

## The Impact of Cognitive Load and Intrinsic Academic Motivation on Learning Outcomes

Students in both school and university settings do not all perform at the same level. Some students perform better than others. While this is often taken to be a sign of differences in innate cognitive ability, research suggests that other factors could be significant contributors to learning outcomes (Mayer, Fennell, Farmer & Campbell, 2004). Such factors involve not being intimidated by the formal presentation of lecture material and engaging with the material in a manner that allows for proper understanding to occur (Mayer et al., 2004). Traditional lecture instruction has involved the formal presentation of information on a blackboard as a means of teaching students. Recently, technological advancement has led to a change in how lecture material is presented. Microsoft PowerPoint has become a popular medium for presenting lecture material to students. While this presentation tool is a product of technical advancement, it is not clear whether its use necessarily leads to improved learning outcomes (Cooper, 2009).

It is important to consider whether lecture instruction takes place in a manner that corresponds to what is currently understood about the nature of human cognitive architecture (van Merriënboer & Sweller, 2005). Some lecturers utilize presentations that feature dense textual material while others present material in a manner that involves a central concept or a graphical representation, which is then discussed (van Merriënboer & Sweller, 2005). Certain presentation formats may be more conducive to meaningful learning than others. Meaningful learning is defined as “deep understanding of the material, which includes attending to important aspects of the presented material, mentally organizing it into a coherent cognitive structure, and integrating it with relevant existing knowledge” (Mayer & Moreno, 2003, p. 43).

In addition to examining whether lecture presentation formats correspond to human cognitive architecture; it is also important to consider whether motivational factors such as personal beliefs, desire to accomplish and the willingness to be stimulated also impact on learning outcomes (Vallerand, Pelletier, Blais, Brière, Senécal & Vallières, 1992). The literature suggests that students who are more motivated are more likely to invest greater effort into a task. This leads to greater success (deBilde, Vansteenkiste & Lens, 2011). The proposed study will investigate whether lecture presentation formats and motivation levels are influential in predicting learning outcomes.

## Background

### Comprehension, Learning and Human Cognitive Architecture

The terms comprehension and learning are often used interchangeably, yet are different. Comprehension is viewed as “the process of constructing a mental representation in working memory, regardless of whether a change in long-term memory takes place or not” (Schnotz & Kürschner, 2007, p. 492). Learning on the other hand is regarded as the process of comprehension which also leads to changes in long-term memory (Schnotz & Kürschner, 2007). The human cognitive architecture for learning is comprised of working memory, long-term memory and schemas (Paas, Renkl & Sweller, 2003). Working memory is where conscious cognitive processing takes place and has a very limited capacity. Working memory involves the holding of elements or units of information coming in through the sensory receptors, for example auditory or visual receptors. Due to its limited capacity, working memory is only capable of holding a few elements at a time, after which they are forgotten (Paas et al., 2003). This capacity is what Miller termed the “magical number seven, plus or minus two” (Miller, 1956). According to Miller, working memory capacity is so limited that it can, on average hold only about seven units of information before this information dissipates (Miller, 1956).

Long-term memory is regarded as virtually unlimited, and allows for the limits of working memory to be vastly expanded. Within long-term memory exists previously constructed cognitive elements known as schemas (Paas et al., 2003). As new information comes in through sensory inputs such as auditory and visual channels, working memory is able to interact with schemas in long-term memory. Since schemas act as a foundation upon which new information is added, they help make this information understandable. This is how complex information can be learnt under conditions where the limits of working memory are exceeded (Paas et al., 2003).

### The Three Assumptions of Multi-Media Learning

Building on concepts of cognitive architecture, Mayer (2002) introduced the Theory of Multimedia Learning. According to this theory, meaningful learning occurs under conditions of substantial visuo-spatial and verbal thinking (Mayer, 2002). This is based on three assumptions. Firstly, working memory is not a single unit but is divided into both an auditory-verbal component and a visual-pictorial component. The auditory component is also called the phonological loop and the visual component the visuo-spatial sketchpad (Baddeley,

1986). Secondly, working memory for each of these components is very limited, and it can be easily overwhelmed by information coming in through the auditory and visual channels (Schnotz & Kürschner, 2007). Thirdly, the mind is an active processor of information and meaningful learning occurs as a result of significant processing in both of these channels (Mayer & Moreno, 2003).

### **Cognitive Load and Cognitive Load Theory (CLT)**

The concept of cognitive load was developed as an attempt to explain why effective learning sometimes fails to take place (Mayer & Moreno, 2003). New information in working memory is often too complex to effectively interact with schemas in long-term memory in order for learning to occur. This is called cognitive overload (Mayer & Moreno, 2003). Sweller (1988) developed the cognitive load concept and the resulting cognitive load theory. He distinguished between three types of cognitive load.

Intrinsic load refers to the number of elements in a task that must be simultaneously processed in working memory, and depends on the level of element interactivity within the task (van Merriënboer & Sweller, 2005). Elements need to interact with each other in order for meaningful comprehension to occur. For instance, in isolation, an element such as a single mathematical symbol, will not lead to meaningful comprehension. The symbol would need to interact with other symbols, variables and constants in the context of an equation to facilitate meaningful comprehension of the mathematical problem. Thus, tasks with low intrinsic load such as those characterized by few interacting elements, are easier to process than tasks with high intrinsic load that have several interacting elements, (van Merriënboer & Sweller, 2005). Relatedly, too little element interactivity leads to reduced comprehension, as there are not enough elements to create meaning, whereas too much element interactivity also leads to reduced comprehension because working memory limits are exceeded.

Extraneous load refers to any visual or auditory variables that increase cognitive load without assisting the learning process (Artino, 2008). This has much to do with the design of the instructional or lecture material. For instance, a PowerPoint slide that features dense text without any pictorial representations may create extraneous load (Artino, 2008). This is due to the student having to mentally formulate a picture of what is being read textually. The additional mental effort is thought to increase cognitive load (Sweller, 1988). Listening to the lecturer while reading the text may also create overload, as what the lecturer says may not directly correspond to sequence of words of the text being visually represented (Sweller, 1994). The slight variation between visual and auditory presentation of text creates distortion

for one who attempts to pay attention to both (Artino, 2008). If the lecturer explains a process within a large diagram, the student would then be able to ‘see’ the process in the context of the diagram, rather than have to grapple with text and listen to an explanation (Sweller, 1988).

The third type of cognitive load is germane load (van Merriënboer & Sweller, 2005), which is the successful interaction of new information with long term memory in order to create a new schema. This is thought to lead to efficient learning. In the above lecture example, a lecturer explaining a process in the context of a diagram rather than through dense text would be an example of a case where germane load is increased while extraneous load is decreased (Mayer, 1989). The pictorial representation reduces extraneous load by saving students from having to create the picture in their own minds in order to make sense of the text (van Merriënboer & Sweller, 2005).

### **Important Effects in Cognitive Load Theory**

The cognitive load theory is a framework that features numerous effects, which highlight situations under which efficient or less efficient learning takes place. These effects are based on the interaction of instructional materials with the human cognitive architecture. Three important effects commonly studied are the spatial contiguity effect, the split-attention effect and the modality effect (Schnotz & Kürschner, 2007).

***Spatial Contiguity Effect.*** The spatial contiguity effect is a process of enhanced learning that comes from the integration of text and graphics formats in a single task (Mayer, 1989). By the learning task being presented in an integrated fashion, it saves the learner from having to perform additional work to mentally integrate the information (Mayer, 1997). It is thus an example of a presentation format that can reduce cognitive load. By reading the text and simultaneously looking at a graphical representation of it, the learner is able to see how the textual information relates to the diagram. This graphical representation does not need to be created in one’s mind (Chandler & Sweller, 1991). If textual and graphical representations are separate rather than spatially integrated, it can lead to the split-attention effect (Sweller, Chandler, Tierney & Cooper, 1990).

***Split Attention Effect.*** The split-attention effect refers to one having to use working memory to hold one piece of information (e.g., textual information) in mind in order to meaningfully integrate it with another piece of information (e.g., a separate diagram). The

textual information or diagram on its own is not sufficient to convey complete meaning. In this case a failure to remember the textual information will therefore lead to failure in mentally integrating it with the diagram, which then leads to limited understanding. This is an example of high cognitive load, as both the textual and graphical sources of information are simultaneously placing a demand on a single processing modality, i.e. the visuo-spatial sketchpad of working memory (Schnotz & Kürschner, 2007).

**Modality Effect.** The modality effect refers to learning material being effectively shared between the visual and auditory modalities. For example, by presenting lecture material in a graphical form and then explaining what the graphic represents, information is being distributed to both the visuo-spatial sketchpad and phonological loop (Baddeley, 1986). This reduces demand on either modality, and allows for effective processing. This process is called dual-coding and reduces cognitive load (Paivio, 1969; Schnotz & Kürschner, 2007). This modality effect is the central theme behind those attempts that are inspired by cognitive load theory that aim at modifying lecture instruction in ways that improve learning (Mayer & Moreno, 2003).

### **Previous Research on Cognitive Load Theory**

Several empirical studies have been conducted to test cognitive load theory. Many of the studies have focused on the spatial contiguity, split-attention and modality effects already discussed. In a study conducted by Florax and Ploetzner (2010), separate groups of participants were each given a different lecture presentation format. One format had integrated pictorial and textual information (spatial contiguity), while the other format involved pictorial and textual information presented as separate sources (split attention). Results from this study showed that the group that learnt from the separately sourced presentation format had significantly poorer learning outcomes compared to another group that had an integrated presentation (Florax & Ploetzner, 2010). Another study conducted by Tarmizi and Sweller (1998) found that when learners were required to split their attention between multiple sources of information in order to create meaning, they showed signs of limited learning. Ward and Sweller (1990) observed that cognitive load could be reduced in circumstances where the need to mentally integrate information was eliminated. By presenting this information in a physically integrated fashion, participants were able to make sense of what was being presented without the need for mental integration (Ward & Sweller,

1990). Studies have generally suggested that the split attention effect leads to inefficient learning while the spatial contiguity effect enhances learning (Mayer, 1997).

Mousavi, Low, and Sweller (1995), conducted multiple experiments that demonstrated the modality effect. They used a simultaneous auditory and visual presentation format to explain geometric concepts to scholars (Mousavi, Low & Sweller, 1995). They found that those who were exposed to the modality condition showed more positive learning outcomes than those simply given a visual presentation. Tindall-Ford, Chandler, and Sweller (1997), showed that participants performed more adequately when presented with instructions in the modality format rather than the split-attention format. These results were consistent across groups for learners with different levels of ability, hence controlling for the fact that difference in learner ability might have led to the observed result (Tindall-Ford, Chandler, & Sweller, 1997).

### **Academic Motivation, Learning and Self Determination Theory**

While cognitive load theory attempts to explain instructional design and learning outcomes in terms of cognitive architecture, it does not consider the role of other important factors such as the influence of motivation on learning. Studies on cognitive load theory can therefore be made more robust by also taking into account such factors. This study therefore looks at learning effects suggested by cognitive load theory as well as motivational influences on learning. Motivation is however a complex multi-dimensional construct. Intrinsic motivation deals with motivational factors within the individual while extrinsic motivation deals with external motivational influences. Self-Determination Theory (SDT) is a theory of motivation that explains the contribution of determination or self-motivation in the motivation process (Bilde et al., 2011). This theory is divided into three aspects, namely; competence, autonomy and relatedness. Competence refers to the desire to control outcomes and experience mastery of specific situations. Autonomy refers to being responsible for what happens in one's own life, but does not imply being isolated from the influences of others (Bilde et al., 2011). Relatedness refers to the need to feel connected to others, which is believed to increase motivation. For the purpose of this study, relatedness does not play any significant role compared to competence and autonomy, as participants will not be tested in an environment where feeling connected to others impacts outcomes.

Studies have indicated that when one is given positive feedback for competence, intrinsic motivation is increased, while extrinsic motivation decreased (Vallerand & Reid, 1984). This is because the self-worth of the individual is increased by the positive feedback.

Positive feedback helps the individual to further engage in academic activities that improve self-worth. Thus, if such an individual receives positive feedback for competent academic performance, he is likely to improve his performance. He would perform better in academic tasks than an individual with less motivation but equivalent cognitive ability (Vallerand & Reid, 1984).

Studies of motivation and autonomy indicate that when one is extrinsically motivated by rewards, intrinsic motivation tends to dissipate. The self-worth of the individual tends to be compromised, as the motivation is coming from the appeal of the reward rather than the opportunity to learn new information and grow in the process (Deci, Eghrari, Patrick, & Leone 1994).

It seemed plausible that both lecture presentation formats and students' intrinsic motivational levels could have an impact on learning outcomes. The literature suggested that the split-attention effect hinders learning while the modality and spatial contiguity effects improve it. Motivation related influences on learning outcomes depend on both extrinsic and intrinsic factors but intrinsic factors are more likely to make the individual want to learn, as it deals with factors such as wanting to experience stimulation and wanting to gain new knowledge. Cognitive load theory assumes that learning outcomes are due to the presentation format of lecture materials. It is however possible that people of roughly similar levels of cognitive ability but different levels of intrinsic motivation might produce different learning outcomes, irrespective of the format of lecture presentation. This underscored the need to conduct research in order to determine the influence of spatial contiguity, split attention and modality effects as proposed in the cognitive load theory, and intrinsic motivation on learning outcomes.

### **Specific Aims and Hypotheses**

This study had two objectives. The primary objective was to investigate using the cognitive load theory - whether different presentation formats lead to significantly different learning outcomes. The second objective was to investigate whether there is a significant influence of the participants' level and type of intrinsic motivation (either 'stimulation' or 'to know') on these learning outcomes for specific conditions. Learning outcomes were determined as a function of scores attained on a test of presented conceptual material. The following hypotheses were tested in the study:

1. Participants in the split-attention effect group will show the poorest learning outcomes of the three groups.
2. Participants in the modality effect group will show the most favorable learning outcomes of the three groups.
3. Higher intrinsic motivational scores with respect to 'stimulation' and 'knowledge' will correlate positively with improved learning outcomes for participants in the modality condition.

## Method

### Design and Setting

This study took place at the University of Cape Town, in the GCS laboratory, which is located in the Department of Psychology. This setting allowed for fairly robust controls to be implemented under experimental conditions. This allowed for testing of all participants under conditions of relative silence, where a standard procedure was applied. The setting was also relevant because the study aimed to test two factors (i.e. presentation format and intrinsic academic motivation) which are directly relevant to a university setting.

The study featured a between subjects, experimental design, with three experimental groups. Group 1 was tested under the spatial contiguity effect condition (see Appendix A). Group 2 was tested under the split-attention effect condition (see Appendix B). Group 3 was tested under the modality effect condition (see Appendix C). In addition; a measure of academic motivation was incorporated into the study, and applied to all participants in the three groups. See (Appendix D) for the Academic Motivation Scale (AMS), and the 2 relevant categories of intrinsic academic motivation ('stimulation' and 'to know').

### Participants

Female University of Cape Town undergraduate psychology students aged between 18 and 25 years old were recruited through the Student Research Participant Program (SRPP) to take part in the study ( $N = 86$ ). They were divided into three independent groups ( $n = 30$ ) for spatial contiguity, ( $n = 26$ ) for split-attention and ( $n = 30$ ) for modality. Research on human cognitive architecture suggests that these architectures are generally the same in all people of a specific age group (e.g., Paas et al., 2003). This eliminates the need to exclude certain individuals on the basis of race. The university also teaches and tests students in an



English format, which eliminated the need to exclude participants based on their first language.

## Measures

**Presentation Format.** Learning materials made up the first independent variable for this part of the study. This IV had three levels. Each level corresponded to a specific format of presentation, and lies within the framework of cognitive load theory. This means that each presentation condition was designed according to the principles of cognitive load theory and the specific effects that it describes. Thus, level 1 of the IV was the spatial contiguity format, level 2 the split attention format and level 3 the modality format. The dependent variable was the score attained for the test based on the information in these three conditions, and ranged from 0 to 10 (See Appendix E). Since psychology students were the participants in this study, the tasks presented information from a different field of study than psychology. This was in order to control for familiarity with test information which can confound task performance. The tasks sampled information from the field of astronomy. The other attraction of this field is that astronomical concepts are easy to visualize, as they involve tangible objects such as stars and planets. This was intended to help to better illustrate the effects of different presentation formats. The source of the astronomical definitions and concepts was from the researchers own knowledge of having read books on the subject.

**Experiment 1 (Spatial Contiguity Effect).** The concept, its corresponding definition and graphical representation were all presented on a single slide (See Appendix A). According to cognitive load theory, this presentation format decreases cognitive load and leads to improved learning, as the participant does not have to mentally integrate information that has already been presented in a spatially integrated format (Chandler & Sweller, 1991; Mayer, Steinhoff, Bower & Mars, 1995). There were ten slides, each with a different concept, its corresponding definition and graphic. These slides were set on a timer, and changed every 5 seconds. Ziefle (1998) found that on average, people are capable of reading approximately 180 words per minute on a computer screen when proofreading. When reading at a normal rate however, the number can exceed 250 words per minute (Ziefle, 1998). Although differences in learning outcomes were being measured in this study, participants were not required to make a great effort to memorize information. All they were required to do was

read the information on the screen. Thus, 5 seconds per slide was adequate to read the presented concepts and definitions once only.

***Experiment 2 (Split-attention Effect).*** For this condition the definition of a concept was presented on a slide, while the label of the concept and its corresponding graphical representation were presented on the consecutive slide (See Appendix B). To make sense of concept and definition, the participant would have to mentally integrate information on both slides, as they were not presented in an integrated visual format. According to cognitive load theory, this leads to increased extraneous cognitive load and reduced learning, as the visual modality is required to process both text and graphics in mind simultaneously. Sweller, Ayres and Kalyuga (2011) found that when students were presented with either split attention and spatial contiguity formats for the same material, the split-attention group took significantly longer than the spatial contiguity group, yet failed to perform as well. Based on this, it was decided that for the split-attention condition participants would be given 5 seconds to look at each source of information. Since this involved 2 sources of information for each concept (2 separate slides), it meant that the participants would have 20 slides to look at instead of the 10 slides in the spatial contiguity condition in order to process the same amount of information. Although the source with the concept and corresponding graphical representation did not have a definition, the participant would be expected to take time to mentally integrate the concept and definition of the second slide with the definition seen on the previous slide (Sweller et al., 2011).

***Experiment 3 (Modality Effect).*** The audio recording for the condition was carried out using a Samsung Galaxy S3 smartphone (See Appendix C). The voice used was that of a colleague. He had no speech impediments and was able to fluently express each definition. The audio stimulus was presented through large muff Canyon headphones supplied by the researcher. The graphical representation of a concept was presented on a slide with its corresponding label. The definition of the concept was simultaneously presented via audio. The participant was thus required to look at a graphical representation while listening to a definition of what this picture was about. According to cognitive load theory, this reduces extraneous cognitive load and increases learning outcomes because the information load is being shared by both auditory and visual modalities, leading to the promotion of schema formation. Williams (1998) conducted a study on multi-media instruction and found that people tend to most effectively process auditory information when it is presented at

approximately 150 words per minute. The modality effect task for this study featured word production that approximately matched the same speed. Several practice tries were required to achieve this result.

**Multiple choice test.** The test for measuring learning outcomes across all 3 groups was designed according to the cognitive load theory framework (see Appendix E). It comprised of 10 concepts, for which definitions are required. The aim was to determine to what extent meaningful learning occurs, and whether a specific presentation format led to more effective schema formation than others (Mayer & Moreno, 2003). The multiple choice options required a very specific understanding of the presented material to answer correctly, and were not aimed at testing general knowledge. This specific understanding related to what was presented in each of the cognitive load conditions. For example, general knowledge about the concept ‘solar flare’ would have still made it rather tricky to choose the right concept, as all four multiple-choice options could have reasonably fit into the general knowledge framework. General knowledge typically involves non-specialist knowledge about something, while the multiple choice test involved more specific knowledge. This format was required to assist in triggering off information about what was presented in the experimental conditions, rather than expecting the participant to recall entire definitions. The familiarity experienced with triggering specific concepts and being able to select the appropriate multiple-choice response would indicate that some schema formation had occurred (Mayer & Moreno, 2003).

***Element interactivity and test design.*** In order for meaningful learning to occur, the participant had to be able to associate a number of elements collectively to make meaning of a concept. Each definition (e.g. *galaxy*) had certain core ideas in it, i.e. “system”, “millions or billions” “stars”, “gas” and “dust”, “held together” by “gravity”. It can be thought of that each of these core ideas is an element. Hence, the definition of galaxy has 7 elements. Each of these elements on its own cannot provide the full definition. The more of these elements interact with each other in a coherent manner, the closer one will be to producing the definition. If only some element interactivity occurs then a limited or vague notion of the concept will be attained. For comprehension of the concept to occur, highly effective element interactivity needs to take place (Merriënboer & Sweller, 2005). Although a multiple choice format was used, answers to questions were structured in a way that creates some overlap. This means that partial element interactivity was prevalent in some of the multiple-choice

options. This partial element interactivity creates confusion, as it produces a distorted notion of which option is the most appropriate for selection. The purpose of this was to force the participant to think carefully prior to making a choice. Without this overlap, the correct options might be too easy to pick out.

**Academic Motivation Scale (AMS)**, Motivation levels were measured with the college version of the Academic Motivation Scale (AMS), (Vallerand et al., 1992), (see Appendix D). This scale is based on Self-Determination Theory (SDT) and consists of 28 items, divided into 7 categories. The 7 categories cover both intrinsic and extrinsic motivation. They also cover amotivation, for people who are neither intrinsically nor extrinsically motivated. The scale is scored via a Likert-type format, ranging from 1 to 7 (Vallerand et al., 1992). It asks the participant the following question: “Why do you go to college”? An example of an item dealing with intrinsic academic motivation is “For the pleasure that I experience in broadening my knowledge about subjects which appeal to me.” For each item one of 7 motivational level options can be chosen. These options range from “does not correspond at all”, which is a score of 1 to “corresponds exactly”, which is a score of 7. Although motivation is the second independent variable, it is not under direct control of the researcher, unlike presentation format.

**Intrinsic Motivation.** This is divided into 3 categories. The first is an intrinsic motivation to want to experience stimulation, and is represented as (*IM-to experience stimulation*), (Vallerand et al., 1992). The second is the intrinsic motivation to know (*IM-to know*), and the third is the intrinsic motivation towards accomplishments (*IM-to accomplish things*), (Vallerand et al., 1992). These three subscales measure the satisfaction gained by the learner by engaging in activities as an individual (Vallerand et al., 1992). The values for Cronbach’s alpha for these intrinsic motivation subscales ranges from 0.84 to 0.86, indicating high internal reliability. Since one of the aims of this study was to test whether a low extraneous load condition like the modality format would be linked to factors that make people want to learn, the intrinsic motivational categories ‘experience stimulation’ and ‘to know’ were regarded as most relevant. It was expected that due to a condition like the modality format being more conducive to learning, participants might favour this condition and thus be academically motivated to want to acquire more knowledge according to such a format. The ‘to accomplish’ category was left out, as it did not involve wanting to learn or be stimulated. Extrinsic motivation, its sub-scales and amotivation were also irrelevant to the

purpose of the study and were left out. The purpose of evaluating intrinsic academic motivation was to explore factors within the individual that could be important in wanting to experience better learning outcomes.

Overall, the AMS has an alpha value of 0.81, indicating high internal reliability. Other studies have also found the AMS to be strong on validity, as confirmed through structural equation modeling (Grouzet, Otis & Pelletier, 2006).

## **Procedure**

This study was advertised on the SRPP website and required participants to sign up for an appropriate slot. Slots were open from Monday to Friday, and were half an hour in length. When the participant arrived, she was presented with an informed consent form (Appendix F), which stated the purpose of the study. It also asked for the permission of the participant in participating. After completing the informed consent form, the participant was asked to sit in front of a computer.

For experiment 1 (spatial contiguity effect) the instructions were as follows: After sitting down in front of a computer and explaining instructions to the participant, she was asked to pay attention to the slideshow and read each concept and definition that flashed on screen. Exposure to each slide occurred just once, as repetition would confound the result. When the presentation was over, the participant was given a distractor task (sudoku puzzle) for 2 minutes (See Appendix H). This was to prevent practice effects, where the participant could rehearse the information that had just been presented to her. The participant was then presented with the test in (Appendix E), and allowed to answer it at her own pace. After this test was completed, the participant was asked to complete the Academic Motivation Scale (AMS) (Appendix D). Once this was done the participant was given a debriefing form (see Appendix G), given an explanation of the study, allowed to ask any questions, proof of participation receipt and thanked for participation in the study. The participant was also told that she could contact the researcher at any time if she wished to enquire about some aspect of the study.

For experiment 2 (split attention effect) the instructions were exactly the same as experiment 1, with exposure to each slide occurring just once. After the slide presentation, the rest of the instructions were the same as before. For experiment 3 (modality effect) the instructions were the same as experiments 1 and 2, both for the task and for the activities following it. The only difference was that for each slide the researcher clicked on the audio

button for the definition to play simultaneously with the picture. Participants were awarded with 1 SRPP point for participation in any of the three experiments.

### Statistical Analysis

All statistical analyses were carried out on the version 21 of the SPSS statistical program (SPSS, 2012). Descriptive statistics were carried out in order to determine how each group performed on the test and how great the standard deviations and standard errors were. The main analysis concerned between group differences in spatial contiguity, split-attention and modality conditions. P-P plots and histograms revealed a normal distribution for most of the data. However, there were 4 outliers for the split-attention condition, as seen on boxplots. They were the data-sets of participants who had performed rather poorly. These were removed, as they were causing the data to be skewed. Various assumptions for specific tests were upheld apart for one. Levene's test for homogeneity of variance was significant, so Welch statistics needed to be looked at. A 1-way ANOVA was run in order to determine if there was any significant difference between the test scores of the 3 independent groups ( $n = 30$  each for spatial contiguity and modality) and ( $n = 26$ ) for split-attention. In addition, a set of planned contrasts were run in order to determine the effect size and significance of differences between each of the groups. A trend analysis was conducted to test for a linear trend, as it follows from previous research that participants in the spatial contiguity condition should perform better than those in the split-attention condition, but should not perform as well as those in the modality effect condition. The effect size for the overall ANOVA was calculated by dividing  $SS_{\text{effect}}$  by  $SS_{\text{total}}$ , while the effect size for specific group differences was calculated according to finding the square root of  $(t^2/t^2 + df)$ , (Cohen, 1992).

Hierarchical multiple regressions were carried out in order to determine if either of the intrinsic motivators ('stimulation' and 'to know') had any significant correlation with the multiple choice scores for each of the cognitive load conditions. Since there was no prior literature documenting any relationship between intrinsic academic motivators and different cognitive load presentation formats, it was decided to first enter the 'to experience stimulation' variable and then the 'to know' variable. The purpose of this was to determine to what extent the two factors of intrinsic academic motivation and presentation formats determine test scores, in terms of the participant first experiencing stimulation and then wanting to acquire more knowledge as a result of it. This regression analysis was done for the spatial contiguity, split-attention and modality presentation formats.

Scores for the multiple choice test and the AMS were standardised by being converted to z-scores. This was required as they were on different scales. For all three cognitive load conditions and 2 intrinsic academic motivators the data was approximately normally distributed. There was also no heteroscedasticity or multi-collinearity. The VIF and tolerance values were well within acceptable range. All observations were independent and the relationship between the dependent variable and each academic motivator were linear. Mahalanobis distances and Cook's distances were also within normal ranges for each of the three conditions, indicating that no particular data point was having a large effect on the outcome variable. The significance values for all tests were left at 0.05.

## Results

### Cognitive Load Conditions

For the ANOVA, Levene's test for homogeneity of variance was statistically significant,  $F(2, 83) = 6.398, p = .003$ , thus homogeneity of variance was violated. The Welch statistic was therefore used and proved significant,  $F(2, 51) = 33.62, p < .001$ . The ANOVA was statistically significant,  $F(2, 83) = 20.87, p < 0.001, r = .33$ . A summary of the ANOVA results is presented in *Table 1*.

*Table 1.* One-way ANOVA summary table for performance on MCQ test for spatial contiguity, split-attention and modality groups.

Source	SS	df	MS	F	<i>p</i>	<i>r</i>
<b>Between Groups</b>	98.815	2	49.408	20.871	< .001	0.33
<b>Within Groups</b>	196.487	83	2.37			
<b>Total</b>	295.302	85				
<b>Contrast</b>	32.267	1	32.267	20.87	< .001	

The 3 planned contrasts revealed that participants in the split-attention group ( $M = 4.4$ ) performed worse than those in the spatial contiguity group ( $M = 5.57$ ). The difference was statistically significant,  $t(83) = -3.046, p = .004, r = .43$ . The contrasts also showed that participants in the modality group ( $M = 7.03$ ) performed better than those in the spatial

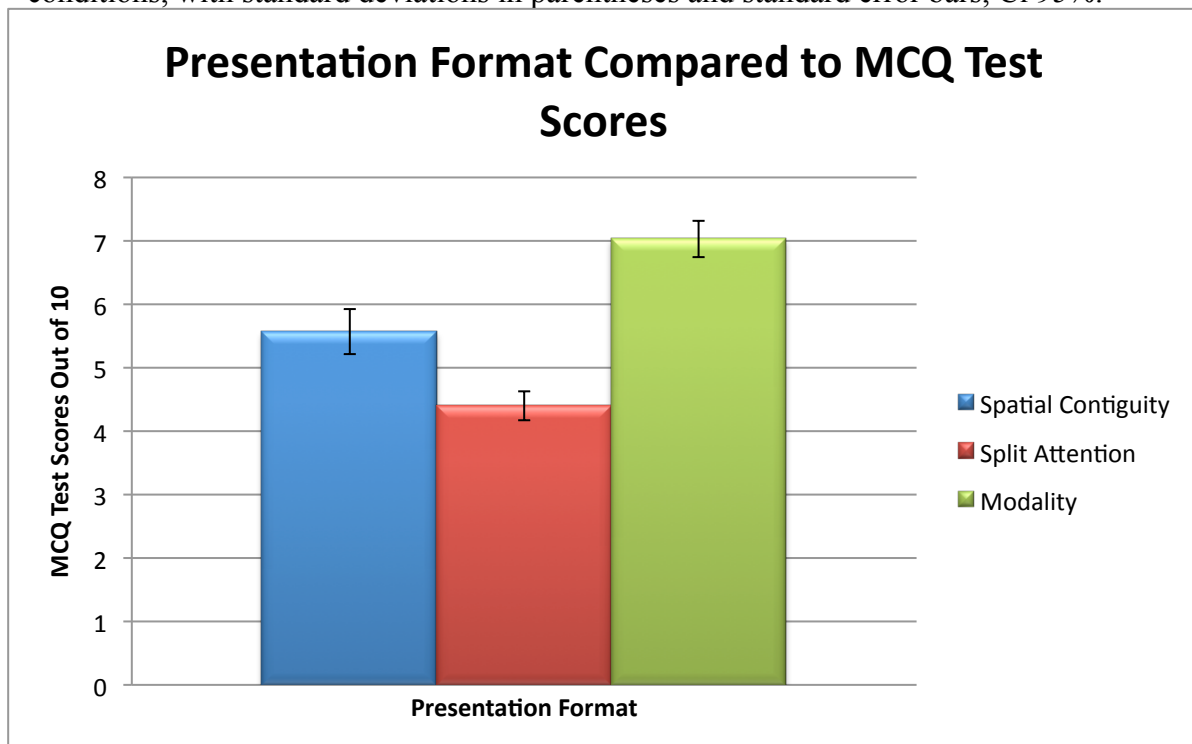
contiguity group ( $M = 5.57$ ). This difference was statistically significant,  $t(83) = 3.221$ ,  $p = .002$ ,  $r = .40$ . Lastly, these contrasts showed that participants in the modality group ( $M = 7.03$ ) performed better than those in the split-attention group ( $M = 4.4$ ). These results were also statistically significant,  $t(83) = 8.119$ ,  $p < .001$ ,  $r = .77$ . Each of these results offers support for both hypothesis 1 and 2. A summary of these results is presented in *Table 2*. SC denotes spatial contiguity, SA denotes split attention and M denotes the modality condition. These symbols are used due to limited table space.

*Table 2.* Group differences for the spatial contiguity, split-attention and modality conditions

Comparison	df	<i>t</i>	<i>p</i>	<i>r</i>
SC and SA	83	-3.046	.004	0.43
SC and M	83	3.221	.002	0.40
SA and M	83	8.119	< .001	0.77

The trend analysis confirmed our a-priori hypotheses  $F(2, 83) = 13.63$ ,  $p < .001$ , indicating that the data does indeed fit a linear trend. A graphical representation of the between group differences is shown in *Figure 1*.

*Figure 1:* Means of scores attained on 10 question MCQ test for each of the three conditions, with standard deviations in parentheses and standard error bars, CI 95%.





### Intrinsic Academic Motivation and Cognitive Load

The regression model summary for the spatial contiguity condition showed that the intrinsic academic motivational variable ‘stimulation’ did not significantly predict MCQ test scores ( $F[1, 28] = 2.064, p = .63, r = .07$ ). When the ‘to know’ variable was added there was still no significant change to the model ( $F[1, 27] = .040, p = .844, r = .07$ ).

The regression model summary for the split attention condition shows that the ‘stimulation’ variable did not significantly predict MCQ test scores ( $F[1, 24] = .0405, p = .531, r = .017$ ). When the ‘to know’ variable was added to the model there was still no significant change to the model ( $F[1, 23] = .102, p = .753, r = .021$ ). Of particular interest in this split-attention condition is that the Beta values are negative for both ‘stimulation’ and ‘to know’. This will be discussed later.

The regression model summary for the modality condition shows that the ‘stimulation’ variable did not significantly predict MCQ scores ( $F[1, 28] = 1.458, p = .237, r = .05$ ). When the ‘to know’ variable was added to the model it had no significant contribution ( $F[1,27] = 1.790, p = .192, r = .109$ ). A summary of the regression results is presented in *Table 3*.

*Table 3.* Summary of regression models for ‘stimulation’ and ‘to know’ intrinsic academic motivators as predictors for the MCQ score for each cognitive load condition.

Con	df1	df2	R	R <sup>2</sup>	F	$\beta$	p	r
SC (stim)	1	28	.261	.068	2.054	.261	.163	.07
SC (know)	1	27	.264	.070	.040	.049	.844	.07
SA (stim)	1	24	.129	.017	.405	-.129	.531	.017
SA (know)	1	23	.145	.021	.102	-.108	.753	.021
M (stim)	1	28	.222	.049	1.458	.222	.237	.05
M (know)	1	27	.330	.109	1.790	.276	.192	.109

## Discussion

Our results showed that presenting information through both visual and auditory formats aided learning and understanding. Participants in the modality condition, where astronomy concepts were presented in both an auditory and visual format performed better than those who only had a visual display or who had information split between different sources. Results from this study are in line with other research that has been done using the cognitive load paradigm. These have shown that people tend to learn and process information differently, based on the format in which this information is presented to them. It seems that people process information most effectively when the presentation format is of an audio-visual type. However, there were no significant relationships between the 2 variables of intrinsic academic motivation and performance in the three cognitive load conditions. How these findings relate to the learning and teaching environment will now be discussed.

### Cognitive Load as an Influencing Factor in Learning Outcomes

The first hypothesis was confirmed by the results of the study, and supports previous research done in this area. Studies such as that conducted by (Mayer & Moreno, 2003) and Florax and Ploetzner (2010), have produced similar results to this study. The split-attention effect tends to tax cognitive resources unnecessarily, leading to unfavorable learning outcomes. Cognitive architecture is not designed to process information in this manner and experiences a reduction in its working ability when stressed. In this study participants scored poorly on the split-attention condition, ( $M = 4.43$ ,  $SD = 0.8$ ). Instructors in schools and universities are often ignorant to principles governing cognitive architecture, comprehension and learning. This could allow them to unintentionally attempt to teach their students in a manner that is not geared towards making the most efficient use of the available cognitive resources of the individual (Sweller et al., 2011).

The modality condition showed favourable learning outcomes, with a few participants even scoring close to 10 ( $M = 7.03$ ,  $SD = 1.6$ ). This supports the second hypothesis. The dual modality format has the advantage of eliminating the need to create a mental representation of a concept, as one is able to see what the concept looks like on screen. This visualization helps to reduce the extraneous load by allowing one to 'see' the concept. The astronomical concepts used in this study were all vivid and colorful. The vividness of the colours could have contributed to better element interactivity by being highly stimulating. In the visual conditions participants could have been distracted by the text and not focused so much on

associating the text with picture. Effects that promote ‘seeing’ concepts and processes rather than having to grapple with representations of them could be used to break down certain types of materials into easier to process pieces. For example, in a field like physics, which is related to astronomy, everything is represented by symbols and equations, the element interactivity is very high (Ornek, Robinson and Haugan, 2008). A reason as to why this field is seen as difficult to many students is because it involves concepts which are abstract and not part of everyday experience (Ornek et al., 2008). Thus, the schemas for understanding physics are unusual and not easy to form. The instruction format for physics typically involves understanding mathematical concepts rather than visually seeing physical processes as they actually occur (Ornek et al., 2008).

According to the principles of cognitive load theory, a lack of understanding corresponds to a lack of schema formation (Schnotz & Kürschner, 2007). If a student is struggling to acquire new schema for a relevant concept, it is likely that he is failing to ‘see’ all the different elements of that concept and how they interact with each other. Often students fail to grasp certain concepts because the elements that make sense of the concept are also foreign (Sweller, 2010). This is where the modality principle could be best applied, as it could reduce the load associated with high element interactivity while helping the student to first acquire the most basic elements and then gradually build upon them until the level of element interactivity eventually reaches that of the concept being studied (Sweller, 2010).

In this study the element interactivity would have been high for those participants who had no background in astronomy. Several terms in astronomy like ‘gravitational lens’, ‘hyperspace’, ‘neutron star’ etc. might have been foreign to them. This could have had an impact on the scores, irrespective of which cognitive load condition the participant was subjected to. If the participant did not know what a neutron was then it would have been more difficult to gauge the definition of a neutron star. On the other hand certain participants could have performed well due to a general interest in science and scientific principles.

### **Intrinsic Academic Motivation and Cognitive Load**

The results from this part of the study proved insignificant and the third hypothesis was not supported. There appears to be no noticeable relationship between intrinsic academic motivation predictors ‘stimulation’ and ‘to know’ for the spatial contiguity condition. This could be regarded as a medium level cognitive load condition, as there is no split visual

format involved, neither is there the benefit of the modality condition. Looking at the  $R^2$  values for this condition tells us that the 'to know' category hardly adds anything to the predictor variable 'stimulation'. The  $B$  values for both are positive but there is no significant relationship. Spatial contiguity might not be reducing extraneous load or inducing it strongly in order for a significant relationship to be found.

A slightly different pattern can be seen with the 2 academic intrinsic motivators for the split attention condition. The  $p$  value is insignificant and there is barely any change in the  $R^2$  value but the  $B$  values are negative for both predictors. This could possibly suggest that as one more stimulation and knowledge under the split-attention format, the more likely one is to attain a poor test score. The modality condition also shows insignificant results for the 2 intrinsic academic motivational categories. The  $R^2$  value changes more than it does in the other 2 cognitive load conditions, and the  $B$  value is positive.

Simply because no significant relationships were found between cognitive load tasks and intrinsic academic motivation does not imply that such a relationship does not exist. The duration of this study was very short and there were only 4 items for 'stimulation' and 'to know' each. In this short space of time with only 4 items per category it would have been difficult to get an accurate idea of how intrinsically motivated the participant was.

Despite having found no significant relationships between cognitive load and intrinsic academic motivation in this study, there is still good reason to believe that they are related in some way. Ryan and Deci (2000) showed that when students are intrinsically motivated they tend to experience more positive learning outcomes. Broers (2009) found that when students are given a difficult task that they do not understand they are likely to go into a state of helplessness, especially if they receive no guided instruction. This might shed some light on the negative beta values seen for the split attention condition. However, highly intrinsically motivated students tend to persist with a difficult task and are less likely to give up as easily as others (Broers, 2009).

## **Limitations**

There were some limitations to this study. The first was the issue of generalizability. Since only the datasets of female participants were used, the results would be difficult to generalize to the rest of the student and wider population. In addition, this study was run in a controlled laboratory setting, and it is possible that people tend to be affected by other factors

that affect their processing in the real world. Thus, a more representative sample of the population is required.

Another limitation was the use of self-report measures. There was no objective way of determining if participants had some sort of background in astronomy. Although all participants claimed that they had no background, it is possible that some of them did have some associated prior knowledge about presented concepts, independent of the test. This could have biased some of the results. The AMS was also a self-report measure. Academic motivation is a rather personal attribute, and participants are likely to miss-represent how academically motivated they are, on numerous predictor variables, including the intrinsic variables of 'stimulation' and 'to know'. An over-representation of intrinsic academic motivation could have led to insignificant correlations with respect to the outcome variable if the participant had performed less than adequately.

### **Future Directions**

Having a cognitive load theory basis for teaching in classrooms could allow the instructor to develop materials for the student to learn from in a way that corresponds to the level of element interactivity that the student requires in order to successfully exercise germane load a form new schema. This will not only lead to a more productive student, but is likely to also help the student to learn how to learn.

One of the ways to enhance this type of study would be to look at neural correlates of the learning effects described by cognitive load theory. The very same hypotheses could be used. What would be different is the method and instrumentation. If the study was carried out using an fMRI scanner, the participant would be required to mentally perform various tasks while having the activity in her brain closely evaluated. This would allow us to see exactly which parts of the brain show signs of increased activity when the participant is being exposed to a specific visual condition or the audio-visual condition. It would also allow the researcher to see just how much a certain area or areas light up at precise moment in the task, giving a good insight into where and when exactly neutrally-correlated mental effort peaks and drops.

In addition to being able to evaluate all the structures and neural correlates of various aspects of cognitive load activity, researchers would also be able to look at how the motivational factor comes in. By focusing on brain regions associated with motivation, one

could tell whether a participant claiming to be high motivated really displays the sort of brain activity known to be associated with this. Furthermore, if the participant is being deceptive about the level of motivation associated with learning, this should in turn activate a different pattern of activity. This would then allow researchers to not only be able to provide neuroscientific evidence for genuine differences in brain activity associated with spatial, split-attention and modality conditions, but also provide such evidence for extraneous load, germane load and the role of motivation in the broader picture of processing and learning. From this type of framework could emerge a more robust understanding of how the brain really processing incoming stimuli, which could then provide a way of maximizing these processes. This could potentially lead to a model that becomes incorporated into the teaching curriculum of educators.

### **Conclusion**

This study set out primarily to test the cognitive load theory (CLT) by examining three core effects that form its framework. The experimental data for all three of the conditions proved statistically significant and supported previous literature on the topic. The notion that the most favourable learning outcomes occur under an audio-visual format rather than a purely visual (either split or integrated) format appears well supported. Since academic motivation is also known to play a significant role in learning outcomes, and since it is not covered with the framework of cognitive load theory, it was incorporated into this study in the form of a survey instrument. Studies have indicated that there is a link between intrinsic motivation and learning. These studies need to be expanded so that they start to look at cognitive load and intrinsic academic motivation. In order for cognitive load studies to become more scientifically robust, they need to incorporate factors such as academic motivation, personal cognitive ability etc., and need to develop ways of explaining differences in terms of underlying neural correlates rather than the less rigorous descriptions typically used in other branches of psychology.

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