LONG-TERM MEMORY: AN OVERVIEW OF THE IMPLICATION FOR EDUCATION AND HEALTH

ABDULLAH ABDULSALAM
Department of Physical & Health Education,
University of Maiduguri,
Maiduguri, Nigeria.

Abstract
The process of long-term potentiation has a significant role in learning and new memory formation; the strong and weak memory depends on the synaptic communication network strength. Strong synaptic links have a high probability of storing new information and correct recall. Various factors have been investigated, which have contributed to retaining more information and recall after a long time. Many of them (such as attention, sleep, rehearsal, etc.) have been experimentally proved, such as their crucial role in utilizing the limited working memory capacity to learn more information, and transfer to long-term storage.

Introduction
In daily life, as we take in new information and store it in our brain, maintaining it and recalling it depends on our needs. This happens because our brain has the capability of learning new skills and experiences, storing what has been learned, recalling and reusing the stored knowledge. These capabilities of storing, recalling and reusing experiences and skills are informally known as the human memory system. Everything we do or think depends on our memory, which is active every moment in receiving new information from our senses, updating existing knowledge using focus and attention, retrieving the stored experiences and skills, and planning for future activities that have not occurred yet. Thus far, neuroscientists have been expecting to find specific stores of memory in the brain and discover their exact location to know which type of memory lies where.

Generally, there are two different memory types—short-term and longterm memory—that store and access information differently, and many brain regions are involved in the process. Short-term memory retains information for a few seconds, and its capacity ranges from seven to nine items for a normal person. It tends to weaken as the individual's age increases. Long-term memory retains unlimited information for an infinite duration. The information could be personal events, temporal and spatial relations among these events, and real-world entities and their meaning such as symbols, words, and concepts.

Interactions between STM and LTM

A widely accepted taxonomy of memory systems differentiates between declarative and non-declarative memory (Squire, 1992). Procedural memory is one of a number of systems that comprise the non-declarative system. Both declarative and procedural systems have the capacity to store information from minutes to years. This can be contrasted with working memory, which holds information in an active state for use in cognition for a short period of time (Baddeley, 2003). Collectively, the declarative and procedural systems allow us to learn and use information and skills across the life span. It is known that disruption to the declarative or procedural system significantly reduces the ability to learn, even if working memory is intact (e.g., Corkin, 2002; Heindel, Butters, & Salmon, 1988).

The declarative memory system principally supports learning, storage, and retrieval of knowledge or memory pertaining to personal events, referred to as episodic memory, and general information, referred to as semantic memory (Squire, 1992; Squire et al., 2004). Examples of episodic memory include knowing particular events that occurred at a dinner party. An example of semantic memory includes knowing that the word 'dog' corresponds to the object or concept of a dog. Learning via the declarative memory system is achieved through binding arbitrarily related pieces of information together (Mayes, Montaldi, & Migo, 2007). In the case of episodic memory, learning might occur after witnessing which person told an anecdote at a dinner party. For semantic memory, this might be learning the association of a particular sound pattern or orthography to its referent.

The procedural memory system underlies the implicit learning, storage and retrieval of skills and knowledge (Gabrieli, 1998; Squire & Zola, 1996). The main neural structures that support this memory system are a collection of subcortical structures referred to as the basal ganglia and cerebellum as well as the prefrontal cortex (Packard & Knowlton, 2002; Parent & Hazrati, 1995). The learning and retrieval of information from the procedural memory system is said to be implicit because conscious awareness is not required.

Unlike declarative memory, procedural memory is better suited to learning sequentially or learning probabilistically structured information (Packard & Knowlton, 2002). This includes learning new motor and perceptual skills (Nissen & Bullemer, 1987) and forming associations between pieces of verbal or visual information that are probabilistically or statistically structured (Conway & Pisoni, 2008; Karuza et al., 2013; Knowlton, Squire, & Gluck, 1994). The neurological architecture of the procedural memory system permits implicit learning, storage, and retrieval processes to be carried out on visual, verbal, cognitive, and also linguistic information (Alexander & Crutcher, 1990; Alexander, DeLong, & Strick, 1986; Ullman, 2006).

Long-Term Memory and Education

In addition to primary memory and working memory, secondary (long-term) memory also plays an important role in mathematical performance. It is the process of transforming primary memory into a different code for its long-lasting preservation or storage, which is the process of secondary long-term memory. The development of long-term mnemonic operation seems to follow a specific order. First, in the infancy stage, recognition is based on familiarity, while later the ability to retrieve specific information appears. Long-term memory, based on the type and nature of the information, is divided into verbal long-term memory and visual long-term memory. Their assessment is similar. There is a perception that long-term visual memory is unclear and easily altered when subjected to interference. Thus, although individuals can remember thousands of images, it is supposed that these memories are devoid of details. Contrary to this hypothesis, research (Brady et al 2008) shows that long-term memory is capable of storing a huge number of images in great detail. Participants saw images of 2,500 items for five and a half hours. Then they were shown pairs of pictures and they were asked to indicate which of the two they had them in three different states. The performance in each of these conditions was extremely high (92%, 88% and 87% respectively), indicating that the participants successfully retained detailed information from thousands of images. These effects have implications for cognitive models (object recognition models) and are challenging for nerve memory storage and recovery models, which must be able to explain and interpret such a large and detailed storage capacity. The theories of the representation of numerical events in long-term memory (Siegler & Shrager, 1984) point out that the performance of simple numeric queries depends on long-term memory recollection. The power with which these elements are stored and therefore the probability of their successful recovery is based on the experience of the correlation of the problems and the responses formed, each time a particular numerical problem is dealt with, regardless of the correctness of the response. A student with long-term memory deficits may have difficulty with mathematical tables, geometric shapes, or algebraic formulas. In a review of research on cognitive deficits in children with mathematical difficulties (Geary, 1993), two main categories were identified. The first one is related to counting deficits, computational skills and working memory (Geary, 1990; Geary, Bow-Thomas, & Yao, 1992) and is manifested by the use of developmental immature numerical procedures which usually return to normal levels after 2 or 3 years of schooling. The second category involves more of a permanent difficulty in the representation and retrieval of numerical events from long-term semantic memory.

Some researchers argued that difficulties in retrieving information, including words and numerical events, from long-term memory represent a specific cognitive deficit that results in serious delays in the early development of mathematical skills (Geary, 1993; Geary et al., 1999). The results of these studies show that the ability to retrieve information from long-term memory is important for the development of early math computing skills. Significant relationships between information retrieval and various fields of mathematics were generally evident from the age of 6 to about 8 years. It appears that after the age of 9, this relationship is weaker.

Retrieval practice produces greater long-term retention than studying alone. This finding suggests that testing, which is commonly conceptualized as an assessment tool, can be used as a learning tool as well (Dempster, 1992). In particular, practising retrieval is beneficial when it requires effortful processing (e.g. production rather than recognition tests), it occurs multiple times with relatively long intervals between retrieval attempts, and it is followed by feedback after each attempt. Under these conditions, tests provide a highly effective means of learning. Educators sometimes decry this approach of what we have called test-enhanced learning (Roediger and Karpicke, 2006) as involving nothing but drill and practice in which students engage in rote rehearsal. However, when used correctly, retrieval practice techniques help to foster deeper learning and understanding so that knowledge can be flexibly retrieved and transferred to new situations (Johnson & Mayer, 2009; McDaniel, et al, 2009; Rohrer et al. 2010; Butler, 2010).

Studies on retrieval practice conducted in educational settings have shown that frequent testing produces substantial benefits to long-term retention (Bangert-Drowns, 1991). For example, research has demonstrated that retrieval practice improves scores in college courses in biological psychology and statistics (McDaniel, 2007), as well as advanced medical education (Larsen, 2009). In addition, experiments in middle-school history, social studies and science classrooms have shown great improvement in children's knowledge derived from repeated quizzing on delayed tests (Carpenter, 2009). Importantly, the tests used to measure long-term retention in some of these studies were the actual tests being given to the class for assessment purposes, not ones made up for the sake of an experiment.

Testing at the university level provides an indirect benefit that complements the direct benefit that is discussed here. Many university courses require only one or two semester tests and a final exam, a practice that leads to the near universal phenomenon of students concentrating their study attempts just before the exams and not keeping up with the course (Mawhinney, 1971; Michael, 1991). Frequent quizzing (say, on a weekly or even a daily basis) forces students to stay current with the course by studying more regularly.

Classroom studies have shown that students who received daily quizzes performed better than those who did not. Importantly, survey questions given at the end of the semester revealed that the students who were frequently quizzed felt they had learned more and reported greater satisfaction with the course, despite (or perhaps because of) the greater effort they exerted (Lyle and Crawford,; Leeming, 2002). In addition, the mnemonic benefits of testing extend beyond the specific information that is tested: retrieval practice can increase retention of related, but non-tested material as well (Chan, 2009; Chan, 2010; Chan, 2006). Of course, retrieval practice need not occur only through quizzing or testing in the classroom. Retrieval practice can be implemented in many different ways, including self-testing (e.g. using flash cards, chapter-ending questions, or other methods).

In a study using animations in a chemistry course, where students have difficulty with mental models about the particular nature of matter, students obtained significantly higher test scores when the animation was viewed as part of a lecture or as a supplement to individual study compared with a control group of students who did not have access to the animation (Williams and Abraham, 1995). In keeping with those studies, it was revealed that students understood a complex signal transduction pathway better after viewing a narrated animation compared with a graphic with an equivalent legend (O'Day, 2006a). Thus, the few studies that have been done indicate that animations provide students with insight into biological processes in a way that traditional lecturing and static graphics do not.

An extensive review of the literature covering all educational disciplines has indicated that there are certain parameters that need to be considered when making a teaching animation (O'Day, 2006a, 2006b). Of relevance here is that animations are most effective when text is adjacent to important structures and is spoken simultaneously to reinforce the learning process ("spatial contiguity effect," "multimedia effect," and "personalization effect," respectively; Mayer, 2003). Many biological animations that are freely available online do not include narratives. Often, these animations are intended for in-class use with the instructor providing the narrative (Stith, 2004; McClean *et al.*, 2005). Students who access these animations online do not have the benefit of the instructor's narration. However, research in other disciplines indicates that animations and graphics with a spoken or written narrative are more effective than those lacking a narrative (e.g., Mayer, 2003).

Animations provide a valuable way to communicate dynamic, complex sequences of biological events more effectively than text or a static graphic (Stith, 2004; McClean et al., 2005; O'Day, 2006a). We are currently teaching an electronic generation of students, individuals whose everyday life is primarily based on auditory and visual communication. Their comments here and in a previous study indicate that they prefer having animations in lieu of reading the textbook (O'Day, 2006a). Although this may be anathema to teachers, it is a reality of academic life that needs to be considered as we develop new courses and curricula. If animations can assist students' learning, then developing more pedagogically meaningful animations to include in our teaching repertoires is worth considering. Research into the pedagogical value of biological animations in the sciences can serve as a guide to developing such animations.

It is well established that memory of specifics declines over time. Originally defined by Hermann Ebbinghaus in 1885, this "forgetting curve" is a general property of essentially all retrospective memory (Hicks *et al*., 2000). The forgetting curve or decline of memory retention over time is essentially logarithmic with a fast early phase of forgetting followed by a progressively slower phase. In educational terms without relearning, most students will remember _25% of learned information after a week and _21% after 2 to 4 weeks in this Animations and Memory Retention.

Long-Term Memory and Health

Long-term memory can be divided into episodic and semantic memory systems. Episodic memory enables people to encode and retrieve personal information, which is encoded in relation to spatial and temporal context. Three processes can be distinguished in manipulating episodic information: encoding or learning of new information, storage of information, and explicit retrieval of information. The other long-term memory system is semantic memory, an organized amount of context-free knowledge, together with rules to manipulate this knowledge. Explicit retrieval processes can also play a role in the retrieval of information from semantic memory. In contrast to these explicit memory systems, there is also implicit memory, which deals with the automatic cognitive and motor processes, which do not require conscious attention.

Labban & Etnier (2011) tested the effect of acute exercise on long-term memory, specifically the timing of exercise relative to the memory challenge. We assessed memory via paragraph recall, in which participants listened to two paragraphs (exposure) and recounted them following a 35-min delay. Participants (n = 48) were randomly assigned to one of three groups: exercise prior to exposure, exercise after exposure, or no-exercise. Exercise consisted of 30 min on a cycle ergometer, including 20 min at moderate intensity. Only the exercise-prior group recalled significantly more than the control group ($p < .05$). Differences among the exercise groups failed to reach significance ($p = .09$). Results indicated that acute exercise positively influenced recall and that exercise timing relative to memory task may have an impact on this effect.

It is commonly observed that both depression and cardiovascular-related diseases are associated with poor subjective memory15 16 39 and objective memory impairment (SMI) (Bergman, Blomberg and Almkvist, 2007; Reed, 2010). Almkvist et al (2017) study has shown that depression, brain infarction, heart failure and diabetes are linked with SMI and that this impairment is primarily associated with the STM component. This finding indicates that SMI is predominantly associated with attention and concentration, as indicated by the STM component, rather than with basic memory problems, as indicated by the LTM component. A clinical consequence of this finding and interpretation is that subjective memory problems have to be differentiated in primary care because the STM component and not the LTM component were associated with disease.

Factors Affecting Memory Retention and Recall

Cognitive research studies (Parker,Wilding and Bussely,2002;Karpicke and Roediger,2007) have emphasized that retention and recall processes are related to one another and also are connected with other concepts such as learning, testing, and capacity limit of memory, attention demand, and complexity of material. However, there are many other factors that affect retention and recall performance, such as attention, rehearsal, sleep, testing, mnemonics, exercise and nutrition, and reward. The conventional concept of learning and retrieval is that learning takes place during studying, while retrieval helps to assess the learned content.A recent study investigated long-term memory retention with full and divided attention. They found superior results with full attention as compared to divided attention during the memory recognition task (Dudukovic, 2009). Recently, Bell et al (2014) investigated the impact of sleep and spacing gap on long-term memory. Their results support the positive effects of sleep on long-term memory retention. Roediger and Butler (2011) investigated the link between retention and learning with repeated testing, and they proposed that the repeated recalling of retained information led to better learning and long-term retention. A study by Abe et al (2011) reported that training under reward conditions results in substantial long-term retention, whereas training under neutral conditions showed a significant decline in memory gain. The effectiveness of all these techniques for memory retention and recall processes is experimentally proved.

Conclusion

The process of long-term potentiation has a significant role in learning and new memory formation; the strong and weak memory depends on the synaptic communication network strength. Strong synaptic links have a high probability of storing new information and correct recall. Various factors have been investigated, which have contributed to retaining more information and recall after a longer time. Many of them (such as attention, sleep, rehearsal, etc.) have been experimentally proved, such as their crucial role in utilizing the limited working memory capacity and learn more information, and transfer to long-term storage. Not all of these factors may be in support of high retention or recall. However, each of them has its own contribution in certain scenario. In the end, various issues regarding memory experimental design were summarized. As a whole, these issues may be useful to consider in designing a memory experiment, especially for new researchers in memory research.

References

Abe, M., Schambra, H., Wassermann, E. M., Luckenbaugh, D., Schweighofer, N., and Cohen, L. G.(2011), Reward improves long-term retention of a motor memory through induction of offline memory gains, *Current Biology*, 21, 557–562.

Almkvist O, Bosnes O, and Bosnes I.(2017) Selective impact of disease on short-term and long-term components of self-reported memory: a population-based HUNT study. BMJ Open ;7:e013586. doi:10.1136/ bmjopen-2016-013586

Baddeley, A. D. (2003). New data: Old pitfalls. Commentary on Ruchkin,Grafman, Cameron & Berndt. *Behavioral and Brain Sciences*, *26*, 728– 729. http://dx.doi.org/10.1017/S0140525X03230168

Baddeley, A. D. (1964). Immediate memory and the "perception" of letter sequences. *The Quarterly Journal of Experimental Psychology*, *16*, 364–367. http://dx.doi.org/10.1080/17470216408416394

Bergman I, Blomberg M, Almkvist O.(2007) The importance of impaired physical health and age in normal cognitive aging. *Scand J Psychol* ;48:115–25

Bell, M. C., Kawadri, N., Simone, P. M., and Wiseheart, M(2014)., Long-term memory,sleep, and the spacing effect, *Memory*, 22, 276–283.

Butler, A. C. (2010). Repeated testing produces superior transfer of learningrelative to repeated studying. *Journal of Experimental Psychology. Learning,Memory, and Cognition*, *36*(5), 1118–1133. https://doi.org/10.1037/a0019902

Carpenter , S. K. , Pashler , H. , & Cepeda , N. J. (2009). Using tests to enhance 8th grade students' retention of U. S. historyfacts . *Applied Cognitive Psychology* , *23* , 760–771 .

Case,W.G.,&Ericson,K.A.(1982). Skill and Working Memory. In J.R. Anderson(Ed.), Congnitive skills and their acquisition (pp. 141-189). Hillsdale, N.J.: Erlbaum

Chan, J.C.K. (2010): Long-term effects of testing on the recall of nontested materials. Memory 18, 49–57

Chan, J.C.K. (2009) :When does retrieval induce forgetting and when does it induce facilitation? Implications for retrieval inhibition, testing effect, and text processing. J. Mem. Lang. 61, 153–170

Conway CM, Pisoni DB. Neurocognitive basis of implicit learning of sequential structure and its relation to language processing. Annals of the New York Academy of Sciences. 2008; 1145:113–131. [PubMed: 19076393]

Corkin S. What's new with the amnesic patient HM? Nature Reviews Neuroscience. 2002; 3:153–160.

Dempster, F.N. (1992) Using tests to promote learning: a neglectedclassroom resource. J. Res. Dev. Educ. 25, 213–217

Dudukovic, N. M., DuBrow, S., and Wagner, A. D(2009)., Attention during memory retrieval enhances future remembering, *Memory and Cognition*, 37, 953–961,

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory *Psychological Review, 102,* 211–245. http://dx.doi.org/10.1037/0033- 295X.102.2.211

Eichenbaum, H.(2002), *The Cognitive Neuroscience of Memory: An Introduction*, Oxford University Press, New York.

Gabrieli JDE. Cognitive neuroscience of human memory. Annual Review of Psychology. 1998; 49:87–115.

Geary D. C., Bow-Thomas C. C., Yao Y., 1992. Counting knowledge and skill in cognitive addition: A comparison of normal and mathematically disabled children. Journal of Experimental Child Psychology, 54(3), 372–391.

Geary D. C., 1993. Mathematical disabilities: Cognitive, neuropsychological, and genetic components. Psychological Bulletin, 114(2), 345–362.

Hicks, J. L., Marsh, R. L., and Russell, E. J. (2000). The properties of retention intervals and their affect on retaining prospective memories.J. Exp. Psychol. Learn. Mem. Cogn. *5*, 1160–1169.

Huttenlocher, J., & Newcombe, N. (1976). Semantic effects on ordered recall. *Journal of Verbal Learning & Verbal Behavior, 15,* 387–399.

Heindel WC, Butters N, Salmon DP. Impaired learning of a motor skill in patients with Huntington's disease. Behavioral Neuroscience. 1988; 102:141–147. [PubMed: 2965592]

Jarrad A. G. Lum1 and Gina Conti-Ramsden (2013) Long-term memory: A review and meta-analysis of studies of declarative and procedural memory in specific language impairment: *Top Lang Disord*. 2013 December 1; 33(4): 282–297.

Jefferies, E., Frankish, C., & Noble, K. (2009). Lexical coherence inshort-term memory: Strategic reconstruction or "semantic glue"? *Quarterly Journal of Experimental Psychology: Human Experimental Psychology,62,* 1967–1982.

Karpicke, J. D. and Roediger, H. L.,III(2007)I, Repeated retrieval during learning is the key to long-term retention, *Journal of Memory and Language*, 57, 151–162.

Karuza E.A, Newport E.L, Aslin R.N, Starling S.J, Tivarus M.E, Bavelier D.(2013) The neural correlates of statistical learning in a word segmentation task: An fMRI study. Brain and language.

Karpicke, J. D. and Roediger, H. L., (2007), Repeated retrieval during learning is the key to long-term retention, *Journal of Memory and Language*, 57, 151–162.

Knowlton BJ, Squire LR, Gluck MA. Probabilistic classification learning in amnesia. Learning &Memory. 1994; 1:106–120. [PubMed: 10467589]

Larsen, D.P. et al. (2009) Repeated testing improves long-term retention relative to repeated study: a randomized, controlled trial.Med. Educ. 43, 1174–1181

McDaniel , M. A. , Anderson , J. L. , Derbish , M. H. , & Morrisette N. (2007). Testing the testing eff ect in the classroom . *European Journal of Cognitive Psychology* , *19* , 494–513 .

Mayes A, Montaldi D, Migo E.(2007) Associative memory and the medial temporal lobes. Trends in Cognitive Sciences. 11:126–135. [PubMed: 17270487]

Mayer, R. E. (2003). The promise of multimedia learning: using the same instructional design methods across different media. Learn. Instr. *13*, 125–139.

McClean, P., Johnson, C., Rogers, R., Daniels, L., Reber, J., Slator, B. M., Terpstra, J., and White, A. (2005). Molecular and cellular biology animations: development and impact on student learning.Cell Biol. Educ. *4*, 169–179.

McDaniel , M. A. , Howard , D. C. , & Einstein , G. O. (2009)Th e read-recite-review study strategy: Eff ective and portable .*Psychological Science* , *20* , 516–522 .

Michael , J. (1991). A behavioral perspective on college teaching *Behavior Analyst* , *14* , 229–239 .

Nissen M.J. and Bullemer, P.(1987): Attentional requirements of learning: Evidence from performance measures.Cognitive psychology; 19:1–32.

O'Day, D. H. (2006a). Animated cell biology: a quick and easymethod for making effective high-quality teaching animations. CBE Life Sci. Educ. *5*, 255–263.

O'Day, D. H. (2006b). How to make pedagogically meaningful animations for teaching and research using PowerPoint™ and Camtasia™. In: Proceedings of the IPSI-2006, International Conference on Advances in the Internet, Processing, Systems, and Interdisciplinary Research, Chapter IV; February 6, Marbella, Spain.

Packard M.G. and Knowlton, B.J.(2002) Learning and memory functions of the basal ganglia. Annual Review of Neuroscience; 25:563–593.

Parent, A.and Hazrati, L.N.(1995): Functional anatomy of the basal ganglia. I. The cortico-basal ganglia-thalamocortical loop. Brain Research Reviews. 20:91–127. [PubMed: 7711769]

Parker, A. W., Wilding, E. L., and Bussey, T. J(2002)., *The Cognitive Neuroscience of Memory: Encoding and Retrieval*, Psychology Press, New York..

Poldrack R, Clark J, Paré-Blagoev E, Shohamy D, Moyano JC, Myers C, Gluck M. Interactive memory systems in the human brain. Nature. 2001a; 414:546–550. [PubMed: 11734855]

Roediger, H. L. and Butler, A. C.(2011), The critical role of retrieval practice in longterm retention, *Trends in Cognitive Sciences*, 15, 20–27.

Rohrer , D. , Taylor , K. , & Sholar , B. (2010). Tests enhance thetransfer of learning . *Journal of Experimental Psychology:Learning, Memory, and Cognition* , *36* , 233–239 .

Squire LR. Declarative and nondeclarative memory: Multiple brain systems supporting learning and memory. Journal of Cognitive Neuroscience. 1992; 4:232–243. [PubMed: 23964880]

Roediger, H. L. and Butler, A. C(2011)., The critical role of retrieval practice in longterm retention, *Trends in Cognitive Sciences*, 15, 20–27.

Karpicke, J. D. and Roediger, H. L.,(2008), The critical importance of retrieval for.learning, *Science*, 319, 966–968.

McDaniel, M.A.(2009):Test-enhanced learning in a middle school science classroom: the effects of quiz frequency and placement. J. Educ. Psychol. in press.

Mawhinney, V.T. et al. (1971) A comparison of students studying behavior produced by daily, weekly, and three-week testing schedules. J. Appl. Behav. Anal. 4, 257–264

Michael, J. (1991) A behavioral perspective on college teaching. Behav. Anal. 14, 229–239

Lyle, K.B. and Crawford, N.A. Retrieving essential material at the end of lectures improves performance on statistics exams. Teach. Psychol. in press.

Leeming, F.C. (2002): The exam-a-day procedure improves performance in psychology classes. Teach. Psychol. 29, 210–212

Reed N.M.(2010). The relationship between subjective memory and objective cognition, depression and anxiety by dementia status. http:// scholorworks. gsu. edu/ gerontology_ thesis/ 19

Ullman MT. Is Broca's area part of a basal ganglia thalamocortical circuit? Cortex. 2006; 42:480–485.[PubMed: 16881254]

Chan, J.C.K. et al. (2006) Retrieval induced facilitation: initially nontested material can benefit from prior testing. J. Exp. Psychol. Gen. 135, 533–571

Labban, J.D., & Etnier, J.L. (2011). Effects of acute exercise on long-term memory. Research Quarterly for Exercise and Sport, 82(4), 712-721.

Stith, B. J. (2004). Use of animation in teaching cell biology. Cell Biol.Educ. *3*, 181–188.

Williams, V. M., and Abraham, M. R. (1995). The effects of computer animation on the particulate mental models of college chemistry students. J. Res. Sci. Teach. *32*, 521–534.