4-28-2015

Distractor Task Manipulation in Offline Associative Learning

Halley K. Bayer
Carnegie Mellon University

Distractor Task Manipulation in Offline Associative Learning

Halley K. Bayer

Carnegie Mellon University

Advisor: J. David Creswell

Abstract

Offline processing is regarded as the continued thought of information that occurs without explicit attention and outside of one's conscious awareness, and it has been shown to be particularly advantageous in comparison to conscious thought and immediate testing in the realm of decision making. There is evidence for an underlying learning mechanism supported by offline processing, and recent work demonstrates advantages of offline processing in associative learning tasks. This study aims to address whether offline processing can be utilized as a practical technique in a real world learning task, and to investigate what specific types of distractor tasks best facilitate offline processing and learning. Participants encoded new real world information and were later tested on the material in either an immediate, same domain distractor, or different domain distractor condition in an online survey. Initial results indicate no advantage or disadvantage for either type of offline processing in comparison to immediate subsequent testing of newly encoded information. It is possible that this study presents evidence contrary to offline processing being a beneficial tool in real world learning, however, as such a newly investigated topic, this study more likely provides useful information as to what may or may not work in order to utilize offline processing in real world learning contexts.

Offline Associative Learning

Usually when attempting to learn, we try to actively engage ourselves as thoroughly as possible and use conscious, deliberate strategies to remember new information. Common theories on learning involve focus on conscious engagement from the learner, while offline-processing techniques have been a less pursued avenue in the learning domain. Offline processing is the continued thought of information that occurs without explicit attention and outside of one's conscious awareness (Dijksterhuis & Nordgren, 2006). From what is currently known, there exists reasonable evidence to believe that offline processing techniques could be beneficially utilized in learning to boost information integration and consolidation, and in turn performance. This study aims to investigate whether offline processing can have an effect on real world associative learning performance, and whether the domain of distractor task utilized to produce offline processing has an impact on this effect.

Research on offline processing, also known as unconscious thought, has detailed its characteristics as a mode of thinking. Offline processing and conscious thought are regarded as two different styles or modes of thinking, each having unique traits that can make one mode more advantageous than another depending on the circumstances. Of interest, offline processing is considered to have a large capacity in contrast to conscious thought, which is known to have a limited capacity (Strick, Dijksterhuis, Bos, Sjoerdsma, Baaren, & Nordgren, 2011). Offline processing has strengths in making rough estimates and holistic choices, while conscious thought is much better at following strict rules with precision. Offline processing thrives in environments where there is there is a large amount of information to integrate with no singular, correct outcome (Dijksterhaus, 2004).

Offline processing has been well studied in the domain of complex decision making, which lends itself as an area favorable to this mode of thinking and it characteristic strengths. It has been demonstrated that when given a complex decision making task with numerous variables, participants who have a period of induced unconscious thought by completing a distractor task make better decisions than participants who make immediate decisions or are allowed to think about the choice consciously (Dijksterhaus, 2006). In these complex decision making studies, in order for participants to make final decisions, they must encode, consolidate, and integrate information that has been presented to them. The suggestion can be made that in these complex decision making tasks, there is an aspect of learning new information underlying the procedure and processes that benefit from offline processing.

Recent research has investigated offline processing techniques in complex decision making tasks that has demonstrated neural evidence for reactivation of brain areas used in encoding during induced offline processing (Creswell, Bursley, & Satpute, A. 2013). It appears as though brain areas active during encoding of new information maintain activity during periods of induced offline processing through a distractor task, which leads to enhanced subsequent behavioral performance in making good decisions. This suggests that neural reactivation during offline processing allows for continued encoding of new information, which allows for enhanced behavioral performance, and that offline processing may involve a general mechanism for learning.

Building on these findings, a recent study was conducted that tested offline processing within a declarative associative learning task using fictitious animal stimuli. Here, results show that a brief two minute period of induced offline processing through a distractor task boosts associative learning performance in the absence of conscious rehearsal. This novel associative learning paradigm suggests that periods of offline processing improve memory representations of learned associations due to encoded memory representations being reactivated during this time, as also demonstrated in the decision making tasks (Bursley, Nester, Tarr, & Creswell 2015). Furthermore, evidence has been shown that offline processes engaged in during sleep supports newly encoded associative memory links (Robertson, 2009). In rats, neural replay of maze running during sleep has been shown to improve later maze running performance, further suggesting evidence for enhancement through continued encoding of offline processes (Peyrache, Khamassi, Benchenane, Wiener, & Battaglia, 2009; Stickgold, 1998).

While recent research has laid groundwork to suggest that offline processing techniques are beneficial in learning, this is counter to the majority of current learning theories and practices. Common learning theories assume that students should be using conscious rehearsal techniques to optimize learning of newly encoded information. For instance, the well-known self-regulated learning theory emphasizes control and autonomy of the learner to actively monitor and direct information acquisition (Paris & Paris, 2001). This theory includes using proactive practices such as problem-based learning, learning by assessment, rehearsal, and other activities with engaged, active involvement from the learner. Modern learning theories could be overlooking the potential advantages of utilizing offline processing techniques in the encoding and consolidation of new information as demonstrated by previous research.

From investigations conducted so far, there is reasonable evidence to believe that offline processing will be beneficial to the encoding and consolidation of new information in a real world learning task, although previous work used a limited range of fictitious associative learning stimuli (Bursley et al., 2015). The goal of this study was to address the unknowns of implementing offline processing techniques in a real world associative learning context, and to investigate specifications around what type of task best induces facilitative offline processing. To address these questions in this study, participants encoded new information of real animal species that they were later assessed on. In order to investigate possible benefits of offline processing in learning, participants either completed the assessment immediately after encoding, or completed one of two distractor tasks. The two distractor tasks differed as to whether they were in the same domain as the previous encoding task or a different one. This domain manipulation allowed for investigation as to the specifications of a distractor task that will best induce the facilitative benefits of offline processing, either a task in the same domain as the previous encoding task or a task in a different domain from the previous encoding task. It is predicted that a different domain distractor task will allow for the facilitation of encoding by offline processing since it will be pulling from different resources in the brain than ones previously used during encoding, effectively allowing offline processing to continue. Accordingly, a same domain distractor task is predicted to not reap the facilitative benefits of offline processing due to interference. In this case, neural reactivation of regions responsible for offline processing will be disrupted by related distractor stimuli, eliminating offline processing benefits on learning. Specifically, it was predicted that offline processing is expected to enhance real world associative learning ability through facilitating encoding and consolidation as compared to immediate testing, but only when the distractor task that induces offline processing is in a different domain than previously encoded information.

Methods

Participants and Design:

A total of 303 eligible participants were recruited through Amazon's Mechanical Turk (MTurk) Artificial Artificial Intelligence marketplace for work and completed the study online on a personal computer. Participants received a set amount of $0.50 for completing the Human Intelligence Task (HIT). All participants were electronically randomized to one of three conditions and completed the study individually. Participants could only complete the study if they were over the age of 18, living within the U.S., and provided informed consent.

Further exclusions were made to 11 participants for not fully completing the study or for taking an excessive amount of time (greater than 40 minutes; 1 subject for taking too brief a time of 5 minutes). Of the remaining 292 subjects, there were 175 females (59.9%), 116 males (39.7%), and 1 who identified as 'other' (0.3%) that participated in the study with an average age of 38.58 (SD =12.88), ranging from 20 to 77 that took an average time of 17.37 minutes to complete the study (SD = 4.04).

IRB approval was obtained through Carnegie Mellon University's Institutional Review Board and each participant provided informed consent before completing the study.

Procedure:

All surveys were completed on a personal computer online through Amazon's Mechanical Turk marketplace and were created through Qualtrics Survey Software. Participants were randomized to complete one of three conditions: immediate, same domain distractor, or different domain distractor. All conditions consisted of completing a consent form with instructions, a five minute encoding period, an encoding quiz, the study manipulation, final test, and debrief explaining the aims of the study. The two distractor conditions included an additional distractor task in either the same or different domain as the encoding task. The stimuli in the main encoding period, quiz, and test consisted of 12 different species of owls native to North America.

Encoding Period:

The encoding period was identical across all three conditions. After an instructions screen, the encoding period consisted of about 5 minutes where the participant was shown pictures of 12 different species of owls native to North America. There was a total of three different pictures of each species of owl shown for a total of 36 different pictures. Each picture was shown twice throughout the encoding period. Every picture was displayed for 4 seconds accompanied by the instructions to "Learn the name of this owl:" along with the name of the owl below. Stimuli were originally adapted from Tanaka, Curran, & Sheinberg (2005) with additional stimuli added that first went through pilot testing. Picture presentation order was randomized for every participant. All pictures were uniformly formatted to be presented as 250 x 250 pixels.

Encoding Quiz:

Directly after the encoding period, all participants completed a brief quiz that tested them on the species names of the owls shown during the encoding period. The first dependent measure of the Encoding Quiz assessed how well participants had initially encoded and acted as a quality check to ensure participants were paying attention during the encoding period. The encoding quiz consisted of 12 questions, one question for each species of owl. One of the three pictures displayed during the encoding period was chosen for the encoding quiz. The participant had 10 seconds to choose the correct species name from a multiple choice selection of 5 out of the 12 species names. All participants received the same encoding quiz with the same pictures and multiple choice selections in a set order. The five multiple choice answer selections were randomly chosen, assuring that the correct answer was present. After participants made a choice selection, they could not change their answer and were given immediate feedback as to whether they had gotten the name correct or not. The participant was either shown a screen that read "Correct!" or "Incorrect: The correct answer is [specie's name]". All pictures were uniformly formatted to be presented as 270 x 270 pixels.

Manipulated variables:

(1) Same Domain Distractor Task:

Encoding Period: Participants randomized to the same domain distractor tasks condition completed an additional task before the final test. The same domain distractor task was similar to the owl encoding task described above, but instead consisted of encoding 6 species of butterflies. The same domain distractor task consisted of an encoding period where the subject was shown pictures of 6 different species of butterflies native to North America. There were three different pictures of each species of butterfly shown for a total of 18 pictures. Each picture was shown twice throughout the encoding period. Every picture was displayed for 4 seconds accompanied by the instructions to "Learn the name of this butterfly:" along with the name of the butterfly below. Stimuli went through pilot testing before being used. Picture presentation was randomized for every participant in this condition. All pictures were uniformly formatted to be presented as 250 x 250 pixels

Distractor Task Quiz: Directly after the encoding period, all participants completed a brief quiz that tested them on the species names of the butterflies shown during the encoding period. The encoding quiz consisted of 6 questions, one question for each species of butterfly.

One of the three pictures displayed during the encoding period was chosen for the encoding quiz. The participant had 10 seconds to choose the correct species name from a multiple choice selection of 5 out of the 6 species names. All participants in this condition received the same encoding quiz with the same pictures and multiple choice selections in a set order. The five multiple choice answer selections were randomly chosen, assuring that the correct answer was present. After participants made a choice selection, they could not change their answer and were given immediate feedback as to whether they had gotten the name correct or not. The participant was either shown a screen that read "Correct!" or "Incorrect: The correct answer is [species names]". All pictures were uniformly formatted to be presented as 270 x 270 pixels.

(2) Different Domain Distractor Task:

Participants randomized to the different domain distractor task condition completed a short reading comprehension activity. Participants were shown a screen of instructions that informed them to carefully read a short passage and then answer the following questions to the best of their ability. When participants were answering the questions, they could no longer view the passage. Participants were shown 3 different short passages with a total of 12 questions for all 3 passages. The passage and question order remained fixed and all participants in this condition received the exact same materials in the exact same order. All reading passages and questions were taken from an Advanced Reading Practice Question Test Prep Review for standardized exams.

Final Test:

The final task and dependent measure for all participants was to complete a test similar to the encoding quiz on the material presented in the encoding period. The final test was an assessment on how well participants can differentiate the owl species encoded earlier using both new and familiar owl stimuli. The test consisted of 24 questions, 2 questions for each species of owl. For each species, there was a question on a picture previously seen during the encoding period and a question on a new picture not previously seen in the survey before. The new stimuli consisted of one additional picture of each of the 12 species of owls. The new pictures displayed the main features of each type of owl but consisted of new positions or settings as to remain recognizable but be novel stimuli. The test was the same across all conditions, however the two distractor conditions completed a distractor task before completing the final test. The immediate condition completed the test immediately following the encoding quiz. Similar to the encoding quiz, participants were shown a picture with the instruction to choose the correct species name from 5 multiple choice selections. Participants had 10 seconds to choose an answer and could not change their selection once made. No feedback was provided during the test. Order of display of the pictures was randomized for each participant, and the 5 multiple choice answer selections remained the same for each picture. Participants were provided with a time counting down from 10 seconds for each question. All pictures were uniformly formatted to be presented as 270 x 270 pixels

Results

Preliminary Analyses. The total time to complete the study was 17.37 minutes (SD = 4.04) and the mean score on the Encoding Quiz was 8.13 out of 12 questions (SD = 2.62). Across all subjects, the mean score on the final test was 14.4 out of 24 questions (SD = 4.39). The mean score for familiar stimuli in the final test was 7.28 (SD = 2.47) and 7.11 for new stimuli (SD = 2.28). In the same domain distractor task, participants scored a mean of 5.28 out of 6 questions (SD = 1.24), and in the different domain distractor task, there was a mean score of 10.08 out of 12 questions (SD = 2.42). 100 participants were randomized to the immediate condition, 97 to the same domain distractor task condition, and 95 to the different domain distractor test condition. Participants who scored two standard deviations below the mean Encoding Quiz score were removed from analyses (N=15). Randomization was successful in equalizing initial encoding performance, there was no condition main effect for encoding quiz score $F(2,274) = .557$, $p = .573$; (immediate: $M = 8.27$, $SD = .23$; same: $M = 8.50$, $SD = .23$; different: $M = 8.62$, $SD = .24$).

Primary Analyses. It was predicted that the different domain distractor condition would have better test performance in comparison to the immediate condition and the same domain distractor condition. To test this hypothesis, a three-way between subjects Analysis of Variance (ANOVA) was conducted with condition as the independent variable. Contrary to predictions, there was no condition main effect for overall test performance $F(2,274) = .427$, $p = .653$; (immediate: $M = 14.50$, $SD = .43$; same: $M = 14.93$, $SD = .42$; different: $M = 15.02$, $SD = .43$), (*Figure 1*). Participants were performing at comparable levels in the final test regardless of what condition they were in and whether they completed a distractor task or not.

It was also predicted that participants in the different domain condition would have better performance for discriminating new stimuli. Additionally, one-way ANOVAs examined the composites of new stimuli and familiar stimuli separately. Again, contrary to predictions, no main effects were found across conditions for differences in performance of discriminating new vs. familiar stimuli. Participants were again performing similarly across conditions for discriminating familiar stimuli $F(2,274) = .130$, $p = .878$; (immediate: $M = 7.42$, $SD = .25$; same: $M = 7.47$, $SD = .24$; different: $M = 7.60$, $SD = .25$) and new stimuli $F(2,274) = .914$, $p = .402$; (immediate: $M = 7.08$, $SD = .22$; same: $M = 7.46$, $SD = .22$; different: $M = 7.43$, $SD = .23$). Not only were participants performing evenly across conditions on the overall test, but were also identifying both familiar and new stimuli at the same performance level for both new and familiar stimuli composite scores and across conditions.

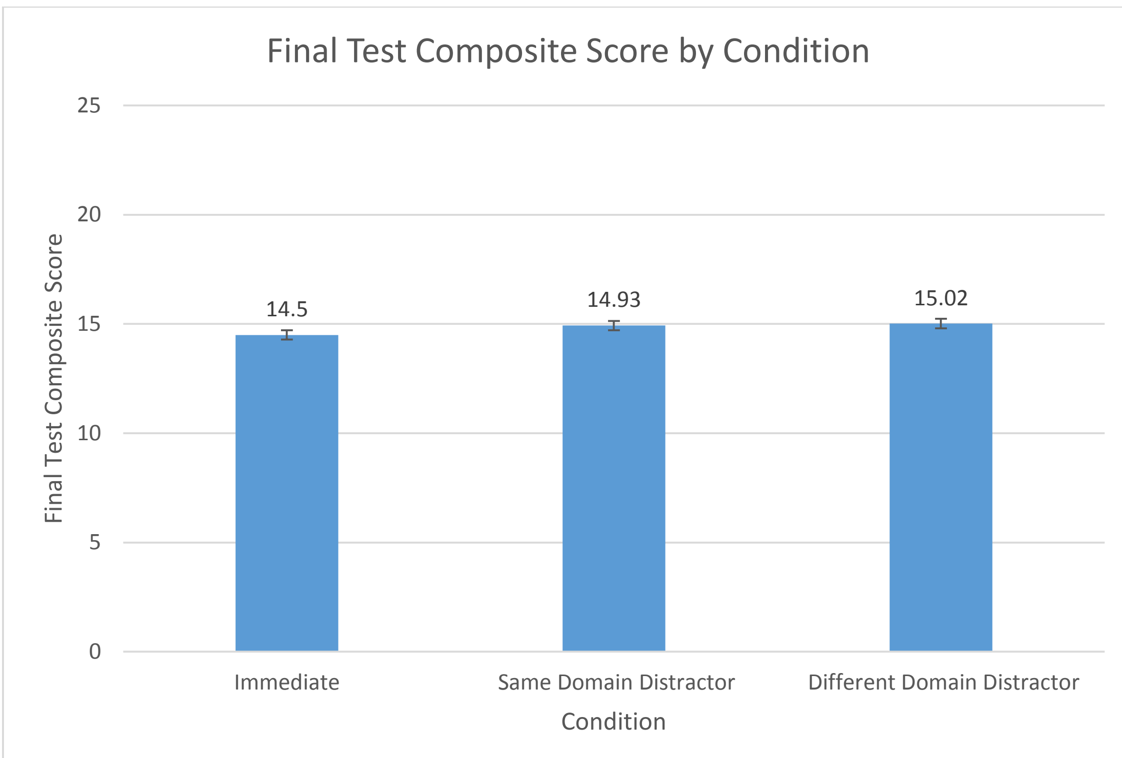
Discussion

This study intended to initially test the possibility of improving real world learning with offline processing. Initial results show no significant effects of completing a distractor task to induce offline processing to be either beneficial or detrimental in subsequent test performance as when compared to immediate testing. It is possible that this demonstrates counter evidence to offline processing potentially being an advantageous tool in the real world learning domain. However, since there has been substantial evidence for facilitative offline processing effects in other related associative learning tasks, it is likely that lack of findings is a result of the specific study design or materials. While broad characteristics are known about offline processing, the specifics remain unknown as to when offline processing functions most optimally, which involves guesswork in creating sufficient paradigms, particularly in real world settings.

This investigation attempted to answer some of these questions by examining specifications of inducing offline processing by implementing two different distractor tasks. There was no evidence from this study for one form of distraction to be more effective for learning. It is possible that the distractor tasks in this study failed to properly induce offline processing. For instance, if either of these tasks were too easy, they may not have been successfully engaging resources in the brain, not allowing for proper offline processing, or rather allowing for possible conscious thought to take place during this time. This would have theoretically disrupted continued encoding from taking place, and subsequently not allowed for enhanced test performance. It could be possible that the stimuli used in this study were not complex enough to engage offline processing capacities. As noted previously, offline processing is beneficial in situations with many complex variables to integrate. Lack of finding main learning effects could be due to a failure in designing tasks and stimuli used in this study to be complex enough to benefit from offline processing. It is also a possibility that participants came into the study with varying background knowledge of the material, which would give some participants a starting advantage. Inherently, it is more of a challenge to have everyone start at the same knowledge level with real world stimuli. It is the hope that any advantages would be equalized with randomization, although in the future, it may be of interest to survey participants on how much of an understanding they currently have on the material that is being tested. These results provide no evidence for offline processing being a practical technique to utilize in real world learning, but there are many avenues that remain untested. Offline processing may not be of beneficial use for all subject materials and activities.

These results may indicate that offline processing is not a strategy that can or should be utilized in purely associative learning contexts. From knowledge of prior research, perhaps it is imperative that there needs to be an element of decision making involved to attain facilitative benefits from offline processing. However, there have been studies, as previously mentioned, that demonstrate encouraging results of benefits of offline processing during associative learning focused tasks. Therefore, it is likely that this current work adds to the growing basis of knowledge around offline processing and how to utilize it, specifically what types of distractor tasks to use or not use. In the future, the distractor tasks may need to revert to focusing on complex working memory activities that are not necessarily real world stimuli, like the n-back task. While this study attempted to provide answers to some of these questions regarding how to effectively utilize offline processing, it is far too undeveloped of an area to make conclusive statements. This means that in the future, there are many other ways to possibly examine offline processing in real world learning settings, and this is just the beginning of discovering what specifications are required. It is possible that this study presents evidence contrary to offline processing being a beneficial tool in real world learning, however, as such a newly investigated topic, this investigation more likely provides useful information as to what may or may not work to advantageously utilize offline processing in real world learning contexts in the future.

Figure 1: Final Test Composite score by condition.



References

Bursley, J., Nester, A., Tarr, M., & Creswell, J. (2015.). Awake, Offline Processing During Associative Learning. *In Press*.

Creswell, J., Bursley, J., & Satpute, A. (2013). Neural reactivation links unconscious thought to decision-making performance. *Social Cognitive and Affective Neuroscience, 8*(8), 863-869.

Dijksterhuis, A. (2004). Think Different: The Merits of Offline processing in Preference Development and Decision Making. *Journal of Personality and Social Psychology, 87*(5), 586-598.

Dijksterhuis, A., & Nordgren, L. (2006). A Theory Of Unconscious Thought. *Perspectives on Psychological Science, 1*(2), 95-109.

Paris, S., & Paris, A. (2001). Classroom Applications Of Research On Self-Regulated Learning. *Educational Psychologist, 36*(2), 89-101.

Peyrache, A., Khamassi, M., Benchenane, K., Wiener, S., & Battaglia, F. (2009). Replay of rule-learning related neural patterns in theprefrontal cortex during sleep. *Nature Neuroscience, 12*(7), 919-930.

Robertson, E. (2009). From Creation to Consolidation: A Novel Framework for Memory Processing. *PLoS Biology, 7*(1), E19.

Stickgold, R. (1998). Sleep: Off-line memory reprocessing. *Trends in Cognitive Sciences, 2*(12), 484-492.

Strick, M., Dijksterhuis, A., Bos, M., Sjoerdsma, A., Baaren, R., & Nordgren, L. (2011). A Meta-Analysis on Offline processing Effects. *Social Cognition, 29*(6), 738-762.

Tanaka, J., Curran, T., & Sheinberg, D. (2005). The Training and Transfer of Real-World Perceptual Expertise.*Psychological Science, 16*(2), 145-151.