

# Cognitive Insights: Exploring the Influence of Segmented Documentary Videos on Students' Brain Activity during Encoding and Retrieval of Information

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## Abstract

In contemporary education, documentary videos have gained widespread usage as powerful tools for teaching and learning, even though many of these videos were originally produced for television audiences. The use of these documentary videos in an educational environment may affect students' multimedia mental effort in the left dorsolateral prefrontal cortex during semantic information retrieval. Although many studies used the segmenting principle in multimedia learning, there were limited studies that utilized documentaries. This study employed a true experimental design, collecting electroencephalogram (EEG) data from 16 participants in the experimental group and 16 participants in the control group. Data analysis involved a one-way ANOVA to examine the statistical significance of the findings. The results revealed no statistically significant difference in the amount of multimedia mental effort used during semantic information retrieval ( $p = 0.431$ ,  $\eta_p^2 = 0.021$ ). However, there was a statistically significant difference for the overall intrinsic processing generated ( $p < 0.001$ ,  $\eta_p^2 = 0.353$ ) and students' performance ( $p < 0.001$ ,  $\eta_p^2 = 0.560$ ). Our findings shed light on the inherent relationship between cognitive load management and multimedia mental effort. Consequently, this study highlights the need to carefully assess the complex effects of cognitive load management strategies, as an increase in intrinsic processing seems to impede the formation of schemas in long-term memory, ultimately reducing semantic information retrieval.

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## Keywords

Cognitive Load, Segmented Documentary Videos, Left Dorsolateral Prefrontal Cortex, Memory Retrieval, Multimedia Learning

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## 1. Introduction

Documentary videos have become an integral part of the contemporary teaching and learning landscape (Russell, 2012; Frank, 2013; Kruger & Doherty, 2016; Azor et al., 2020; Wijewantha, 2021; Maskun et al., 2021; Gampala, 2023), with some originally designed for television audiences. The integration of such documentary videos into educational settings can potentially influence students' cognitive processes, particularly within the left dorsolateral prefrontal cortex during encoding and retrieval of semantic information (Blumenfeld & Ranganath, 2006; Plaza et al., 2007; Klaus & Schutter, 2018; Hertrich et al., 2021). This is due to the high intrinsic cognitive load associated with these multimedia resources. To address this challenge, educators often employ the instructional strategy of segmenting, which involves dividing information into manageable segments rather than presenting it as a whole (Mayer, 2009; Castro-Alonso et al., 2019; Castro-Alonso et al., 2021). Additionally, electroencephalography (EEG) has been used in many studies (Babu et al., 2022; Fraser, 2021; Sarailoo et al., 2022) because of its sensitivity and reliability for capturing the electrical signal of the brain. It is also an objective method for measuring cognitive load (Antonenko & Keil, 2017; Tiwari et al., 2023). However, EEG is a promising method for exploring the measurement of mental effort (Zhu et al., 2021). It has been proven to be a reliable and valid method of measurement (Zarjam et al., 2015; Di Flumeri et al., 2019; Medeiros et al., 2021).

While numerous studies have explored the effectiveness of the segmenting principle in multimedia learning (Mayer & Chandler, 2001; Spanjers et al., 2011; Mayer, 2017; Wang et al., 2023), there is a notable absence of research in the Caribbean region that employs electroencephalogram (EEG) technology to investigate the impact of integrated segmented documentary videos on the left dorsolateral prefrontal cortex during semantic information retrieval. This study shows that segmenting documentary videos allow better management of intrinsic processing but does not affect multimedia mental effort during generative processing.

The primary purpose of this study was to investigate the influence of segmented documentary videos on students' cognitive processes during memory encoding and retrieval. Specifically, we aim to explore the effects of cognitive load management strategies in the form of segmenting principle on documentary videos during brain activity, with a focus on the left dorsolateral prefrontal cortex. By examining how these strategies impact memory encoding and retrieval, our research seeks to provide valuable insights into optimizing multimedia learning environments and enhancing pedagogical practices for improved edu-

cational outcomes. The following three research questions set the parameters for this study:

1) How does the implementation of cognitive load management techniques in documentary videos influence the level of multimedia mental effort exerted by students in their working memory?

2) How does the implementation of cognitive load management techniques in documentary videos influence the retrieval of semantic information from students' long-term memory?

3) How does the implementation of cognitive load management techniques in documentary videos influence the intrinsic processing in students' working memory?

## 2. Literature Review

### 2.1. Working Memory System

Studies suggest that cognitive load management is partly dependent on the instructor's ability to manage intrinsic and extraneous loads in multimedia presentations. When these loads are properly managed by the instructor, the learner can better manage the internal processing of the working memory system. The working memory system is essential for learning semantic information in education (Ozfidan, 2021; Hu & Hu, 2023).

Working memory systems involve the selection, maintenance, monitoring, and manipulation of stimuli in the prefrontal cortex (Baddeley, 1998; Petrides, 1996; Masse et al., 2018; Funahashi, 2022). The ventrolateral prefrontal cortex is responsible for selecting, maintaining and monitoring (Nyhus & Badre, 2015) whereas the dorsolateral prefrontal cortex is responsible for monitoring and manipulation (Funahashi et al., 2004; Barbey et al., 2013; Funahashi, 2022). Additionally, the rostrolateral prefrontal cortex is responsible for determining which stimulus should be selected (Blumenfeld & Ranganath, 2017). However, the left dorsolateral prefrontal cortex is necessary for semantic memory manipulation whereas the right dorsolateral prefrontal cortex is associated with spatial manipulation (Barbey et al., 2013).

To determine the multimedia mental effort required during semantic information retrieval, EEG measurements must be obtained from the left dorsolateral prefrontal cortex, which is responsible for monitoring and manipulating stimuli. Increased alpha power was measured to determine the required amount of multimedia mental effort for semantic information retrieval. However, some studies have shown that increased alpha power was associated with multimedia mental load (Jensen et al., 2002; Antonenko et al., 2010; Qayyum et al., 2018), while others suggest that alpha power decreases with increased mental effort and mental load (Gevins et al., 1997; Gevins & Smith, 2000).

### 2.2. Cognitive Load Theory

A study conducted by Sweller (1988) concluded that an increase in cognitive load limits the schema development in long-term memory, introducing the con-

cept of cognitive load theory to the field of educational design. Although the concept of cognitive load has been used in instructional design by other researchers at that time (Gagné & Briggs, 1979; Reigeluth & Darwazeh, 1982; Hannum & Briggs, 1982; Gagné, 1985; Reigeluth, 1987; Gagné & Driscoll, 1988), Moreno (2010) stated that cognitive load theory “predicts that overload (and lack of learning) occurs when the total amount of load induced by the learning environment exceeds the maximum cognitive capacity of the learner” (p. 137). Many researchers share Moreno’s (2010) point of view on cognitive load theory (Young et al., 2014; Leppink, 2020; Zhao, 2023; Lopez, 2024).

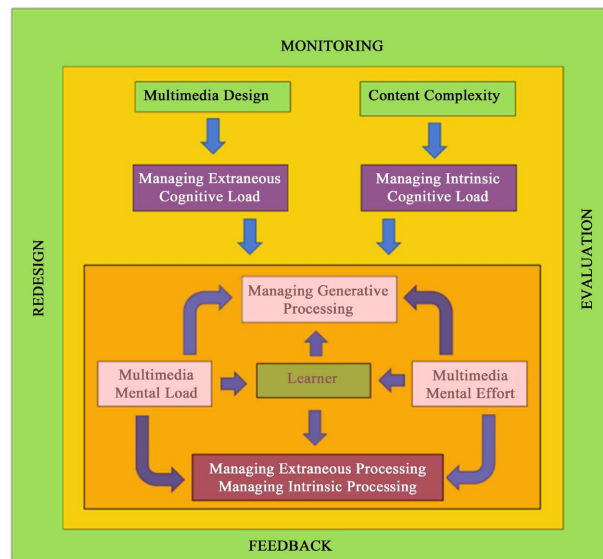
Three types of loads are identified in cognitive load theory (Sweller, 1993; Sweller et al., 1998): intrinsic cognitive load, extraneous cognitive load and germane cognitive load (Leppink, 2020). Mental load and mental effort are also related to cognitive load theory (Kirschner, 2002; Schnaubert & Schneider, 2022). Intrinsic cognitive load pertains to the complexity of the content to be learnt (Kumar & Kumar, 2016) and can increase intrinsic processing in the learner’s working memory if not managed effectively. Extraneous cognitive load is associated with poorly designed multimedia presentations (Sweller, 2016), which increases extraneous processing in the learner’s working memory if not managed effectively.

Additionally, in a review paper entitled “Cognitive Architecture and Instructional Design” by Sweller et al. (1998) stated that “germane cognitive load reflects the effort that contributes to the construction of schemas”. However, load and element are distinct elements. Effort is exerted by an individual, while load is experienced by an individual (De Jong, 2010). Intrinsic and extraneous cognitive loads are external to the learner. The working memory system experiences multimedia mental load when the learner interacts with the multimedia instructional material. Cognitive effort is internal to the learner. Multimedia mental effort is exerted by the learner to manage the multimedia mental load experienced in the creation of schemas through generative processing.

Therefore, in a multimedia presentation, cognitive load refers to the cognitive loads experienced due to the multimedia instructional message. The intrinsic and extraneous cognitive load stemming from the multimedia instructional message induces intrinsic and extraneous processing in the working memory system. Moreover, multimedia mental load encompasses the intrinsic and extraneous demands imposed on the working memory system by a multimedia instructional message.

Conversely, the management of intrinsic and extraneous processing falls to the cognitive effort of the long-term memory network. Therefore, cognitive effort represents the generative cognitive exertion by the long-term memory network to regulate intrinsic and extraneous processing within the working memory system, facilitating the formation of schemas relevant to a multimedia instructional message. Additionally, multimedia mental effort represents the exertion by the executive function to regulate intrinsic and extraneous processing within the working memory system prompted by a multimedia instructional

message. Consequently, germane cognitive load is replaced by generative cognitive effort. These elements are intertwined with semantic memory. A graphical representation of the cognitive load management framework for multimedia learning was created for this study as shown in **Figure 1**.



**Figure 1.** The cognitive load management framework for multimedia learning as it relates to the different associated loads and processes.

**Figure 1** illustrates the instructor's role in overseeing both the extraneous load in the multimedia design and intrinsic load of the content. As the learners engage with the multimedia presentation, they encounter multimedia mental load within their working memory system. To manage this load, the learner exerts multimedia mental effort. Moreover, the learner's working memory system handles both extraneous and intrinsic processing. This impacts the level of schema development and automation achieved through generative processing in long-term memory. It is important for the instructor to monitor and evaluate the entire process. By applying the principles of multimedia learning, intrinsic and extraneous loads can be more effectively managed through the redesign of multimedia instructional messages, guided by feedback from the monitoring and evaluation processes.

### 2.3. Segmenting Principle

The principle of multimedia learning (Mayer, 2009) evolved from the cognitive theory of multimedia learning, rooted in constructivism (Piaget, 1952), dual coding theory (Paivio, 1986) and cognitive load theory (Sweller, 1988). The segmenting principle is one of the principles of multimedia learning (Castro-Alonso et al., 2019). This principle suggests that "People learn better when a multimedia message is presented in user-paced segments rather than as a continuous unit" (Mayer, 2009: p. 175). Creating educational videos based on this

principle aids in better managing intrinsic processing in the working memory system of the learner.

In a study conducted by Wang et al. (2023: Experiment 2), students exhibited improved performance on retention and transfer tests when segmented videos were used with formative assessment during pauses, as opposed to continuous videos. These findings are further supported by research (Mayer & Chandler, 2001: Experiment 2; Spanjers et al., 2010; Mayer, 2017; Afify, 2020). Segmented educational videos enhanced the management of intrinsic processing in the working memory system, fostering schema construction during generative processing. However, it is worth noting that the implementation of the segmenting principle may vary for novice and expert learners (Greer et al., 2013; Castro-Alonso et al., 2021).

### 3. Method

#### 3.1. Theoretical Framework

The theoretical framework of the study is informed by Sweller et al. (1998), whose Cognitive Load Theory provides a comprehensive framework for understanding cognitive processes involved in learning and the management of cognitive load to enhance learning outcomes. Key components of the Cognitive Load Theory include intrinsic cognitive load, extraneous cognitive load, generative cognitive effort and working memory.

#### 3.2. Participants and Design

The participants were 38 students (21 males and 17 females). However, six of the participants' EEG data were corrupted (three males and three females); therefore, the total number of participants analyzed in the study was 32 students (18 males and 14 females), aged 14 to 18 years. These students scored 30% and under in the Secondary Entrance Examination (SEA) and were placed in the North-eastern Educational District secondary schools. Additionally, they continued to score 30% and under throughout Form One to Form Three. These students were selected based on the Form Three Theatre Arts Curriculum, which outlined several cultural art forms. The documentary used in the study highlighted one of those cultural art forms.

A true experimental design was employed in this study. Multistage sampling with stratification was used by stratifying Trinidad and Tobago schools in the North-eastern Educational District according to size. Form three students who scored 30% and under for the academic year were chosen for further stratification according to gender. A simple random sample was then used to select participants from the different strata, where they were randomly assigned to a control group and an experimental group. The sample size was calculated based on a priori power analysis using the effect size, statistical power and significant level from previous research in cognitive theory of multimedia learning. Consent was obtained from both the parents of the participants and the participants. Approv-

al was granted by The Ministry of Education (MOE) and The University's Institutional Review Board (IRB).

### 3.3. Materials and Procedure

The participants were randomly assigned to two groups: 16 participants in the control group interacting with the entire documentary video and 16 participants in the experimental group interacting with the integrated segmented documentary videos. Information about the experiment and materials used was discussed in a meeting with each participant and their parents before accepting to be a part of the study. Once satisfied with the information presented, the parents were asked to sign a consent form for their child to participate in the study and participants were asked to sign an assent form. Each participant was assigned a time to visit the X Secondary School Audio-Visual Library for the study. When the participants arrived at X Secondary School, they were taken to the audio-visual library with their parents. Participants were briefed about the experiment in the Audio-Visual Library before the start of the experiment.

The EPOC felt sensors were placed in a bowl and soaked in warm saline solution. The saline solution was created by mixing two teaspoons of table salt in 250 ml of hot water. The solution was left to cool and only warmed before use. The EPOC felt sensors were removed from the bowl filled with the saline solution and inserted into the Emotiv EPOC X. There were two computers situated close to each other, one for the participants to take part in the experiment and the other for the researcher to monitor the EEG activity. The participant was asked to sit by the computer and the Emotiv EPOC X was placed on the participant's head according to the 10 - 20 international system of electrode placement. The researcher monitored the participant's brain activity, using the Emotiv PRO software for proper signals. Once proper signals were received from the Emotiv EPOC X, the baseline was set.

The screen of the participant's computer was recorded using Microsoft PowerPoint screen recording feature. This gave the researcher the ability to review the participant's activity and have documented evidence of the activity performed by the participant. The researcher's computer screen was recorded using the QuickTime Pro screen recorder feature. The researcher could review the participant's brain activity and provide documented evidence that the brain activity was captured from the participant. The entire experiment was recorded using a video camera set up behind the participant and the researcher. This was documented evidence that the study was conducted. The participants' faces were not captured in the video recording. The full anonymity of the participants was maintained.

The pre-assessment, post-assessment, questionnaire and documentary videos were stored in the P Cloud software, which functions as a server. These contents were linked to a website where a pass code was required to log into the activity. The participant completed the pre-assessment which had 10 fill-in-the-blanks questions to assess the knowledge of the participants before interacting with the

documentary videos. This ensured that questions answered correctly by the participants were not used in the post-assessment as part of the statistical analysis. This was conducted to maintain the integrity of the research. The participants then looked at the documentary videos.

Participants in the control group interacted with the entire documentary video and participants in the experimental group interacted with the integrated segmented documentary videos. The entire documentary video used for the control group was played from beginning to end, while the integrated segmented documentary videos had five elemental parts with interactive features, formative assessment, summative assessment and the participants were allowed to learn at their own pace. The post-assessment was completed after the participants interacted with the documentary videos.

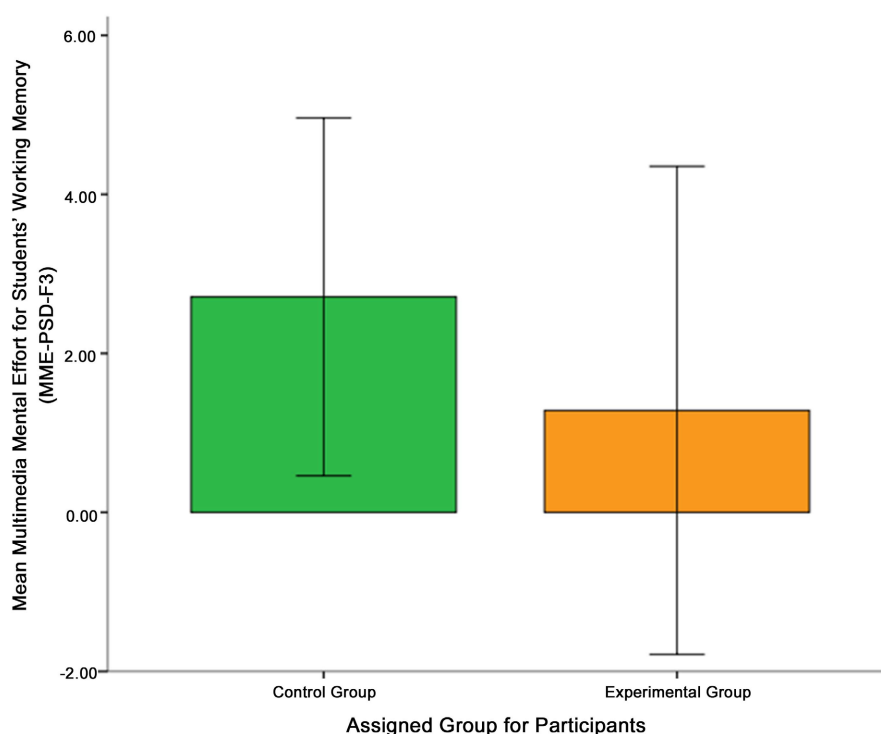
The post-assessment included five multiple-choice questions and five true/false questions. The post-assessment questions were the same as those used in the pre-assessment. The questionnaire was the final activity to be completed. The first section of the questionnaire comprised 11 questions that elicited personal data from the participants. This provided insight into the socioeconomic background of the participants. The second section used a subjective rating scale, which consisted of numerical rating from one to nine. This was used to collect data on multimedia mental effort, semantic information retrieval and multimedia intrinsic processing from the participants after the completion of the lesson. All recordings were stopped and backed up on a password protected hard drive. The EEG data from the Emotiv PRO were also downloaded and backed up on the hard drive.

## 4. Results

One-way ANOVA was applied to statistically analyze the data. The participants were 38 students (21 males and 17 females). However, six of the participants' EEG data were corrupted (3 males and 3 females), therefore the total number of participants analyzed in the study was 32 students (18 males and 14 females). Dependent variables being examined were semantic information retrieval from semantic memory, multimedia mental effort used during semantic information retrieval, overall multimedia mental effort used during encoding of semantic information and intrinsic processing generated in the brain during semantic information encoding.

**Figure 2** shows the mean multimedia mental effort of students' working memory associated with power spectral density (MME-PSD-F3) for the control group and experimental group using standard deviation error bars. The use of segmented documentary videos had an insignificant influence on the multimedia mental effort used during semantic information retrieval from semantic memory related to the power spectral density of the left dorsolateral prefrontal cortex within a control group and an experimental group. The results demonstrated that there was no statistically significant difference between groups as determined by one-way ANOVA  $F(1, 30) = [0.638]$ ,  $p = 0.431$ ,  $\eta_p^2 = 0.021$ .

The control group had a mean of 5.63 and a standard deviation of 1.857, while the experimental group had a mean of 7.06 and a standard deviation of 1.731. Therefore, practically a similar amount of multimedia mental effort is required to retrieve semantic information from long-term memory when integrated segmented documentary videos and an entire documentary video are used in the learning environment.



**Figure 2.** Mean multimedia mental effort of students' working memory (MME-PSD-F3) for the control group and experimental group. *Note.* The multimedia mental effort of students' working memory (MME-PSD-F3) as it relates to the power spectral density of the left dorsolateral prefrontal cortex (ldlpcf-F3).

Additionally, similar results were revealed for the overall multimedia mental effort in students' working memory during encoding of semantic information related to a subjective rating scale (MME-SRS) as shown in **Table 1** below.

**Table 1.** Results for multimedia mental effort used during retrieval and encoding for semantic information.

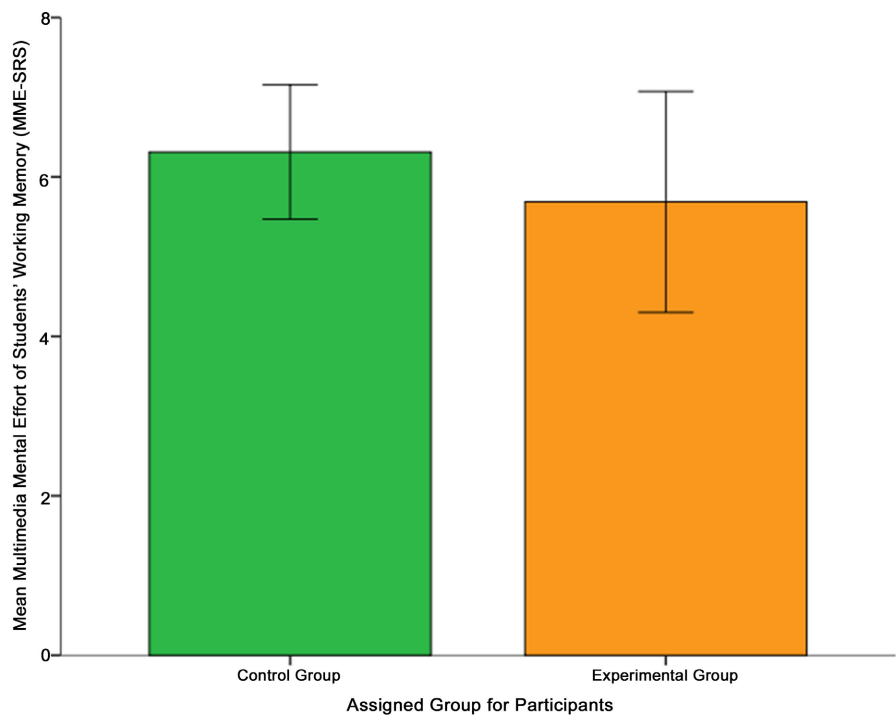
Multimedia Mental Effort	Entire Documentary Video	Integrated Segmented Documentary Videos	Statistical Significance <i>p</i>	Practical Significance $\eta_p^2$
Generative Processing Retrieval (During Post-Assessment)	Practically a similar amount of Multimedia Mental Effort (EEG)		0.431	0.021

Continued

<b>Generative Processing Encoding (During Presentation)</b>	Practically a similar amount of Multimedia Mental Effort (Subjective Rating Scale)	0.418	0.022
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Note: Comparison of the multimedia mental effort used during post-assessment (retrieval) and presentation (encoding).

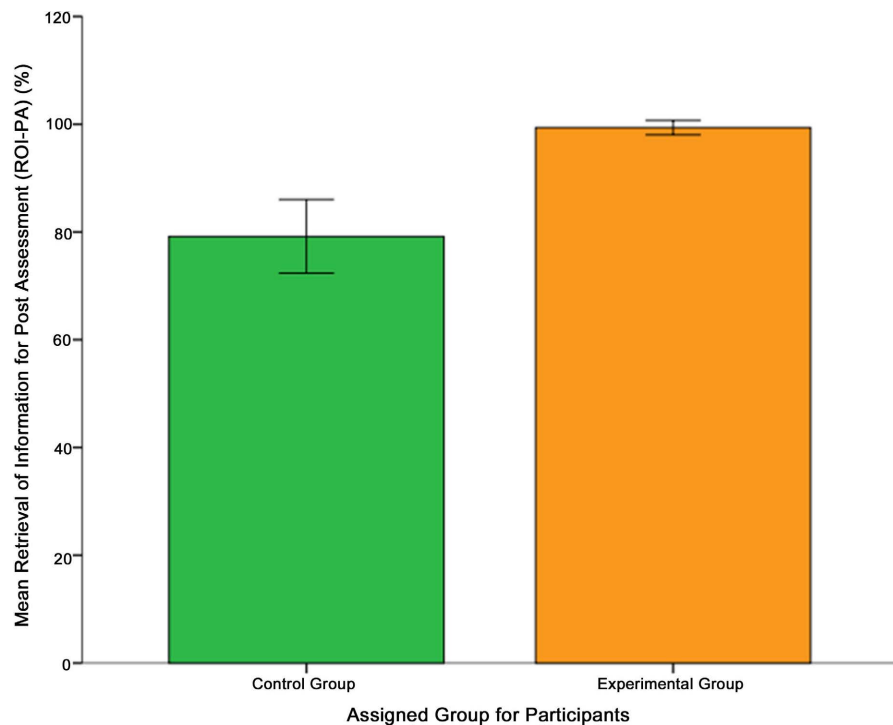
Standard deviation error bars for the mean multimedia mental effort of students' working memory (MME-SRS) for the control group and experimental group are shown in **Figure 3**. The results indicated that there was no statistically significant difference between groups as determined by one-way ANOVA  $F(1, 30) = [0.675], p = 0.418, \eta_p^2 = 0.022$ . The control group had a mean of 6.31 and a standard deviation of 1.580, while the experimental group had a mean of 5.69 and a standard deviation of 2.600. Therefore, the overall multimedia mental effort used during encoding of semantic information was practically the same for the use of integrated segmented documentary videos and an entire documentary video.



**Figure 3.** Mean multimedia mental effort of students' working memory (MME-SRS) for the control group and experimental group. *Note.* The Multimedia mental effort of students' working memory related to a subjective rating scale (MME-SRS).

**Figure 4** shows the mean retrieval of semantic information for a post-assessment (ROI-PA) related to the control group and experimental group using standard deviation error bars. The use of integrated segmented documentary

videos generated better performance than the use of an entire documentary video. The results showed that there was a statistically significant difference between groups as determined by one-way ANOVA  $F(1, 30) = [38.137]$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.560$ ). The control group had a mean of 79.18 and a standard deviation of 12.839, while the experimental group had a mean of 99.38 and a standard deviation of 2.500.



**Figure 4.** Mean retrieval of semantic information for post-assessment (ROI-PA) related to the control group and experimental group. *Note.* Retrieval of semantic information from students' long-term memory related to post-assessment marks (ROI-PA).

Additionally, retrieval of semantic information for a subjective rating scale (ROI-SRS) had a similar result as shown in **Table 2**. The results revealed that the use of segmented documentary videos had significantly better performance than the use of an entire video,  $F(1, 30) = [5.129]$ ,  $p < 0.031$ ,  $\eta_p^2 = 0.146$ ). The control group had a mean of 5.63 and a standard deviation of 1.857, while the experimental group had a mean of 7.06 and a standard deviation of 1.731. Standard deviation error bars for the mean retrieval of information for (ROI-SRS) related to the control group and experimental group are shown in **Figure 5**.

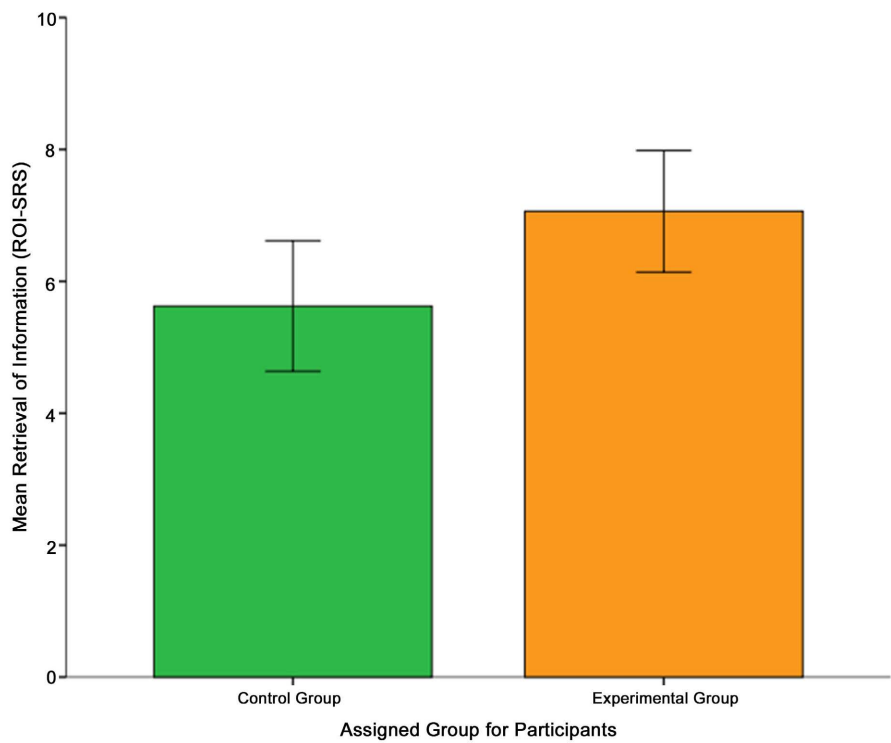
The mean multimedia mental load related to intrinsic processing generated for a subjective rating scale (MML-IPG-SRS) in students' working memory during encoding of semantic information within a control group and an experimental group related to a subjective rating scale is shown in **Figure 6**. Higher intrinsic processing was generated with the use of an entire documentary video than with the use of segmented documentary videos,  $F(1, 30) = [16.347]$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.353$ ). The control group had a mean of 4.88 and a standard deviation of 1.234, while the experimental group had a mean of 6.12 and a standard deviation of 1.123.

ation of 2.306, while the experimental group had a mean of 1.94 and a standard deviation of 1.769.

**Table 2.** Results for generative cognitive effort used during retrieval of semantic information.

Generative Cognitive Effort	Entire Documentary Video	Integrated Segmented Documentary Videos	Statistical Significance <i>p</i>	Practical Significance $\eta_p^2$
Schema Development (Post-Assessment)	Practically lower	Practically Higher	<0.001	0.560
Schema Development (Subjective Rating Scale)	Practically lower	Practically Higher	<0.031	0.146

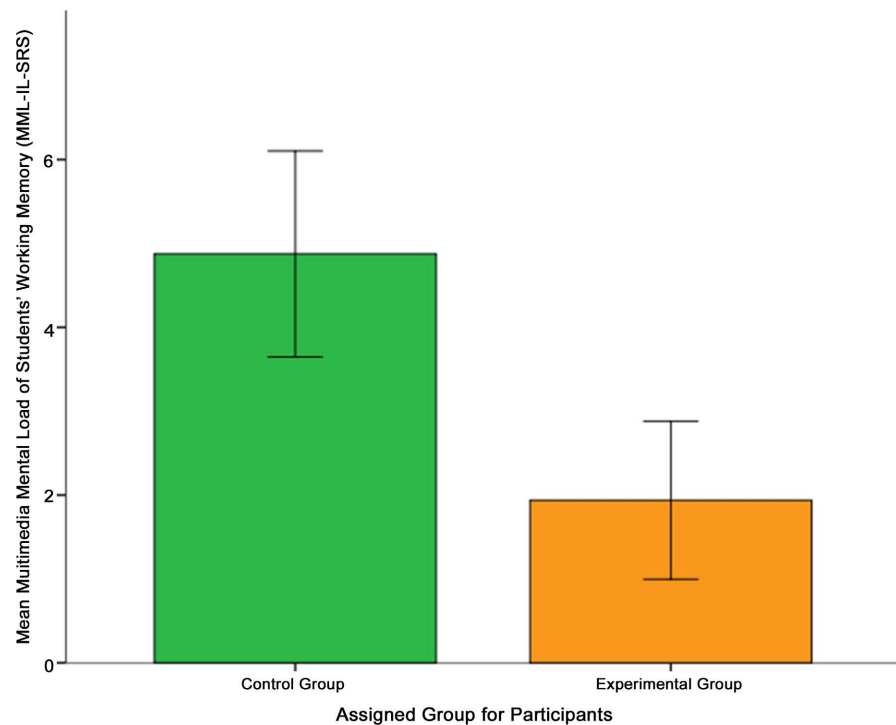
Note: Comparison of the generative cognitive effort used during post-assessment and for a subjective rating scale (retrieval). This determines the level of schema development in the brain.



**Figure 5.** Mean retrieval of semantic information (ROI-SRS) related to the control group and experimental group. *Note.* Retrieval of semantic information from students’ long-term memory related to a subjective rating scale (ROI-SRS).

### 5. Discussion

The findings from this study indicate that breaking down a documentary video into smaller interactive segments leads to more effective management of intrinsic



**Figure 6.** Mean multimedia mental load (intrinsic processing generated) of students' working memory (MML-IPG-SRS) for the control group and experimental group. *Note.* The multimedia mental load (intrinsic processing generated) of students' working memory related to a subjective rating scale (MML-IPG-SRS).

processing within working memory. Consequently, this approach enhances both the encoding and retrieval of information associated with semantic memory. It also shows that segmented documentary videos can enhance the performance of students facing academic challenges. These findings align with many studies on the segmenting principle in multimedia learning. Mayer and Chandler (2001: Experiment 2) conducted an experiment that involved segmenting of an entire animation video on lightning. Their results showed that students performed significantly better with the use of segmented animation videos than those who watched a continuous animation video. Additionally, Wang et al. (2023: Experiment 1) conducted an experiment that involved segmenting a video lesson. Their results showed that students' retention was higher when they interacted with the segmented video lessons than when they used a continuous video.

This provides further evidence that incorporating the segmenting principle alongside interactive elements in videos contributes significantly to the science of learning. In an educational setting, when instructors utilize the segmenting principle to manage the intrinsic cognitive load in documentary videos, students' performance may improve. The improved performance observed in participants exposed to integrated documentary videos may also stem from the strengthened connection between the working memory system (including dorsolateral prefrontal cortex (dlPFC) and ventrolateral prefrontal cortex (vlPFC)) and semantic long-term memory regions (such as the perirhinal cortex, para-

hippocampal cortex and hippocampus) during encoding. This strengthened connection allows for the easier retrieval of information from long-term memory by reducing interference from competing information, thus promoting successful retrieval. This explanation is supported by studies which revealed that “during retrieval, vLPFC may support the ability to resolve competition to retrieve relevant items from memory” (Blumenfeld & Ranganath, 2017: p. 288).

However, despite a comparable level of multimedia mental effort during the encoding and retrieval of semantic information related to semantic memory, participants who interacted with the segmented documentary videos performed significantly better on the summative assessment, indicating better schema development. This improvement may be attributed to the intrinsic processing generated in the working memory system, which remained at a manageable level when integrated segmented documentary videos were used in an authentic learning environment. Consequently, the intrinsic processing generated in the working memory system remained sufficiently low, facilitating enhanced management of intrinsic processing. This, in turn, allowed the working memory system (dorsolateral prefrontal cortex (dlPFC) and ventrolateral prefrontal cortex (vlPFC)) to enhance encoding in semantic long-term memory regions (perirhinal cortex, parahippocampal cortex and hippocampus).

However, the encoding was less robust when participants engaged with the entire video lesson. This may be attributed to the absence of segmenting and interactive elements within the video lesson resulting in lower participant performance. This deficiency may stem from the ventrolateral prefrontal cortex’s inability (vlPFC) to assist in the successful retrieval of information from long-term memory as competition among relevant items remained unresolved. This process did not require a great amount of multimedia mental effort to retrieve the information from long-term memory. This may have contributed to some of the incorrect responses in the post-assessment. Studies by Danker et al. (2008) and Badre and Wagner (2007) corroborate these findings. Hence, it may suggest that the multimedia mental effort did not substantially contribute to schema development in semantic memory; rather it was influenced by low intrinsic processing generated in the working memory system, which may have played a more significant role in schema development.

An important finding from the results was that participants expended a similar amount of multimedia mental effort during both encoding and retrieval. This has far-reaching implications as it suggests that multimedia mental effort has minimal effect on encoding in the semantic memory network and retrieval from long-term memory. Instead, it appears to be heavily influenced by the amount of intrinsic processing generated in the working memory system.

## 6. Limitations and Delimitations

### 6.1. Delimitations

- Only students who scored 30% or less throughout the academic year were se-

lected for the study. This specific criterion impacts the generalizability of the study, as the results may not be applicable to students with higher academic performance.

## 6.2. Limitations

- The study aims to investigate whether the performance of low academic achievers can be enhanced by using segmented documentary videos in the classroom. By using segmented videos, it is hypothesized that students may encounter less intrinsic cognitive load, allowing for better encoding of information in long-term memory.
- A significant limitation is the lack of existing studies focused on the segmentation of documentary videos from a Caribbean cultural perspective. This gap in research makes it difficult to compare the results of this study with other studies conducted in the Caribbean. However, the findings can still be compared to global studies on segmented documentary videos to provide some context for the results.

## 7. Conclusion

In conclusion, this study aimed to provide cognitive insights into the effect of segmented documentary videos on students' brain activity during the encoding and retrieval of semantic information. The findings suggest that the use of segmented documentary videos in an educational environment facilitates the formation of more schemas in long-term memory, which is likely due to lower intrinsic processing demands on the working memory system. Despite similar amount of multimedia mental effort being used both between encoding and retrieval for segmented and whole documentary videos, intrinsic processing was higher when interacting with entire documentary videos.

This study provides new insights into the relationship between segmented documentary videos and alpha brain activity during semantic information retrieval. An increase in power spectral density was associated with an increase in multimedia mental effort. Further research is needed to explore the effects of theta brain activity on multimedia mental effort.

The cognitive load management framework for multimedia learning developed in this study serves as a guide for using and creating segmented documentary videos with effective cognitive load management. Educators can benefit from applying this framework in educational settings to enhance student performance.

The successful retrieval and encoding of semantic information in relation to educational documentary videos to enhance students' performance depends on the proper management of cognitive loads. Educators and researchers should apply the segmenting principle in conjunction with the cognitive load management framework for multimedia learning to further develop the educational landscape. Understanding how students process semantic information during

encoding and retrieval can better equip educational practitioners to engage students for improved performance and learning outcomes.

## 8. Recommendations

- Instructors should use segmented documentary videos instead of entire documentary videos to improve the performance of low academic achievers.
- Instructors should incorporate interactive elements with low element interactivity in segmented documentary videos to enhance student performance in summative assessments.
- Documentary content creators should produce segmented documentary videos tailored for educational environments to aid in better cognitive load management.
- Educators should select resources that offer segmented documentary videos to provide students with materials that effectively manage cognitive loads.
- Future research should investigate how gifted and average students interact with high element interactivity content to assess differences in multimedia mental effort and intrinsic processing.

Researchers should explore whether generative processing is higher for gifted or average students using segmented documentary videos compared to entire documentary videos.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References

- Afify, M. K. (2020). Effect of Interactive Video Length within E-Learning Environments on Cognitive Load, Cognitive Achievement and Retention of Learning. *Turkish Online Journal of Distance Education*, 21, 68-89. <https://doi.org/10.17718/tojde.803360>
- Antonenko, P. D., & Keil, A. A. (2017). Assessing Working Memory Dynamics with Electroencephalography. In R. Z. Zheng (Ed.), *Cognitive Load Measurement and Application* (pp. 93-111). Routledge. <https://doi.org/10.4324/9781315296258-7>
- Antonenko, P., Paas, F., Grabner, R., & van Gog, T. (2010). Using Electroencephalography to Measure Cognitive Load. *Educational Psychology Review*, 22, 425-438. <https://doi.org/10.1007/s10648-010-9130-y>
- Azor, R. O., Asogwa, U. D., Ogwu, E. N., & Apeh, A. A. (2020). Youtube Audio-Visual Documentaries: Effect on Nigeria Students' Achievement and Interest in History Curriculum. *The Journal of Educational Research*, 113, 317-326. <https://doi.org/10.1080/00220671.2020.1819182>
- Babu, T. A., Gadde, S., Ravi, S., Rao, K. V. V., Mamillu, Y., & Krishna, D. (2022). Analysis of Mental Task Ability in Students Based on Electroencephalography Signals. In *2022 IEEE International Conference on Signal Processing, Informatics, Communication and Energy Systems (SPICES)* (pp. 274-278). IEEE. <https://doi.org/10.1109/spices52834.2022.9774092>
- Baddeley, A. (1998). Working Memory. *Comptes Rendus de l'Académie des Sciences—*

- Series III—Sciences de la Vie*, 321, 167-173.  
[https://doi.org/10.1016/s0764-4469\(97\)89817-4](https://doi.org/10.1016/s0764-4469(97)89817-4)
- Badre, D., & Wagner, A. D. (2007). Left Ventrolateral Prefrontal Cortex and the Cognitive Control of Memory. *Neuropsychologia*, 45, 2883-2901.  
<https://doi.org/10.1016/j.neuropsychologia.2007.06.015>
- Barbey, A. K., Koenigs, M., & Grafman, J. (2013). Dorsolateral Prefrontal Contributions to Human Working Memory. *Cortex*, 49, 1195-1205.  
<https://doi.org/10.1016/j.cortex.2012.05.022>
- Blumenfeld, R. S., & Ranganath, C. (2006). Dorsolateral Prefrontal Cortex Promotes Long-Term Memory Formation through Its Role in Working Memory Organization. *The Journal of Neuroscience*, 26, 916-925.  
<https://doi.org/10.1523/jneurosci.2353-05.2006>
- Blumenfeld, R. S., & Ranganath, C. (2017). Prefrontal Cortex and Human Memory: An Integrated Account from the Cognitive Neuroscience of Working and Long-Term Memory. In J. H. Byrne (Ed.), *Learning and Memory: A Comprehensive Reference* (pp. 275-293). Elsevier. <https://doi.org/10.1016/b978-0-12-809324-5.21082-1>
- Castro-Alonso, J. C., Ayres, P., & Sweller, J. (2019). Instructional Visualizations, Cognitive Load Theory, and Visuospatial Processing. In J. Castro-Alonso (Ed.), *Visuospatial Processing for Education in Health and Natural Sciences* (pp. 111-143). Springer International Publishing. [https://doi.org/10.1007/978-3-030-20969-8\\_5](https://doi.org/10.1007/978-3-030-20969-8_5)
- Castro-Alonso, J. C., de Koning, B. B., Fiorella, L., & Paas, F. (2021). Five Strategies for Optimizing Instructional Materials: Instructor- and Learner-Managed Cognitive Load. *Educational Psychology Review*, 33, 1379-1407.  
<https://doi.org/10.1007/s10648-021-09606-9>
- Danker, J. F., Gunn, P., & Anderson, J. R. (2008). A Rational Account of Memory Predicts Left Prefrontal Activation during Controlled Retrieval. *Cerebral Cortex*, 18, 2674-2685.  
<https://doi.org/10.1093/cercor/bhn027>
- De Jong, T. (2010). Cognitive Load Theory, Educational Research, and Instructional Design: Some Food for Thought. *Instructional Science*, 38, 105-134.  
<https://doi.org/10.1007/s11251-009-9110-0>
- Di Flumeri, G., Borghini, G., Aricò, P., Sciaraffa, N., Lanzi, P., Pozzi, S. et al. (2019). EEG-Based Mental Workload Assessment during Real Driving: A Taxonomic Tool for Neuroergonomics in Highly Automated Environments. In H. Ayaz, & F. Dehais (Eds.), *Neuroergonomics* (pp. 121-126). Elsevier.  
<https://doi.org/10.1016/b978-0-12-811926-6.00020-8>
- Frank, J. (2013). The Claims of Documentary: Expanding the Educational Significance of Documentary Film. *Educational Philosophy and Theory*, 45, 1018-1027.  
<https://doi.org/10.1111/j.1469-5812.2012.00849.x>
- Fraser, A. K. (2021). *Using an Electroencephalography Brain-Computer Interface for Monitoring Mental Workload during Flight Simulation*. Doctoral Dissertation, Carleton University.
- Funahashi, S. (2022). Prefrontal Cortex and Working Memory. In S. Funahashi (Ed.), *Brain Science* (pp. 515-543). Springer Nature Singapore.  
[https://doi.org/10.1007/978-981-19-7268-3\\_10](https://doi.org/10.1007/978-981-19-7268-3_10)
- Funahashi, S., Takeda, K., & Watanabe, Y. (2004). Neural Mechanisms of Spatial Working Memory: Contributions of the Dorsolateral Prefrontal Cortex and the Thalamic Mediodorsal Nucleus. *Cognitive, Affective, & Behavioral Neuroscience*, 4, 409-420.  
<https://doi.org/10.3758/cabn.4.4.409>
- Gagné, R. M., & Briggs, L. J. (1979). *Principles of Instructional Design* (2nd ed.). Holt.

- Gagné, R. M., & Driscoll, M. P. (1988). *Essentials of Learning for Instruction* (2nd ed.). Prentice Hall.
- Gagné, R. M. (1985). *Conditions of Learning and Theory of Instruction*. Holt, Rinehart and Winston.
- Gampala, M. (2023). Innovative Approaches to Teaching and Learning. *Shanlax International Journal of English*, 12, 138-145. <https://doi.org/10.34293/rttdh.v12is1-dec.86>
- Gevins, A., Smith, M. E., McEvoy, L., & Yu, D. (1997). High-Resolution EEG Mapping of Cortical Activation Related to Working Memory: Effects of Task Difficulty, Type of Processing, and Practice. *Cerebral Cortex (New York, NY: 1991)*, 7, 374-385. <https://doi.org/10.1093/cercor/7.4.374>
- Gevins, A., & Smith, M. E. (2000). Neurophysiological Measures of Working Memory and Individual Differences in Cognitive Ability and Cognitive Style. *Cerebral Cortex*, 10, 829-839. <https://doi.org/10.1093/cercor/10.9.829>
- Greer, D. L., Crutchfield, S. A., & Woods, K. L. (2013). Cognitive Theory of Multimedia Learning, Instructional Design Principles, and Students with Learning Disabilities in Computer-Based and Online Learning Environments. *Journal of Education*, 193, 41-50. <https://doi.org/10.1177/002205741319300205>
- Hannum, W. H., & Briggs, L. J. (1982). How Does Instructional Systems Design Differ from Traditional Instruction? *Educational Technology*, 22, 9-14.
- Hertrich, I., Dietrich, S., Blum, C., & Ackermann, H. (2021). The Role of the Dorsolateral Prefrontal Cortex for Speech and Language Processing. *Frontiers in Human Neuroscience*, 15, Article 645209. <https://doi.org/10.3389/fnhum.2021.645209>
- Hu, Q., & Hu, Y. (2023). The Relationship between Working Memory and Academic Outcomes: An Empirical Review. *Lecture Notes in Education Psychology and Public Media*, 15, 216-222. <https://doi.org/10.54254/2753-7048/15/20231060>
- Jensen, O., Gelfand, J., Kounios, J., & Lisman, J. E. (2002). Oscillations in the Alpha Band (9-12 Hz) Increase with Memory Load during Retention in a Short-Term Memory Task. *Cerebral Cortex*, 12, 877-882. <https://doi.org/10.1093/cercor/12.8.877>
- Kirschner, P. A. (2002). Cognitive Load Theory: Implications of Cognitive Load Theory on the Design of Learning. *Learning and Instruction*, 12, 1-10. [https://doi.org/10.1016/s0959-4752\(01\)00014-7](https://doi.org/10.1016/s0959-4752(01)00014-7)
- Klaus, J., & Schutter, D. J. L. G. (2018). The Role of Left Dorsolateral Prefrontal Cortex in Language Processing. *Neuroscience*, 377, 197-205. <https://doi.org/10.1016/j.neuroscience.2018.03.002>
- Kruger, J., & Doherty, S. (2016). Measuring Cognitive Load in the Presence of Educational Video: Towards a Multimodal Methodology. *Australasian Journal of Educational Technology*, 32, 19-31. <https://doi.org/10.14742/ajet.3084>
- Kumar, N., & Kumar, J. (2016). Measurement of Cognitive Load in HCI Systems Using EEG Power Spectrum: An Experimental Study. *Procedia Computer Science*, 84, 70-78. <https://doi.org/10.1016/j.procs.2016.04.068>
- Leppink, J. (2020). Revisiting Cognitive Load Theory: Second Thoughts and Unaddressed Questions. *Scientia Medica*, 30, e36918. <https://doi.org/10.15448/1980-6108.2020.1.36918>
- Lopez, S. (2024). Impact of Cognitive Load Theory on the Effectiveness of Microlearning Modules. *European Journal of Education and Pedagogy*, 5, 29-35. <https://doi.org/10.24018/ejedu.2024.5.2.799>
- Maskun, M., Sumargono, S., Pratama, R. A., & Maydiantoro, A. (2021). The Effectiveness of Historical Documentary Films as Information Technology in Improving Student

- Learning Outcomes. *International Journal of Education and Information Technologies*, 15, 183-190. <https://doi.org/10.46300/9109.2021.15.19>
- Masse, N. Y., Grant, G. D., & Freedman, D. J. (2018). Alleviating Catastrophic Forgetting Using Context-Dependent Gating and Synaptic Stabilization. *Proceedings of the National Academy of Sciences of the United States of America*, 115, E10467-E10475. <https://doi.org/10.1073/pnas.1803839115>
- Mayer, R. E. (2009). *Multimedia Learning* (2nd ed). Cambridge University Press. <https://doi.org/10.1017/cbo9780511811678>
- Mayer, R. E. (2017). Using Multimedia for E-Learning. *Journal of Computer Assisted Learning*, 33, 403-423. <https://doi.org/10.1111/jcal.12197>
- Mayer, R. E., & Chandler, P. (2001). When Learning Is Just a Click Away: Does Simple User Interaction Foster Deeper Understanding of Multimedia Messages? *Journal of Educational Psychology*, 93, 390-397. <https://doi.org/10.1037//0022-0663.93.2.390>
- Medeiros, J., Couceiro, R., Duarte, G., Durães, J., Castelhana, J., Duarte, C. et al. (2021). Can EEG Be Adopted as a Neuroscience Reference for Assessing Software Programmers' Cognitive Load? *Sensors*, 21, Article 2338. <https://doi.org/10.3390/s21072338>
- Moreno, R. (2010). Cognitive Load Theory: More Food for Thought. *Instructional Science*, 38, 135-141. <https://doi.org/10.1007/s11251-009-9122-9>
- Nyhus, E., & Badre, D. (2015). Memory Retrieval and the Functional Organization of Frontal Cortex. In D. R. Addis, M. Barense, & A. Duarte (Eds.), *The Wiley Handbook on the Cognitive Neuroscience of Memory* (pp. 131-149). Wiley.
- Ozfidan, B. (2021). Verbal Working Memory and Short-Term Memory: Bilingual vs Monolingual Children. *3L the Southeast Asian Journal of English Language Studies*, 27, 171-182. <https://doi.org/10.17576/3l-2021-2703-11>
- Paivio, A. (1986). *Mental Representations: A Dual-Coding Approach*. Oxford University Press.
- Petrides, M. (1996). Specialized Systems for the Processing of Mnemonic Information within the Primate Frontal Cortex. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 351, 1455-1462. <https://doi.org/10.1098/rstb.1996.0130>
- Piaget, J. (1952). *The Origins of Intelligence in Children*. W. W. Norton & Co. <https://doi.org/10.1037/11494-000>
- Plaza, M., Gagnon, P., Cohen, H., Berger, B., & Duffau, H. (2007). A Discrete Area within the Left Dorsolateral Prefrontal Cortex Involved in Visual-Verbal Incongruence Judgment. *Cerebral Cortex*, 18, 1253-1259. <https://doi.org/10.1093/cercor/bhm169>
- Qayyum, A., Faye, I., Malik, A. S., & Mazher, M. (2018). Assessment of Cognitive Load Using Multimedia Learning and Resting States with Deep Learning Perspective. In *2018 IEEE-EMBS Conference on Biomedical Engineering and Sciences (IECBES)* (pp. 600-605). IEEE. <https://doi.org/10.1109/iecbes.2018.8626702>
- Reigeluth, C. M. (1987). *Instructional Theories in Action*. Routledge.
- Reigeluth, C. M., & Darwazeh, A. (1982). The Elaboration Theory's Procedure for Designing Instruction. *Journal of Instructional Development*, 5, 22-32. <https://doi.org/10.1007/bf02905492>
- Russell, W. B. (2012). The Art of Teaching Social Studies with Film. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 85, 157-164. <https://doi.org/10.1080/00098655.2012.674984>
- Sarailoo, R., Latifzadeh, K., Amiri, S. H., Bosaghzadeh, A., & Ebrahimpour, R. (2022). Assessment of Instantaneous Cognitive Load Imposed by Educational Multimedia Us-

- ing Electroencephalography Signals. *Frontiers in Neuroscience*, *16*, Article 744737. <https://doi.org/10.3389/fnins.2022.744737>
- Schnaubert, L., & Schneider, S. (2022). Analysing the Relationship between Mental Load or Mental Effort and Metacomprehension under Different Conditions of Multimedia Design. *Frontiers in Education*, *6*, Article 648319. <https://doi.org/10.3389/educ.2021.648319>
- Spanjers, I. A. E., van Gog, T., & van Merriënboer, J. J. G. (2010). A Theoretical Analysis of How Segmentation of Dynamic Visualizations Optimizes Students' Learning. *Educational Psychology Review*, *22*, 411-423. <https://doi.org/10.1007/s10648-010-9135-6>
- Spanjers, I. A. E., Wouters, P., van Gog, T., & van Merriënboer, J. J. G. (2011). An Expertise Reversal Effect of Segmentation in Learning from Animated Worked-Out Examples. *Computers in Human Behavior*, *27*, 46-52. <https://doi.org/10.1016/j.chb.2010.05.011>
- Sweller, J. (1988). Cognitive Load during Problem Solving: Effects on Learning. *Cognitive Science*, *12*, 257-285. [https://doi.org/10.1207/s15516709cog1202\\_4](https://doi.org/10.1207/s15516709cog1202_4)
- Sweller, J. (1993). Some Cognitive Processes and Their Consequences for the Organisation and Presentation of Information. *Australian Journal of Psychology*, *45*, 1-8. <https://doi.org/10.1080/00049539308259112>
- Sweller, J. (2016). Cognitive Load Theory, Evolutionary Educational Psychology, and Instructional Design. In D. Geary, & D. Berch (Eds.), *Evolutionary Perspectives on Child Development and Education* (pp. 291-306). Springer International Publishing. [https://doi.org/10.1007/978-3-319-29986-0\\_12](https://doi.org/10.1007/978-3-319-29986-0_12)
- Sweller, J., van Merriënboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive Architecture and Instructional design. *Educational Psychology Review*, *10*, 251-296. <https://doi.org/10.1023/a:1022193728205>
- Tiwari, S., Goel, S., & Bhardwaj, A. (2023). EEG Signals to Digit Classification Using Deep Learning-Based One-Dimensional Convolutional Neural Network. *Arabian Journal for Science and Engineering*, *48*, 9675-9691. <https://doi.org/10.1007/s13369-022-07313-3>
- Wang, Y., Wang, F., Mayer, R. E., Hu, X., & Gong, S. (2023). Benefits of Prompting Students to Generate Summaries during Pauses in Segmented Multimedia Lessons. *Journal of Computer Assisted Learning*, *39*, 1259-1273. <https://doi.org/10.1111/jcal.12797>
- Wijewantha, N. W. S. C. (2021). Documentaries as Multimodal Texts to Promote Reading in the Virtual Language Classroom: An Experimental Study. *Journal of English Language Teaching and Linguistics*, *6*, 633-642. <https://doi.org/10.21462/jeltl.v6i3.611>
- Young, J. Q., Van Merriënboer, J., Durning, S., & Ten Cate, O. (2014). Cognitive Load Theory: Implications for Medical Education: AMEE Guide No. 86. *Medical Teacher*, *36*, 371-384. <https://doi.org/10.3109/0142159X.2014.889290>
- Zarjam, P., Epps, J., & Lovell, N. H. (2015). Beyond Subjective Self-Rating: EEG Signal Classification of Cognitive Workload. *IEEE Transactions on Autonomous Mental Development*, *7*, 301-310. <https://doi.org/10.1109/tamd.2015.2441960>
- Zhao, Y. (2023). The Impact of Cognitive Load Theory on Online Learning Outcomes for Adolescent Students. *Journal of Education, Humanities and Social Sciences*, *18*, 50-55. <https://doi.org/10.54097/ehss.v18i.10946>
- Zhu, Y., Wang, Q., & Zhang, L. (2021). Study of EEG Characteristics While Solving Scientific Problems with Different Mental Effort. *Scientific Reports*, *11*, Article No. 23783. <https://doi.org/10.1038/s41598-021-03321-9>