciences and Engineering*, 71(9-B)
- Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is (little more than) working-memory capacity?! *Intelligence*, 14(4), 389-433. doi:10.1016/S0160-2896(05)80012-1
- Lovelace, E. A. (1990). *Aging and cognition: Mental processes, self-awareness, and interventions*. Oxford England: North-Holland
- Murray, N. P., & Russoniello, C. (2012). Acute physical activity on cognitive function: A heart rate variability examination. *Applied Psychophysiology and Biofeedback*, 37(4), 219-227. doi:10.1007/s10484-012-9196-z
- Nadel, L., Hupbach, A., Gomez, R., & Newman-Smith, K. (2012). Memory formation, consolidation and transformation. *Neuroscience and Biobehavioral Reviews*, 36(7), 1640-1645. doi:10.1016/j.neubiorev.2012.03.001

- Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*(5), 1170-1187. doi:10.1037/0278-7393.26.5.1170
- Potkin Bunney García, K. T. E. V. (2012). Sleep improves memory: The effect of sleep on long term memory in early adolescence. Sleep Improves Memory: The Effect of Sleep on Long Term Memory in Early Adolescence. *PLoS ONE*, *7*(8), e42191. doi:10.1371/journal.pone.0042191
- Rasch, B., & Born, J. (2008). Reactivation and consolidation of memory during sleep. *Current Directions in Psychological Science*, *17*(3), 188-192. doi:10.1111/j.1467-8721.2008.00572.x
- Roth, D. A., Kishon-Rabin, L., Hildesheimer, M., & Karni, A. (2005). A latent consolidation phase in auditory identification learning: Time in the awake state is sufficient. *Learning & Memory*, *12*(2), 159-164. doi:10.1101/87505
- Vergauwe, E., Dewaele, N., Langerock, N., , & Barrouillet, P. (2012). Evidence for a central pool of general resources in working memory. *Journal of Cognitive Psychology*, *24*(3), 359-366. doi:10.1080/20445911.2011.640625
- Whiting, W. L. I., & Smith, A. D. (1997). Differential age-related processing limitations in recall and recognition tasks. *Psychology and Aging*, *12*(2), 216-224. doi:10.1037/0882-7974.12.2.216

Appendix A

List 1	Imegeary Level	List 2	Imegeary Level	List 3	Imegeary Level	List 4	Imegeary Level
Famous	3.8	Prospect	2.6	Marble	5.9	Surround	3.9
Absorb	4.6	Depart	4	Future	3.5	Acre	4.6
Frankly	1.8	Occur	1.7	Kindom	4.8	Outline	3.9
Patience	3.4	Resort	5.2	Behold	2	Transfer	3.3
Limit	2.5	Little	5	Civil	2.1	Vapor	5
Unit	3	Quarter	5.6	Beside	3.9	Reserve	2.7
Measure	4	Favor	2.7	Judgment	3	Exchange	3.3
Pupil	5.8	Attain	2.4	Precious	4	Recken	1.9
Platform	5.5	Upward	4	Wonder	3.2	Boundary	4.8
Witness	4.4	Ribbon	5.8	Review	2.9	Surface	4.7
Belief	2.6	System	2.8	Derive	1.7	Standard	2.1
Custom	2.7	Theory	2.5	Status	3.1	Purely	2.5
Stumble	5.3	Painter	6	Moisture	5.3	Lazy	5
Virtue	3.1	Conclude	2.9	Dealer	4.2	Remark	2.6
Replace	3.2	Matter	2.7	Helmet	5.9	Mixture	3.7
Elbow	6	Gesture	5.1	Tribute	2.9	Intend	2.3
Thunder	5.8	Banner	5.8	Rarely	2.4	Neglect	2.8
Accord	1.8	Signal	5.7	Simple	3.9	Member	3.1
Further	2.3	Worthy	2.8	Mission	3.3	Product	3.7
Whisper	5.6	Likewise	1.3	Degree	3	Fountain	6.4
Consume	3.7	Sheriff	6.3	Formal	5	Oven	6
Handle	4.3	Legend	3.8	Oppose	3	Echo	4.7
Manage	2.6	Section	2.8	Furnish	3.4	Sustain	2.1
Permit	3.1	Indeed	1.4	Triumph	4.8	Distance	4.7
<i>Mean</i>	3.79		3.79		3.63		3.74
<i>SD</i>	1.33		1.60		1.17		1.26

Appendix B

Below are three examples of the spot-the-difference puzzle used. There were in total 16 puzzle pictures being used, eight in each puzzle condition.

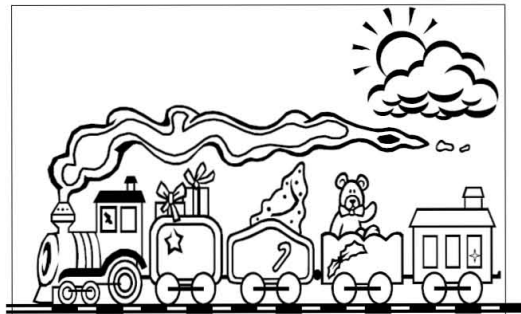
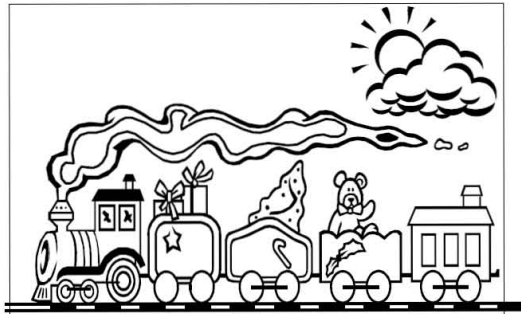
SPOT 5 DIFFERENCES!



Spot the Difference Level 2 - worksheets

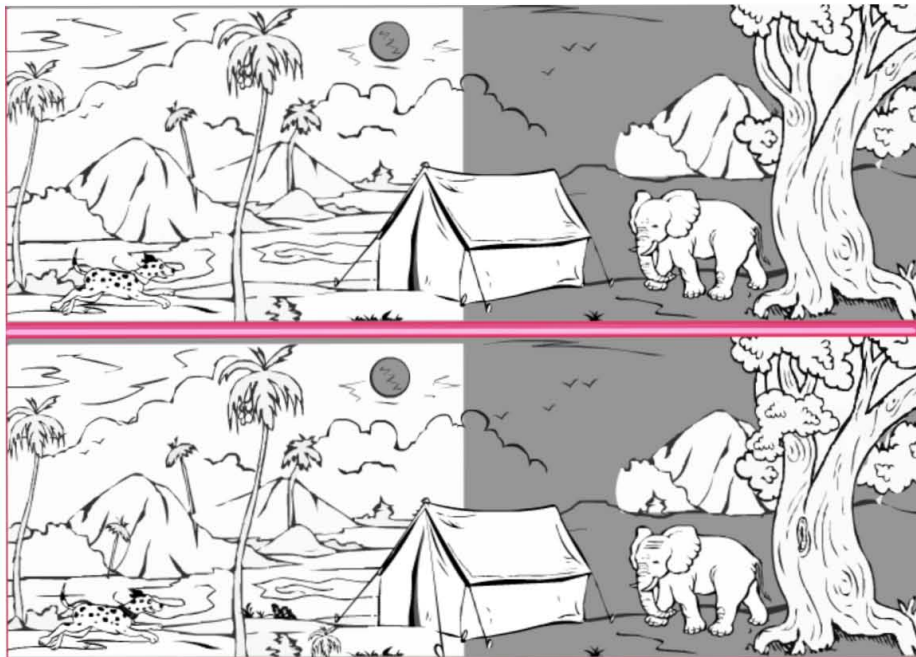
Take a good look at these 2 pictures.

Can you spot all the 8 differences ?



Copyright © 2008-2009 Best Preschool Ideas. All rights reserved.

www.bestpreschoolidea.com



SPOT 10 DIFFERENCES!

Appendix C

Lab Questionnaire

1. How were you feeling during wakeful rest? Were you thinking about anything?
2. Were you rehearsing the word list during any of the delay sessions?
3. Did you adapt any memorization strategy for any of the word list?
4. Please tell me anything during the study that you believe is relevant.

Appendix D

Email Questionnaire

Instruction This is a follow-up questionnaire for the memory study you participated in yesterday. Please fill this questionnaire out first thing in the morning.

Q0 OCMR

Q1 Gender

- Male
- Female

Q2 Are you in the college or the conservatory?

- A&S College
- Conservatory
- Double Degree

Q3 What year are you?

- 1st
- 2nd
- 3rd
- 4th
- 5th & up

Q4 How many hours of sleep did you have yesterday?

Q5 Did you review the word lists after the study session?

Q6 Please provide any words you can recall from any of the words you learned yesterday.

Q7 Please provide any comments here.