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The Effect of Simultaneous Cognitive Module Interaction

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Abstract

The current study looks at the relationship between cognitive modules when they are competing for cognitive resources during multitasking. The brain is an efficient organ in that it attempts to minimize the amount of energy wasted during tasks. To this end, organized networks of neurons (or *cognitive modules*) ensure that response to specific stimuli occurs as quickly and efficiently as possible by interpreting and responding to specific stimuli. In an attempt to determine the nature of poor performance during spatially or language oriented tasks, four groups of participants were evaluated on their ability to complete a multitasking exercise where tasks are oriented towards either the spatial or language modules. Results indicated that there was no significant difference between groups where one module completed two tasks or when two modules completed two tasks.

The Effect of Simultaneous Cognitive Module Interaction

There are a number of mechanisms within the mind responsible for interpretation and behaviour in response to an environmental stimulus (Carlson, et al., 2010). These internal mechanisms are accountable for the encoding of environmental stimuli, based on the relationships these stimuli share with other scripts and schemas that have been stored in the brain (Domjan, 2006). However, because these cognitive mechanisms cannot be directly perceived, they are inferred by behaviour, and remain a theoretical construct (Domjan, 2006). How cognitive mechanisms interact with each other, as well as what effect this interaction has on performance and mental health is still under great scrutiny. Additionally, a growing concern over the prominent use of media platforms (such as computers, cell phones, mp3 players, hand held gaming devices, etc.) has caused researchers to ask what kind of effect constant access to multitasking has on our cognitive performance. The current study seeks to address some of the concerns of between-module relationships.

Influenced heavily by the functionalist paradigm and an evolutionary approach to psychology, it is commonly understood that these mechanism or *cognitive module*s, are an adaptive advantage because this organization in the brain allows for efficient behaviours to respond to specific situations (Friston & Price, 2011). This modern understanding of the organization of the brain provides us with the idea that the brain is a structured organ with modules responsible for specific tasks. Organization allows for specialization in the brain, creating an efficient and economic mechanism for manifestation of behaviour and homeostasis of bodily functions. This arrangement is demonstrated through the evidence of stroke patients who suffer from a cerebral hemorrhage. For example, a patient who suffers from brain damage localized near the hippocampus may suffer from a loss of memory performance (Jarrett & Ginsburg, 2013).

Also under scrutiny is the nature of the cognitive module according to different paradigm definitions, and whether modules substantially communicate with each other (Henson, 2011). Part of the issue with studying cognitive modules is that there are many definitions among researchers as to what exactly are the theoretical constructs that make up a cognitive module (e.g., are they isolated or localized?) (Henson, 2011). Research using fMRI scans has indicated that during multitasking the brain undergoes a tremendous amount of stress and may rely on other regions of the brain, even by depending less on regions that specialize towards that specific situation (Mizuno, Tanaka, Tanabe, Sadato & Watanabe, 2012). More so, research by Erikson et al. (2007) indicated that multiple areas of the brain are activated during dual-task processing and that after participants underwent training in a task, their performance not only increased but their brain activity in these regions was less active – indicating that as participants became more familiar with a task, activity in the brain became more concentrated and less chaotic as they performed better on their tasks. For the sake of this paper, cognitive modules are understood according to the evolutionary argument, that they are specialized areas of the brain organized for efficient behaviour in response to specific stimuli and that these modules are both individually and collectively malleable, working together to solve tasks (Pinker, 1997).

Unlike many computing systems which run serially (processing one task at a time), the human mind is seen to be able to conduct parallel processing as well as serial processing. However, cognitive modules simultaneous interaction with multiple activities has been seen to result in an abatement of performance in all tasks as a result of a limited availability of cognitive resources (American Psychological Association, 2006). The brain has a limited number of resources in which it can spend on a task and according to *cognitive load theory*, as a task approaches either a high or low complexity, the performance quality of the organism degrades on the task (Paas, Renkl, & Sweller, 2004). FMRI imaging indicates that the more similar two tasks are during multitasking, the more psychic strain is applied to the modules responsible for those tasks, resulting in poorer performance (Nijboer, Borst, Van Rijn, & Taatgen, 2014). While this ability to engage in two tasks simultaneously is under investigation, it is important to differentiate between three common manifestations of multitasking. Multitasking is considered to transpire when someone tries to perform two tasks at the same time (*dual-task processing*), perform two tasks in rapid succession of each other, or switches between two independent tasks in a process referred to as *task switching* (American Psychological Association, 2006).

Studies such as those conducted by Gopher, Armony, and Greenshpan (2000) attempt to demonstrate the cognitive costs that multitasking has on performance when participants who engage in task-switching are compared to participants who do not. Despite the fact that the participants used performance strategies, there were significant costs (low response rates) as a result of the task-switching multitasking. In the task-switching group, it was seen that the attentional shift between the two tasks was slower than in the non-task-switching group - indicating that participants in the task-switching group incurred some cost in switching between tasks (Gopher et al., 2000).

In order to better understand the differences in multitasking styles between those who are familiar with media devices and those unfamiliar with media devices, Ophir, Nass, and Wagner (2009) conducted a study whereby participants were required to identify themselves as either a heavy or light media user (those who engage in activities that use a television, cell phone, computer, etc.) and were then exposed to a task-switching exercise. The researchers hypothesized that because of their frequent use of multitasking while using media devices, heavy users would perform better than light users in the experiment. Contrary to the researchers hypotheses however, their familiarity with different forms of media had no positive affect their performance. In fact, heavy media users had higher (worse) response times than light media users. This may have occurred because heavy media users were trying to use dual-task processing, which was incompatible with the task-switching exercise. Ophir et al. (2009) theorized that multitask learning begins with task-switching and progresses into dual-task processing through practice. The high media users were unable to regress into task-switching processing because of their familiarity with dual-task processing (Ophir et al., 2009). The poor performance of high media multitaskers could be attributed to their inability to ignore dual-processing principles when they are presented with a task-switching exercise (Ophir, et al., 2009).

In a study attempting to build on the work of Ophir et al. (2009), researchers measured both task-switching and dual-processing cognitive mechanisms so as to determine whether the multitasking abilities of high and low media users correlate with performance during parallel or serial processing (Alzahabi & Becker, 2013). In the event that heavy media users performed better during dual-processing tasks than they did during task-switching exercises, the discrepancy would occur as a result of heavy media users' extensive use of task-switching abilities converting into dual-processing abilities (Alzahabi & Becker, 2013). Alzahabi and Becker (2013) found that high media multitasking experience had no effect in dual-processing tasks, but was instead associated with higher performance during task-switching trials - contrary to the results of Ophir et al. (2009). In an attempt to explain this discrepancy, the researchers state that frequent multitasking may reinforce the ability to rapidly shift between tasks (Alzahabi

& Becker, 2013). Additionally, the nature of the study does not take into consideration that multitasking may be task specific (i.e. high media multitaskers' skills may not translate across to other multitasking exercises) (Alzahabi & Becker, 2013).

The technological progress of the last two decades has given many insights into the cognitive mechanisms of the brain. Computer imaging creates visual representations of the pathways used during cognitive module interactions (Erikson et al., 2007; Henson, 2011; Mizuno et al, 2012; Nijboer et al, 2014). Despite this, there is still some debate as to how dual-task processing in the brain impacts specific cognitive modules. When a cognitive module is being used on two different tasks, research indicates that the quality of performance in the task will be diminished (Paas et al., 2004). However, when two different cognitive modules are being used in specific skill oriented tasks, how do they interact? Will quality of performance in both tasks be diminished or will they be unaffected? The following study seeks to determine whether, or how, different cognitive modules in the brain interact with each other when two modules engage in two tasks simultaneously, either on tasks that activate one module specific to that task, or tasks that activate alternate modules. I hypothesize that despite two different modules of the brain being used in the tasks, performance in all tasks will be diminished; but, not to the same extent as the performance on tasks where a single cognitive module engages in two module-specific tasks.

Method

Participants

Seventy undergraduate students (fifty-one female, nineteen male) provided informed consent before participating in the Algoma University Research Ethics Board (RED) certified study. Students ranged in age from eighteen to thirty-eight, with a mean age of twenty.

Participants were offered no compensation for their participation in the study; acting strictly as volunteers as per REB demands. Participants varied in their academic major – including Psychology, Biology, Socialwork, English, Computer Science, Music, Fine Arts, Law & Justice and Business. Upon entry to the study, participants were encouraged to provide basic demographic information including their age, major, gender and primary language.

Materials

Primary Spatial Task. The Primary Spatial Task was composed of a spatial module oriented task. This task was a packet of ten, medium difficulty, pen and paper mazes, with each page having only a single maze on it. Each participant was told that there was a single path through each of the mazes and that it was their task to find that path. Participants were allowed to start from the top of the maze, start from the bottom of the maze or complete the maze from both ends as long as the strategy helped them finish the task. Each participant completing the primary spatial task was also paired to simultaneously complete one of the distracter tasks.

Primary Language Task. The primary language task was composed of a language module oriented task, consisting of a two page packet of 47 randomly selected words ranging from low to high difficulty. Each word was misspelt through either the addition of a letter into the word, the removal of a letter from the word or the transposition of a letter within the word. Participants were instructed to correctly spell the word to the best of their knowledge, on the line adjacent to the misspelt word. Any line left blank was marked as incorrect. Participants were graded on the time it took to complete the task as well as how many they correctly spelled during the exercise. Each participant completing the primary language task was also paired to simultaneously complete one of the distracter tasks.

Distracter Spatial Task. An inability for the participants to synchronize two spatial tasks at the same time required the researchers to manipulate the exercise to include two different spatially-oriented distracter tasks. The spatial distracter task paired with the spatial primary task was modeled after 3D mental rotation tasks, composed of three smaller mazes located underneath the primary maze task they were asked to complete. Participants were instructed to complete the primary spatial task and then circle the maze that matched it out of the three smaller mazes found below the first. The second distracter spatial task is based on the primary spatial task, a 15 page packet of pen and paper mazes paired with the primary language spatial task. Participants were graded on how many mazes they were able to complete before finishing the primary task.

Distracter Language Task. The distracter language task was a language module oriented exercise composed of a list of 64 words ranging from low difficult to high difficulty. Participants were read aloud the list of words while completing the primary task. They were instructed to indicate whether the word was an adjective (adj), a noun (n) or a verb (v). Additionally, before the exercise began, participants were given a brief objective explanation as to what an adjective, noun or verb is. Participants were also told that it was possible for one word to act as multiple parts of speech. Since each of the words was not read in the context of a sentence, they were told to indicate any of the parts of speech a word may belong to. For example, if a participant was read aloud the word *'Bad'*, they could answer adjective, noun or adjective and noun - any answer would correspond as correct during grading of the distracter task. Participants were graded based on how many words they were correctly able to define, as well as how many they were able to complete before finishing the primary task.

Procedure

Participants were randomly divided into one of two experiments composed of two groups each testing simultaneous task performance. In experiment one, participants were asked to complete a primary task that activated the spatial module. While completing this task, participants were also asked to complete a distractor task. Depending on which group they were divided into, participants either completed another spatial module oriented task or a language module oriented task.

In order to control for differences in cognitive resource drain between the tasks in experiment one, a second experiment was designed. In experiment two, participants were asked to complete a primary task that activated the language module. While completing this task, participants were also asked to complete a distractor task. Depending on which group they were divided into, participants either completed another language module oriented task or a spatial module oriented task. Participants were only measured on the time it took to complete the primary task while distracted with the secondary task. This organization is best demonstrated in Figure 1 and Figure 2 in the Tables section.

Scoring. Over the course of the study, a number of factors were given consideration during statistical analysis. Highest consideration was given to the time it took to complete the primary task while distracted with either the spatial or language distracter task. However, the percentage of correctly answered distracter test questions was also examined.

Results

An α level of .05 was used for all statistical analyses

Experiment One

In experiment one, participants were measured on the time it took to complete the primary task while simultaneously completing a distracter task.

Time to complete primary task. The averages between the two groups were analyzed using t-test statistical analysis which was used to detect statistically significant differences between the scores of both groups. Group one (completed spatial primary, spatial distracter) took an average of 338.37 seconds to complete their task while group two (completed spatial primary, language distracter) took an average of 399.16 seconds to complete their task. These data are presented in Figure 3.

A between sample t-test indicated that T(df) = -1.443; there was no statistically signitifant difference between the time it took to complete the primary task in both groups.

Experiment Two

In experiment two, participants were measured on the time it took to complete the primary task while simultaneously completing a distracter task. Additionally, participants were also measured on their level of accuracy in completing the primary task.

Time to complete primary task. Participants were measured on the time it took to complete the primary task while distracted with a secondary task. These data are presented in Figure 2. Group one (completed language primary, language distracter) took an average of 441.33 seconds to complete their task while group two (completed language primary, spatial distracter) took an average of 402.46 seconds to complete their task. An independent sample t-test indicated that T(df) = 0.962, there was no statistically signitifant difference between the time it took to complete the primary task in both groups. These data are presented in Figure 4.

Accuracy of primary task. Participants were also measured on the number of words correctly spelt (%age) while distracted with either a language or spatially oriented distracter task. These data are presented in Figure 3. Group one (completed language primary, language distracter) scored an average of 70.2% correctly spelt words while group two (completed language primary, spatial distracter) scored an average of 73.2% correctly spelt words. An independent sample t-test analysis indicated that T(df) = 0.378; there was no statistically signitifant difference between the time it took to complete the primary task in both groups. In order to confirm these results, the data was transformed using x^1=2arcsin(sqrt(x)). There was no difference in results. These data are presented in Figure 5.

Discussion

No differences were found between groups in both Experiment One or Experiment Two. This indicates a number of things. Assuming that there was no discrepancies between participant's experience during their exercise and that the design of the experiment was flawless; the results would suggest that a single module completing two tasks oriented towards itself would appear to use no more cognitive resources than two modules completing two tasks. This is an inference, as the only thing that the data actually says is that group one and two performed the same in both experiments. But when we assume that the decrease in performance is influenced by an increase on cognitive load, we can conclude that cognitive resources are being used just as much in a single activated module exercise as they would be in an exercise that activated two modules. Why this occurred requires some speculation, as the data did not expressly pinpoint why there was no difference.

It could be that the cognitive resources that were assumed to be saved by sharing the energy burden between two modules, was actually spent in communication between the two modules used, as well as others. We should keep in mind that participants were not trained in the exercise they performed. According to the research by Erikson et al. (2007), which used fMRI imaging to observe the impact of training on multitasking, the brain relies on numerous areas of the brain when undertaking a task and only refines itself to using specific modules after training has occurred. It could be that because there was no training period in either exercise, the brain was still struggling to determine which modules were needed for the task it was completing. As such, it ended up spenting a great deal of cognitive resources communicating between different modules that may not have pertained to the task being completed. Although it was not empirically recorded, it was noted that as participants became more familiar with their exercise they were able to progress through it with much greater ease. Based on what the results have explicitely expressed, we can only conclude that during an exercise where the participants have not been trained, that those tasks who actived one module will perform just as well as those who that activated two modules.

However, it should be noted that there were some flaws in the design of the study. For example, it was incredibly difficult to have a participant engage in two spatial tasks simultaneously, as it was impossible for them to actively divide their eyesight between the two tasks. Thus, we could not ensure that they were engaging in dual-task processing. Rather, it was more likely that they used task-switching processing for the whole of the exercise. It should be noted that other exercises experienced similar problems. In experiment two, the primary language task had to be read to the participant so that they were able to look at the spatial task (and thus encouraging the use of dual-task processing). However, because this primary task was expressed across a different medium (through audio rather than through visual represenation), there could be discrepancies in the difficulty of the tasks between groups.

Future research should seek to control any variances between between task difficulty and ensure that there is consistency between the mediums used in the study (i.e. primary task is conveyed on a visual medium and distracter task is conveyed on an auditory medium). It may be worth looking into the use of an alternative module to substitute for the spatial module – as it's qualities (reliance upon a visual medium) presented some unique obsticles.

Tables

Figure 1 (shows the design of Experiment One)

	Primary Task	
Distracter Task		**Spatial**
	Spatial	Group One
	Language	Group two

Figure 2 (shows the design of Experiment Two)

	Primary Task	
Distracter Task		**Language**
	Language	Group One
	Spatial	Group two

Figure 3 (Visual representation of the difference in time taken to complete the primary task in Experiment One)

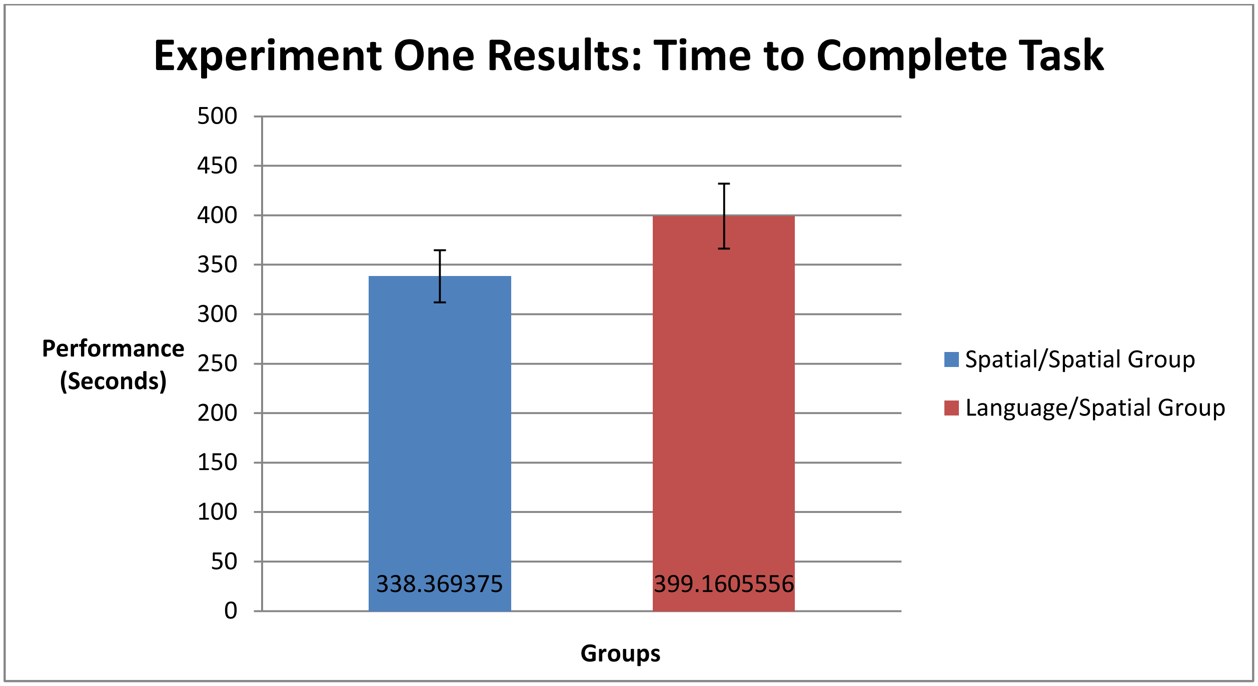


Figure 4 (Visual representation of the difference in time taken to complete the primary task in Experiment Two)

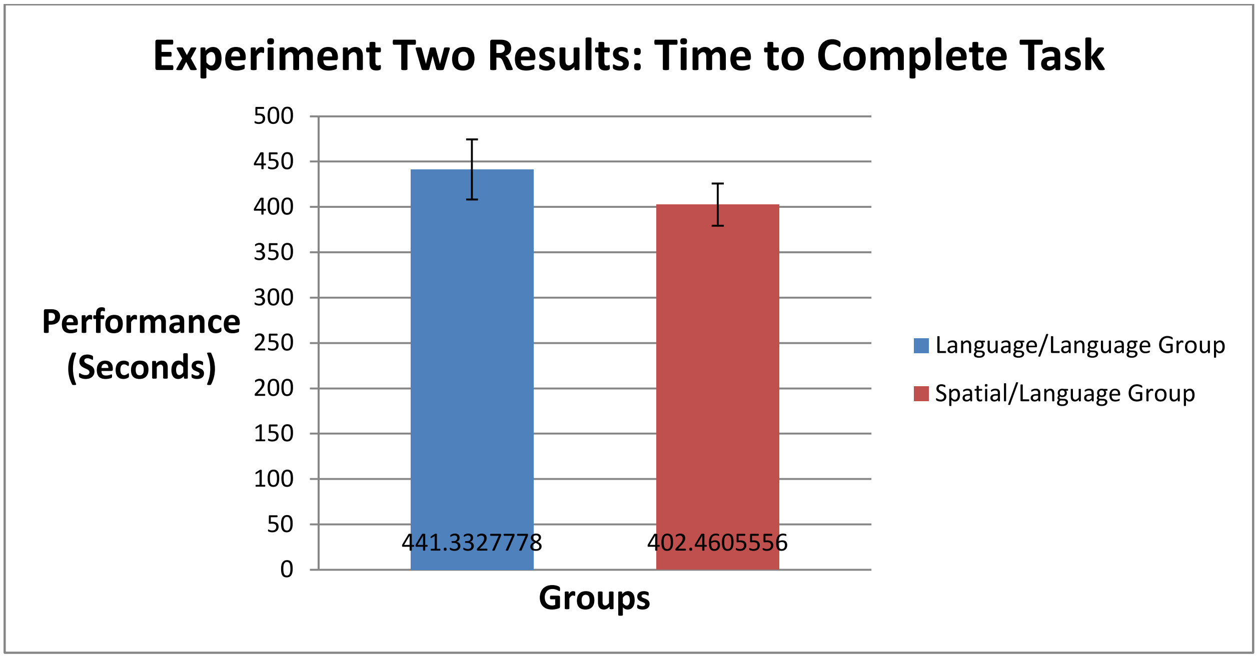
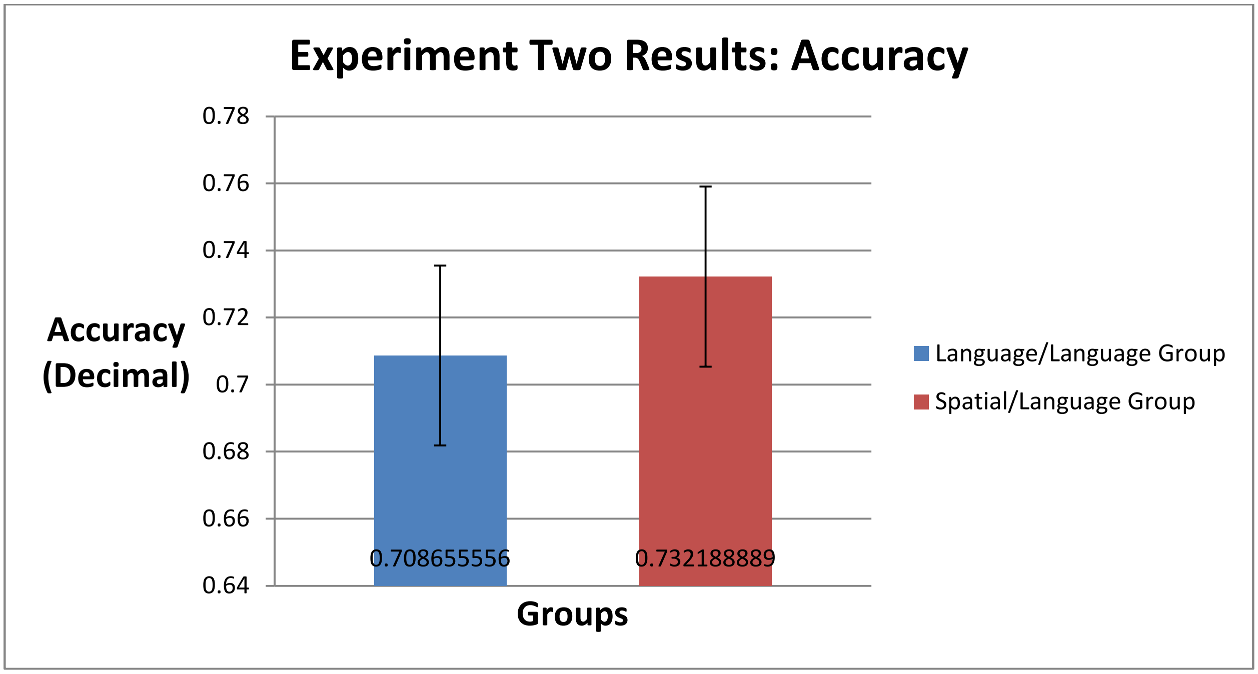


Figure 5 (Visual representation of the difference in Accuracy for the primary task in Experiment Two)



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