Improving Online Instructional Design using Memory, Attention, and Engagement

Ritika Chanda
Georgia Institute of Technology
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Approved by:

Dr. Eric Schumacher, Advisor
College of Sciences
Georgia Institute of Technology

Dr. Mary Katherine Holder
College of Sciences
Georgia Institute of Technology
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Introduction

Education primarily involves the practice of semantic learning, which is the process of acquiring specific events and facts for recall (Ohlsson, 2012). One of the most important factors that contributes to learning, especially declarative learning, is the level of selective attention and engagement present during the process (Roy & Park, 2016). Attention is defined as the ability to selectively focus on one task, while engagement is when an individual is fully immersed into or involved with the task (Le Pelley et al., 2016; Rotgans & Schmidt., 2011). Neuroscience research has supported a relationship between the psychological constructions of attention and engagement. For example, as engagement increases, attention becomes more focused promoting better recall of specific details surrounding the events (Bezdek et al., 2015; Bezdek et al., 2017). Taken together, these data indicate that engagement and attention play a crucial role in learning and recalling learned information.

A long-standing area of research within the educational field has been identifying new methods that improve how learning material is presented to students. Many models, such as the Gagné’s Nine Events of Instruction, have attempted to tackle this issue using a philosophical approach (Gagné, 1965). However, with the development of Educational Neuroscience, also known as Neuroeducation, there is now the possibility of designing an optimal learning environment based upon the neural mechanisms involved in learning (Kim, 2012). Neuroscience discoveries regarding the link between learning and attention, memory and engagement show a potential for using neuroscience to improve teaching strategies and learning techniques in education and to provide a scientific basis of teaching and learning.

With the recent rise in online learning, new questions regarding the improvement of educational design, teaching techniques and learning have created a new avenue of investigation
within the field of Neuroeducation. Therefore, the objective of this study is to identify whether attentional brain networks related to Gagné’s Nine Events of Instruction and engagement can predict learning in an online setting. Gagné’s Nine Events of Instruction is a nine-step process that addresses the conditions of learning (i.e., verbal information, intellectual skills, cognitive strategies, motor skills and attitudes) as presented in Gagné’s book, *The Conditions of Learning*. The purpose of these events is to provide detailed instructions that will create a strong foundation for instruction and advance learning (Gagné’s 9 Events of Instruction, n.d.; Gagné's Nine Events of Instruction, n.d.).

My research aimed to characterize and identify successful online learning strategies based on Gagné’s Nine Events of Instruction using assessment that test recall and engagement. In addition, I aimed to identify key neural hallmarks of learning using fMRI techniques. This investigation will allow for further advancements in online educational design as it will provide instructors with guidance on how to properly build their curriculum and modify the content structure of online classes to highlight techniques that promote successful learning among students.

**Literature Review**

Neuroscience is a rapidly-growing, versatile field with the potential to impact various other fields with scientific knowledge. Two major areas of research involve identifying specific neuromarkers in the brain that correspond to learning and finding new techniques to improve the learning process in educational settings. Despite vast amounts of research, little focus has been directed towards developing new learning techniques in higher education and functionally localizing learning within the brain. With the recent use of online tools to support learning, a
need for further investigation regarding the impact Neuroscience can have on improving online instructional design and learning methods is needed.

**Introduction to Learning and Memory**

Learning is the process of acquiring new information, while memory is the ability to store and retrieve learned information (Cowan, 2008). Memory is crucial in learning as it allows for the application and expression of acquired information. Many different forms of learning exist, such as perceptual learning, associative learning, relational learning, declarative learning and procedural (skill) learning. Simultaneously, memory can be categorized into long-term and short-term memory. Short term memory is the capacity to store small amounts of information in a readily available state for a short period of time. In contrast, long-term memory is the storage of information for a long period of time (Cowan, 2008). Without intact long-term memory, learning is impossible. For example, patients suffering from injuries of the hippocampus, a specific brain region, can experience anterograde amnesia. They are unable to form new memories and learn new things (Kostic et al., 2015). Deficits in short-term memory also produces difficulties in learning and lower achievement in academic settings (Maehler & Schuchardt, 2016).

Perceptual learning occurs when experiences improve sensory systems’ response to stimuli, while associative and relational learning involve forming and understanding relationships between different stimuli (Watanabe & Sasaki, 2015; Le Pelley et al., 2016). Declarative and procedural learning create declarative and procedural memory, respectfully. Declarative memory is a type of long-term memory that comprises an individual’s ability to state facts. Procedural memory is type of long-term memory involving learned skills and actions (Csábi et al., 2016).
Neural Structures Involved in Learning & Memory

The neuroscience behind learning and memory has been widely investigated for decades. Scientific evidence shows that these processes are modulated on a cell and molecular level and a broader structural level. Long-term potentiation (LTP) is the strengthening of neuronal connections (i.e., synapses) caused by excitation patterns of activity (Nabavi et al., 2014). Neurotransmitter systems (e.g., glutamatergic, GABAergic and cholinergic systems) create the patterns of neural activity that modulate LTP. Neurotransmitter interactions with their receptors determines whether the patterns are excitatory or inhibitory. As a result, research supports the idea that many neurotransmitter systems interact to promote learning and memory (Myhrer, 2003).

Many studies related to learning and memory focus on the glutamatergic pathways, while very few focus their efforts on serotoninergic and norepinephrinergic pathways. This trend among research studies exists due to NMDA and AMPA receptors, which are glutamatergic receptors, primarily causing LTP. Studies using antagonists of both receptors show that NMDA plays an active role in acquisition (i.e., learning) and AMPA plays a crucial role in retrieval (i.e., pulling information out of long-term memory) (Myhrer, 2003).

Different types of memory are localized in different areas of the brain. Declarative memory primarily occurs in the medial temporal lobe and largely plays a role in processes that modulate memory (e.g., emotion, attention, and motivation) (Tyng et al., 2017). Deep within the medial temporal lobe is the basal ganglia and hippocampus. The dorsal striatum is a region of the basal ganglia shown to play a role in associative learning and formation of relationships, in addition to its motor-related functions (Packard & Knowlton, 2002). The hippocampus plays a role in declarative memory and spatial learning (Jarrard, 1993).
A recently investigated role of the hippocampus is the process of moving information from short-term memory to long-term memory (i.e., memory consolidation). The hippocampus serves as a fast-learning store for memory. During sleep, representations of memory originating in the hippocampus transform and integrate in the neocortical networks of the cerebral cortex, the slow-learning store for memory (Klinzing et al., 2019; Schapiro et al., 2019). This process represents memory consolidation. With time and repetition, the hippocampal representations fully integrate with the cortex and the information becomes a part of long-term memory. To use the information of a specific long-term memory, individuals are required to pull the information back into working memory through the process known as retrieval (Cowan, 2008; Klinzing et al., 2019).

**Neural Markers of Learning and Engagement**

Several neural markers of learning have been identified through significant research. Some examples include structural changes in the hippocampal volume, specific patterns of neural activation, an event-related potential (ERP) of preparatory attention (Murray et al., 2011; Oby et al., 2019; Supekar et al., 2013). While these findings have allowed for significant progression in visualizing the process of learning, there is still much confusion regarding where the learning process occurs within the cerebrum of the brain. Research shows that engagement is related to attention which positively influences information recall, a display of successful learning. Attention is the ability to actively process information in a selective manner (i.e., tuning out non-salient information), while engagement is the extent that an individual is willing to participate in a task (Rotgans and Schmidt, 2011; Le Pelley et al., 2016). As engagement increases, attention becomes increasingly selective, and information acquired during those periods can be recalled with higher accuracy and detail. Therefore, further investigation should
be conducted to see whether attentional networks active in high periods of engagement could predict the active learning (Bezdek et al., 2015, Bezdek et al., 2017; Szafir & Mutlu, 2012).

Recent research also focuses on emotion’s role in memory processing and its influence on learning. Emotions influence the type of information that is salient to an individual, which appropriately result in shifts in attention (Meneses & Liy-Salmeron, 2012). This shift in attention facilitates encoding (i.e., the process of converting information into a form that can be processed and stored in the brain) and improves retrieval of the information (Cowen, 2008). Emotion can enhance or impair long-term memory retention, consolidation and formation based on interactions occurring among the amygdala, prefrontal cortex, and the medial temporal lobe. Understanding the role of memory modulators, such as emotion, are crucial as many individuals are affected by these modulators daily. These modulators can influence the student performance in an academic setting, especially when taking exams, completing homework, and studying (Tyng et al., 2017).

Early Interventions for Improving Education

During the late-1800s, educational research developed from a realization sparked by issues resulting from institutional change. It presented the need for researchers focused on developing methods to promote intelligence and highlight advancements in education (Goodman & Grosvenor, 2009). Since then, many renowned educational researchers and psychologists developed instructional design models that served as the initial basis of many curriculum and course structures today. Two of the earliest, but well-developed models, include Robert M. Gagné’s Nine Events of Instruction and John Keller’s ARCS Model of Motivational Design. While Keller argued that educational design should be built on instilling and maintaining motivation, Gagné’s focus was on capturing attention and engaging the student (Gagné, 1965;
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Keller, 1987). Recent models of learning, such as Merrill’s Principles of Instruction and Bloom’s Taxonomy (revised), have attempted to incorporate neuroscience knowledge on learning, but since their development, there have been many advances in the neuroscience of learning (Simarmata et al., 2018).

Gagné’s Nine Events of Instruction are widely used today to capture the attention of a student and keep them engaged throughout instruction. These instructional events can be viewed as steps an instructor can take when teaching learning material. They encourage instructors to inform and guide through instruction and build in moments of practice and feedback from students. The goal of the instructional events is to provide a holistic method to improving meaningful learning within an educational setting (Gagné’s Nine Events of Instruction, n.d.). Each event can be further associated with a known cognitive process that describes the purpose and intended effect of the event (see Figure 1) (Woo et al., 2016).

**Figure 1. Gagné’s Nine Events of Instruction**

<table>
<thead>
<tr>
<th>Instructional event</th>
<th>Cognitive process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gaining attention</td>
<td>Reception</td>
</tr>
<tr>
<td>2. Informing learner of objectives</td>
<td>Expectancy</td>
</tr>
<tr>
<td>3. Stimulate recall of prior learning</td>
<td>Retrieval</td>
</tr>
<tr>
<td>4. Presenting stimulus</td>
<td>Selective perception</td>
</tr>
<tr>
<td>5. Providing learning guidance</td>
<td>Semantic encoding</td>
</tr>
<tr>
<td>6. Eliciting performance</td>
<td>Responding</td>
</tr>
<tr>
<td>7. Providing feedback</td>
<td>Reinforcement</td>
</tr>
<tr>
<td>8. Assessing performance</td>
<td>Retrieval</td>
</tr>
<tr>
<td>9. Enhancing retention and transfer</td>
<td>Generalization</td>
</tr>
</tbody>
</table>
This table presents Gagné’s Nine Events of Instruction and their correlated cognitive process, which represents the purpose of each event. Adapted from Woo et al., 2016.

Improving Online Education

Many studies have illustrated the current gap between education and neuroscience (i.e., the lack of translating the neural basis of learning and memory into teaching and instructional design) within the realm of online education (Wang et al., 2018; Jaggars & Xu, 2016; Hermida et al., 2015; Morris & Sah, 2016). They also implemented interventions, such as the ARCS Model of Motivation or an interdisciplinary curriculum, with the hope of improving students’ academic performance through activities that enhance their motivation or cognitive function (Karakis et al., 2016; Hermida et al., 2015). While some of these studies found that their interventions improved academic performance, most studies conveyed unclear methodologies or presented abstract findings questioning their reliability and reproducibility. For example, a study attempted to validate quality standards for online courses analyzed end-of-semester assessments in 23 online courses to develop a rubric for instructors to use when developing their online course. Missing from their article were the criteria of the created rubric or any information on whether the researchers validated their rubric (Jaggers & Xu, 2016). Other studies focused primarily on elementary education without much emphasis on whether their findings could be applicable for students in higher education (Karakis et al., 2016; Hermida et al., 2015). It is evident that there is substantial effort towards improving online teaching methods, but also a need for reliable and generalizable studies in this field.
Problem of Investigation

The current study investigates whether attentional brain networks identified in previous literature can predict learning in an online environment with the use of engagement measures, Gagné’s Nine Events of Instruction, and fMRI techniques. This study will be conducted using college students to provide further insight into improving instructional design in higher education. Additionally, it will help identify which elements of Gagné’s Nine Events of Instruction have the largest contribution towards successful learning. We hope to identify specific regions of the cerebrum involved in active learning processes, as well. Using these findings, we plan to assist in the modification of current Georgia Tech online instructional design to highlight elements that promote increased learning among college students.

Methodology

Participants

Ten participants (eight female, mean age of 19.8) were recruited from a pool of undergraduate students at the Georgia Institute of Technology. Participants were right-handed, neurologically intact and screened for their knowledge on Human Computer Interfaces (i.e. the topic of the videos used in this study). All participants completed the necessary MRI safety documentation and study consent forms. They were compensated using course credit. This protocol was approved by the Georgia Institute of Technology’s Institutional Review Board (IRB).

Materials and Methods

The study was conducted using a 3T Siemens MAGNETOM Trio MRI scanner. T1-weighted magnetization was utilized for structural scans (i.e., MRI images) and T2-weighted
echo-planner imaging sequences was used for functional scans (i.e., fMRI images). Fifty minutes of educational video excerpts on the topic of Human Computer Interfaces (HCI) were used in the MRI and engagement portions of the study. This topic was chosen based on participant trends seen in previous studies in the lab. Most participants come from an undergraduate background and would be unlikely to know the graduate level information presented in the HCI course. The educational excerpts were divided into short segments and marked by the nine events in Gagné’s Nine Events of Instruction. All excerpts are currently in use by the Georgia Tech Professional Education department as part of Georgia Tech’s Introductory to Human Computer Interfaces course. Two memory assessments were developed and administered through Qualtrics, and a Pre-Test Survey on Human Computer Interfaces was created for the participant to complete. MRI safety forms required by the Center for Advanced Brain Imaging (CABI) at Georgia Tech and Georgia State University were also used. PsychoPy was used in the development of the stimuli.

**Procedure**

This study incorporates two sessions that are conducted one week apart for each participant. The first session of the study (Session 1) assesses the participant’s average engagement using fMRI techniques and memory of the material presented in the videos. This portion of the study is conducted during the morning and evening times and is heavily dependent on MRI availability within the research facility. The second session of the study (Session 2) assesses the participant’s ability to retrieve information learned during Session 1 and their instantaneous engagement when re-watching the videos. This portion of the study is usually conducted in the evening due to the limited availability of the participants.
Assessing Engagement

During Session 1, whole-brain MRI scans of each participant were acquired while monitoring their level of engagement of the educational videos. They were provided a straight 4-button fiber optic controller for their right hand and instructed after each video to indicate their average level of engagement over the video they previously watched (Figure 2). On average, each video’s length was approximately five minutes. Before beginning the experiment, a structural scan of the participant was taken. Afterwards, the screen projector within the MRI was turned on so the participants can view the educational excerpts and the stimuli associated with the excerpts. Instructions provided onscreen were read to the participant using the microphone panel in the MRI suite.

Figure 2. Session 1 Engagement Rating Visualization

This diagram depicts what the participant sees while in the MRI. After being shown a short video with content, participants were asked to indicate their average level of engagement on a scale from one (not at all engaging) to four (very engaging).

During Session 2, participants re-watched all the videos using a computer interface. They were instructed to use the computers’ mouse to provide engagement ratings instantaneously while viewing the videos. Definitions for engagement were provided to ensure standardization
among participants at the start of the session (Figure 3). In between each educational video, participants were reminded to indicate their engagement while re-watching (Figure 4).

**Figure 3. Session 2 Definition of Engagement**

The statements above are provided to participants at the start of Session 2 to help standardize participant’s definition of engagement. Example-like statements are provided to help participants comprehend what engagement means.

**Figure 4. Session 2 Engagement Rating Visualization**

This diagram presents what the participant sees while re-watching the videos in Session 2. Their current instantaneous rating is located at the bottom right corner and changes as they use the
mouse. Between each video, the participant is reminded to provide instantaneous engagement ratings while viewing the videos.

**Assessing Memory and Retrieval**

After viewing and rating the educational videos’ engagement in Session 1, participants were escorted to a lab computer to complete a memory assessment using the Qualtrics programing system. This multiple-choice assessment consisted of 46 questions regarding the information presented in the educational videos. A similar assessment was provided to participants during Session 2 before re-watching the educational videos. This assessment consisted of the same 46 multiple choice questions provided in the Session 2 memory assessment, with two additional free response questions. The multiple-choice questions were provided in the same order; however, the order of answer choices was changed using a randomization function.

**Data Analysis**

The fMRI data collected underwent a preprocessing stage before being compared to data collected from the assessments and re-watching of the educational videos. The purpose of preprocessing is to transform raw fMRI data into a standardized format with reduced noise and artifacts ideal for data analysis (Park et al., 2019). During preprocessing, several aspects of the fMRI data were corrected: distortion correction, slice timing correction, and motion correction. The MRI scanner has a low temporal and spatial resolution meaning that it is unable to take high quality images quickly. Therefore, during the MRI scan, brain scans are obtained one at a time and are offset by several seconds. Additionally, the images obtained are unclear and distorted. Because of these characteristics of MRI and fMRI data, correction is required. Spatial smoothing
is also incorporated into the preprocessing. This correction improves the signal-to-noise ratio (fMRI Data Preprocessing, n.d.). Once preprocessing is completed, individual-level and group-level General Linear Model (GLM) contrasts, an analysis approach to separating stimuli from noise fMRI signal, were developed (fMRI Data Preprocessing, n.d.). From this, trends of activity in different areas of the brain were identified from the fMRI data. Additionally, the data was analyzed using Spyder to evaluate the relationships between fMRI data and memory assessment data. The following relationships were investigated: engagement and memory, Gagné’s Nine Events of Instruction and engagement, and data from this study with previous similar studies in the past.

Results

fMRI Evidence of Engagement

Whole-brain analysis revealed changes in specific regions of the brain in response to increased engagement. Brain areas of primary interest include calcarine sulcus, posterior cingulate cortex, inferior parietal lobule, occipitotemporal cortex, hippocampus, temporoparietal cortex and ventral frontal cortex (Bezdek et al., 2015, Vossel et al., 2014). These areas were identified as potential regions of interest as they experienced changes in neural activity in a previous study conducted in the lab. The previous study investigated the relationship between viewing emotional content, engagement and memory (i.e. Bezdek et al., 2015). fMRI data obtained in this current study depicted increased activation of the occipitotemporal cortex and ventral attention network (Figure 5), which is comprised of the temporoparietal cortex and the central frontal cortex (Vossel et al., 2014). Engagement ratings that followed videos where the
ventral attention network was highly activated indicated higher engagement of the participants. Some activation was also seen in other areas of the frontal cortex (Figure 6).

**Figure 5. Activation of Occipitotemporal Cortex and Ventral Attention Network**

*Increased activation (warm colors) of the temporoparietal junction (cortex) and anterior insula can be seen on the lateral view of the right hemisphere. This finding is indicative of increased activation of the ventral attention network. Increased activation of the occipitotemporal cortex is seen on the medial view of the brain on both hemispheres.*
Increasing engagement has been shown to improve cognitive performance, particularly in the memory and retrieval domains. A study by Buckner et al. (2013) demonstrated that increased engagement in educational videos is correlated with decreased activity in the default mode network, especially in the medial prefrontal cortex, posterior cingulate cortex, and inferior parietal lobe. This is evidenced by fMRI findings, which show a decrease in activity in these areas when individuals correctly answer questions on memory assessments, as opposed to when they answer incorrectly. No hippocampal activity was identified in this context (Figure 7).
**Figure 7. Default Mode Network Activity During Correct Answers**

The data presented in this figure represent brain activity during educational content that participants correctly answered questions about in the memory assessments. Decreased activation (cool colors) is seen in the medial prefrontal cortex and posterior cingulate cortex is indicative of a decrease in the default mode network activity. Additionally, no hippocampal activity was identified.

**Changes in Engagement and Activity During Gagné’s Nine Events of Instruction**

Seven out of nine Gagné’s Nine Events of Instruction were identified in the videos used in the study. Out of the seven identified, the utilization of three events (Events 5, 6, and 7) by the instructor resulted in consistent increase in engagement (Figure 8). When using Gagné’s first event in instruction, an increase in activity within the primary visual and auditory processing regions were identified (Figure 9). Visual processing activity was also identified during utilization of the third event. Reduced activity in the medial frontal regions (i.e., which is part of the default mode network) was depicted when using the third and fourth events (Figure 10).
Figure 8. Average Change in Instantaneous Engagement Ratings

The data presented in this scatterplot reflect the average change in engagement ratings during each event of Gagné’s Nine Events of Instruction during Session 2. Each of the ten participants are represented by a blue dot. Dots above the dashed line indicate an increase in engagement during the presentation of that specific Gagné event. During the presentation of Events 5 and 7 in the educational videos, all of participants indicated an increase in engagement. 90% of participants indicated an increase in engagement during the presentation of Event 6.
**Figure 9.** Activation of Primary Visual and Auditory Processing Brain Regions

Greater activation (warm colors) of the primary visual processing regions and temporal cortex is depicted by the increased activity seen in the lateral view of both hemispheres of the brain. Increased activation of the temporal cortex is indicative of auditory processing. These trends are similar to those seen in Bezdek et al., 2015 and indicate narrowing of attention (i.e., an increase in selective attention).

**Figure 10.** Reduced Activity of the Default Mode Network
A medial view of the brain is presented for Events 3 and 4 for Gagné’s Nine Events of Instruction. A decrease in activity (cool colors) in the medial frontal cortex is indicative of a decrease in the default mode network. This finding is also indicative of narrowing of attention (i.e., an increase in selective attention).

Discussion

This study is an extension of two previously conducted studies in the lab that show how narrative suspense via audiovisual narratives results in increased selective attention and memory encoding. Researchers of these studies found that increasing narrative suspense reduced activity in the peripheral visual processing regions and in the default mode network (Bezdek et al., 2015). The default mode network is one of the two sensory-oriented systems in the brain that is active when an individual is participating in introspection or mind-wandering (Li et al., 2014). The structures that make up this network include medial prefrontal cortex, posterior cingulate cortex, and inferior parietal lobe (Buckner et al., 2013). They also identified increased activity in the central and dynamic visual processing regions, as well as in the frontal and parietal regions recruited for attention (Bezdek et al., 2015). Regarding memory encoding, they identified increased activity in the occipital, parietal, and parahippocampal regions, and decreased activity in the lateral temporal cortices (Bezdek et al., 2017).

fMRI Evidence of Engagement

The current study aimed to identify whether similar patterns of brain activity identified in the previous studies were seen when participants were presented with educational content. It was found that some patterns were present, such as increased activation of the occipitotemporal cortex and the ventral attention network and decreased activation of the default mode network,
and new patterns emerged. The replicated activation patterns are critical as it shows participants being attentive during specific times while watching educational videos. It also validates the data collected as increased activation in occipitotemporal cortex is expected when participants watch and listen to the information presented in the video.

The occipitotemporal cortex is a region of the brain responsible for recognizing visual patterns and rapidly identifying different word forms (e.g., nouns, verbs, adjectives) (Lerma-Usabiaga et al., 2018). Therefore, seeing activity in this region is indicative that the fMRI machine and data analysis tools used are working correctly. The ventral attention network is the other sensory-oriented system in the brain composed of the temporoparietal cortex and the central frontal cortex. It primarily functions to reorient an organism’s attention towards salient, or noticeable, stimuli (Vossel et al., 2014). Activation of the ventral attention network indicates that participants have redirected their attention to information salient to them. This finding, when complemented by a decrease in the default mode network that was also simultaneously observed in the current study, replicates the result found in the previous studies conducted. This means that the default mode network and the ventral attention network can be used to identify changes in engagement for educational content, as well. A limitation of this finding is that the results of this study only consider ten participants, while the previous study had a total of 19 participants. With increased data collection, which is ongoing, many of the current patterns identified may change.

Some activation was also seen in frontal cortex of the participants in this study (Figure 6), but there was no activation of this region present in Bezdek et al., 2017 (Figure 11). Activation of this brain region could be indicative of an increase in working memory capacity when watching the educational videos (D’Ardenne et al., 2012). Working memory is a type of short-
term memory that plays a role in consolidating information into long-term memory. Information in working memory can easily be used in the execution of cognitive tasks, such as making decisions and reasoning through a problem (Cowen, 2008). Since working memory has a limited capacity, increasing its capacity allows for more information to be easily recalled and used when taking an assessment.

**Figure 11. Areas of Activation During Memory Encoding**

![Figure 11. Areas of Activation During Memory Encoding](image)

This is a figure from Bezdek et al., 2017 depicting changes in activity during memory encoding. Within this previous study, changes in activity were identified in the superior temporal gyrus (STG), occipital gyrus (OG), parahippocampal gyrus (PHG), superior parietal lobe (SPL), supramarginal gyrus (SMG) and occipitotemporal cortex (OT). Activation of the frontal cortex is not present unlike the results found in the current study.

**Engagement’s Role in Memory and Retrieval**

The pattern of activity seen in the default mode network (i.e., less activity present during content that questions were answered correctly) in comparison to the results of the memory tests...
support the findings regarding engagement. Less activity in the default mode network is indicative of less mind-wandering and corresponds with an increase in the ventral attention network. This means that increased attention was present during content that was answered correctly (Buckner, 2013). This finding validates a key concept regarding attention and memory: memory recall tends to be higher of moments with high attentional focus (Bezdek et al., 2017).

Although no significant hippocampal activity was identified in the current study, hippocampal activity was expected as it plays a role in memory consolidation and can predict whether information will be brought back into working memory for recall purposes (Baldassano et al., 2017; Jarrard, 1993). A possible reason for the lack of hippocampal activity could be because the data collected represents the brain’s activity during the educational videos and did not consider changes in brain activity after the educational videos were completed. Hippocampal activity is shown to be high following an event (e.g., an educational video) rather during an event. Future changes in data collection to include collecting data at the end of the can provide further insight into whether there are any neural markers of the process of learning (Baldassano et al., 2017).

**Changes in Engagement and Activity During Gagné’s Nine Events of Instruction**

A primary purpose of this study was to identify potential events from Gagné’s Nine Events of Instruction that can be the most effective in promoting learning in an online setting. With findings from this study showing increased engagement and attention while viewing portions of the educational videos and increased attention improving memory recall, inferences regarding effective events from Gagné’s Nine Events of Instruction can be drawn (Hodges, 2020; Kim, 2012; Morris & Sah, 2016). Educational videos depicting Gagné’s Events 5, 6 and 7 were shown to have consistent increase in their engagement (Figure 1; Figure 8). The events with the
most increase change in engagement were centered around guidance, practice, and feedback from the instructor, which can be more active and meaningful to the participant when compared to the previous four Gagné’s events. The active aspect to these events likely contributes towards the higher engagement seen during portions of the educational videos utilizing these events (Hodges, 2020).

There are several limitations to these findings. While there are a total of nine events to Gagné’s educational design, only the first seven were present in the videos shown to participants. As a result, it is not known how Gagné’s Events 8 and 9 would change engagement and whether the changes they elicit differ from the changes in engagement seen in Gagné’s Events 5, 6 and 7. Additionally, each of the seven events used were not equally represented within the educational video content presented. For example, some events occurred more times than others. This could lead to results that are not fully representative of the impact each event can have on the engagement of participants.

Conclusions

The findings of this study replicated previous results found regarding the relationship between attention, engagement, and memory. Viewing engaging educational videos resulted in an increase of selective attention and likelihood of correctly recalling information. Further, it expands the field of Neuroeducation by providing insight into which potential events of Gagné’s Nine Events of Instruction influence successful online learning the most. A future direction of this study can involve investigating how individual learning differences, such as academic ability and achievement levels, may affect successful online learning. This study supports that further use of neuroscience principles in the field of education can be extremely beneficial in optimizing learning for students and ensuring greater academic success.
References


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# LMC 4701 Research Work Plan for Fall 2021-Spring 2022

## Name
Ritika Chanda
- **Project Title**: Watching Instructional Videos
- **Advisor**: Dr. Eric Schumacher

### Topic:
- **Question**: Can attentional brain networks related to Gagne’s Nine Events and engagement predict learning in an online setting?
- **Purpose**: To use fMRI techniques to characterize and identify successful online learning strategies

### Goals Behind the Tasks:
- Complete all course assignments on time
- Be able to collect enough data to have a large enough power
- Determine which statistical methods would be ideal measures for the study
- Be able to provide many slots of potential participants interested in the study
- Run data analysis and draw conclusions for the next follow up study

### Task Title
- **Literature Search & Proposal Writing**
- **Data Collection**
- **Data Analysis and Thesis Writing**

### Priority Key
- **High**: Main focus at that time
- **Medium**: Make sure to be working on the task at this time
- **Low**: Begin working on the task or thinking about the task

### Approval
- **Advisor**

### Task Description

<table>
<thead>
<tr>
<th>Task Title</th>
<th>Completed</th>
<th>Fall 2021</th>
<th>Spring 2022</th>
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<tbody>
<tr>
<td><strong>Literature Search &amp; Proposal Writing</strong></td>
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<tr>
<td>Review the literature search conducted at the start of the project (Summer 2019) to determine sources that are still relevant</td>
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<tr>
<td>Conduct a revised literature search based on the project changes since Summer 2019 and feedback given by advisor and Tiffany</td>
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<td>Present literature search to advisor and Tiffany for feedback</td>
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<tr>
<td>Work on developing an annotated bibliography for LMC 4701 and submit by due date</td>
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<tr>
<td>Work on writing a literature review for LMC 4701 and submit by due date</td>
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<td>Work on writing an introduction for the proposal for LMC 4701 and submit by due date</td>
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<td>Create a presentation about the research project for LMC 4701 and submit it by the due date</td>
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<td>Finish writing the research proposal for LMC 4701 and submit to the course instructor (Dr. Hoffman) and the UROP by the due date</td>
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<tr>
<td><strong>Data Collection</strong></td>
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<tr>
<td>Reviewing the Experimenter’s instructions and working with the Tiffany to learn how to run participants</td>
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<td>Recruiting new Research Assistants (RAs) for the study</td>
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<td>Onboarding and training the new RAs involved in the study and obtaining their availability to run participants</td>
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<td>Learning how to use the fMRI scheduling system and determining the fMRI availability</td>
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<td>Adding time slots on SONA for participants to sign up to participate in the study</td>
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<td>Advertising for the study within Georgia Tech to obtain participants</td>
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<td>Conduct both parts of the study with 20+ participants</td>
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<td>Export memory related Qualtrics data and behavioral data from PsychoPy and share it with the lab for preliminary data analysis</td>
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<td>Evaluate protocol and make changes where necessary</td>
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<tr>
<td><strong>Data Analysis and Thesis Writing</strong></td>
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<td>Work with Matt to learn how to conduct data analysis with Tiffany and Jenna</td>
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<td>Run data analysis using the findings from the preliminary analysis and advisor feedback</td>
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<td>Present data analysis to advisor and Tiffany for feedback and review</td>
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<tr>
<td>Work on drafting research thesis 1 for LMC 4702 and submitting it by due date</td>
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<tr>
<td>Work on drafting research thesis 2 for LMC 4702 and submitting it by due date</td>
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<tr>
<td>Review Final Thesis Draft with advisor, second reader and Tiffany for feedback</td>
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<td>Make edits to the research thesis for LMC 4702 and submit it by due date to course instructor and UROP</td>
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<td>Create a final research thesis presentation for LMC 4702 and submit it by the due date</td>
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