STUDY HABITS AND MUSIC: HOW THEY AFFECT ATTENTION AND ACADEMIC PERFORMANCE

by

Michael S. Widerman
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Committee:

_______________________ Director

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_______________________ Department Chairperson

_______________________ Dean, College of Humanities and Social Sciences

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Michael S. Widerman
Bachelor of Arts
McDaniel College, 2008

Director: Timothy W. Curby, Professor
Department of Psychology

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DEDICATION

This is dedicated to my mother, Debra Mancuso, my father, Jeffrey Widerman, and my grandparents, Nicholas and Barbara Boxwell, and Claude and Katherine Widerman for all of their support and love.

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ABSTRACT

STUDY HABITS AND MUSIC: HOW THEY AFFECT ATTENTION AND ACADEMIC PERFORMANCE

Michael S. Widerman, M.A.

George Mason University, 2013

Thesis Director: Dr. Timothy W. Curby

This thesis examines how the application of different study modalities (deep/surface-level) and stimuli (music) while studying may affect how engaged students are and how well they perform academically. 20 participants studied both long reading comprehension passages and vocabulary words/definitions before being tested on each type of material. Half of the participants listened to self-selected music, as they studied, while the other half of participants studied in silence. Cerebral blood flow velocities (CBFV) while studying, which indicated levels of sustained attention, were obtained for all participants through use of transcranial Doppler sonongraphy (TCD).Results indicated that participants struggled to remain attention as they continued to study. This decremented effect was further shaped by differences between hemispheric CBFV values and the type of studying that occurred. CBFV values remained more concordant between hemispheres during deep-level studying than surface-level studying.

APPROACHES TO STUDYING

Studying for tests and exams is an activity which is integral to any college student's academic success. Students often review class material prior to taking an exam to ensure that they are knowledgeable on the key concepts and ideas. Though the need to study is nearly universal, the exact study habits and methods utilized by students span a broad range of techniques. Past research has described several of these study habits Marton & Säljö, 1984; Hay 2007). However, the ultimate success of any one technique over another may not entirely be dictated by the material to be studied and the personal study habits of the student. Study settings may differ greatly in terms of the external stimuli present in the surrounding environment. Some of these stimuli, such as music, may be chosen by the student, depending on his/her personal study preferences. Students regularly listen to music while studying as a way to help them stay engaged in studying (Beentjes, Koolstra, & van der Voort, 1996). Although many students view listening to music as helpful, it is unclear whether listening to music actually helps students sustain their attention while studying. In fact, under some circumstances, listening to music may actually be a distraction. The purpose of this study is to examine how the students' study habits combine with whether or not they are listening to self-selected music to predict sustained attention and performance on academic tasks.

An initial investigation of the past literature on how music affects cognitive performance, particularly in academic facets, will first be explored. The use of self-selected music specifically and any potential benefits of listening to such will also be examined. In order to consider how self-selected music may be used in various study scenarios, a breakdown of the study habits continuum will be provided. The role which attention may play while studying, in combination with listening to music, will be reviewed as well.

Music and Performance

There are reasons to believe that music may be both helpful and hurtful to effective studying given different conditions. There have been multiple studies demonstrating the negative effects associated with listening to music. Deficits in short-term memory have been detected for various types of music (Salamé & Baddeley, 1989). Vocal music (i.e., songs with lyrics), followed next by instrumental music, was found to hinder memorization more so than other noise or silence. When completing a stock price calculation task, students who listened to rock music (fast-paced) performed better than those listening to slow-paced music (Mayfield & Moss, 1989). However, the authors do make a point to note that the subjective level of distraction was higher in the rock music group; a finding that has received repeated evidence.

Recently, Tze and Chou (2010), assigned Taiwanese college students to one of three music conditions (classical music, hip hop music, or no music) and asked them to complete a reading comprehension task while the music played. The results showed that that those students in the music-free condition performed best, followed by those in the classical condition and finally those in the hip hop condition. Tze and Chou concluded that studying in a quiet (i.e., music free) environment was best as it possessed fewer distractions. Similarly, Martin, Wogalter, and Forlano saw participants struggle to block out background music containing meaningful words, but not nonsense words or purely instrumental pieces, to the extent that their reading comprehension was impaired (1988).

Alternatively, there is also an extensive history of findings which report the positive effects of listening to music. For example, improvements in reading comprehension in the presence of background music were clearly seen in Hall's classic (1952) study with eighth and ninth grade students when background music was played during study hall. Those students who were deemed 'below average intelligence' showed an increase in their scores on the Nelson Silent Reading Tests. More recently, children with emotional and behavioral difficulties scored significantly better on mathematics questions when background music was played in the classroom (Hallam & Price, 1998). Listening to background music also yielded increased problem completion in a study of students taking an arithmetic exam, though overall arithmetic performance remained unchanged (Hallam, Price, & Katsarou, 2002). Similarly, increases in reading comprehension performance have been found for students who listened to music while working on academic tasks (Beentjes, Koolstra, & van der Voort, 1996; Črnčec, Wilson, & Prior, 2006).

Another well known finding in this area is the Mozart Effect, which refers to potential increase in levels of spatial-temporal reasoning after listening to classical music (Rauscher, Shaw, & Ky, 1995). College students who listened to Mozart's Sonata K. 448

over the course of three days showed significant improvement on the Paper Folding and Cutting tasks of the Stanford-Binet Intelligence Scale and 16 short-term memory items. It should be noted that even though this finding has received much publicity, it is not without its criticisms. Several studies seeking to either replicate or disprove these findings have found fault with the original results, claiming that they may either be an experimental artifact (Jones & Estell, 2007), or that they are simply not replicable in repeated trials or in a broader population (Steele, Bass, & Crook, 1999).

Regardless of these criticisms, Rauscher, Shaw, and Ky (1995) suggest that an underlying element in the effect they found might be that listening to music induces more organized and excitatory cortical firing patterns in the participants' brains. This sentiment was guided by a theory proposed by Leng and Shaw (1991), known as the "trion model". The trion model suggests that music-related activities share underlying neural firing patterns with other cognitive mechanisms in the brain. As such, listening to music may prime neurons for use in other capacities (e.g., spatial performance tasks). Relatedly, near transfer theories suggest that learning during musical instruction, specifically, may be applied in other cognitive functions (Rauscher, 2002, Schellenberg, 2001).

Listening to music has long been thought to play a role in increased productivity in the workplace (Uhrbrock, 1961). The believed benefits include increased production output in young employees while performing repetitive work. The effect of music has been found to significantly increase performance, organization, satisfaction, and mood states for retail workers who preferred to listen to a stereo on the job (Oldham, Cummings, Mischel, Schmidtke, & Zhou, 1995) More recently, office employees who listened to music through their personal computers or headphones reported increases in their inspiration and concentration towards work tasks (Haake, 2011). College students also benefitted in comparable fields from listening to music; they showed improvements during manual assembly and letter-matching tasks, and significant improvements in mental tasks (Konz, 1962).

Perhaps most interesting in terms of the positive effects of music, has been that it serves many functional purposes. These functional purposes do not lend themselves to being measured empirically; rather they function as aids to enable enhancements when performing a wide array of tasks. In the aforementioned study by Hallam and Price (1998), not only did students with emotional and behavioral difficulties show mathematical improvements when background music was played, but the act of listening to music itself may have satisfied some “stimulus hunger” in these students (Hallam & Price, 1998). In essence, the music may provide just enough stimulation for someone beginning to be distractible or restless that they are able to stay engaged in the task at hand. This notion of stimulus hunger, originally proposed by Eysenck (1967), referred to a personal attribute found in extravert test subjects. In general, extraverts possessed innate sensation/arousal seeking behaviors (i.e., stimulus hunger) in reaction to incoming stimuli, that is, they seek an increased level of stimulation. (Conversely, introverts possessed “stimulus aversion” and seek diminished levels of stimulation). Davies and Hockey (1966) found that the presence of high intensity white noise fulfilled stimulus hunger in extraverts and helped facilitate better performance on a task of visual vigilance. Furthermore, the white noise also led to increased cortical excitation, which too was related to the task performance. Although some research traditionally felt only extraverts display stimulus hunger, other studies have found the differences between introverts and extraverts to be small (Gale, 1969; Elliot, 1971). Of the studies referenced, only a handful (Beentjes et al., 1996; Haake, 2011) allowed participants to full control in the selection of the music that was listened to. Other studies allowed participants to select from a pre-determined collection of song choices (Oldham et al., 1995; Hallam & Price, 1998; Hallam et al., 2002). In relation to this study then, the complete control of musical selections may satiate a stimulus hunger for students while studying.

Self-Selected Music

Martin et al.'s (1988) finding may stand in stark contrast to the above studies promoting music's ability to enhance reading comprehension (Hall, 1952; Beentjes, Koolstra, & van der Voort, 1996; Črnčec, Wilson, & Prior, 2006), yet some of that variability may lie in the interaction between specific genre of music present and each person. Hall's study only described the music as "background", making it nearly impossible to discern which genre the music was. In the Beentjes et al. study, the genre of music that students most preferred to listen to was pop, house, and rock. In Črnčec et al. the music was only described as 'soothing.' Such descriptions are too ambiguous though, as each of these genres may be differentially distracting or helpful to different people. Personal representations of soothing and calming music rely on the individual musical tastes of each participant. Furthermore, listening to self-selected music almost always results in a person listening to music that they've heard before. In experimental conditions with researcher-selected music, this may not be the case, and participants may in fact be distracted by the novel music. The present study will address these shortfalls by letting participants self-select musical pieces. By doing so, an individual can tailor their auditory environment to help induce certain moods and feelings.

An exploratory study by Bjerke Batt-Rawden (2010) outlined several of the advantageous effects of listening to self-selected music. Although the advantages of the self-selected music are seen, these studies are not taking place in the context of learning environments. These included improving patient outcomes in psychiatric settings (Covington & Crosby, 1997) and enabling someone to recall memories while working through grief situations (Wigram, Nygaard Pedersen, & Bonde, 2002). Bjerke Batt-Rawden made use of self-selected music to investigate the effect it had on the health and well-being of people with either past or present chronic illness (both mental and physical ailments). While the results were congruent with past studies and beneficial across numerous facets, the real point of interest is gleaned from the participants' anecdotes. One participant noted that they needed "steadiness and predictability" in their lives in order to combat anxiety, and that self-selected music provided certain calmness for them (p. 306). This predictability goes hand in hand with self-selected music; it is familiar and non-alarming, so it allows one to remain calm. Other anecdotes made mention of self-selected music as a motivational device which helped them to "move out of low moods or depression" (p. 305). Here, self-selected music can be thought of as a facilitator for productiveness and drive. It has been shown above to apply to non-ill populations and increase overall productivity, such as in work settings (Oldham, Cummings, Mischel, Schmidtke, & Zhou, 1995). Certainly, if self-selected music could assume such a dichotomous role as both a relaxation and motivational device, it would be of great benefit to students trying to remain calm, yet productive, in their study efforts.

In a study by Burns, Labbé, Williams, and McCall (1999) music choice had a significant effect on levels of reported relaxation. Participants who listened to self-selected “relaxing” music for 15 minutes showed greater increases in perceived levels of relaxation against baseline (57%), than did those who listened to either hard rock (26%) or classical music (39%) for the same time period. However, those participants who were not given any music and sat in silence showed comparable levels of relaxation (58%). It should be noted though that the experiment did not include any stressor as a means for manipulating the levels of relaxation in the participants. In a follow-up study by Labbé, Schmidt, Babin, and Pharr (2007), the inclusion of a “cognitive speed test” acted as a stressor in order to induce a pre-baseline state of arousal and anxiety. The 10-minute cognitive speed test was quite representative of study material that a student might cover before an examination; 80 simple calculations; 16 difficult mathematical operations; 8 number memory items (string of 9-10 single digits); 12 difficult verbal analogies, and spelling 14 difficult words (Labbé et al, 2007). After the test, participants were assessed on various scales of relaxation and state (e.g., present) anxiety and then listened to either self-selected, classical, heavy metal, or no music (i.e., silence) for 20 minutes before being assessed again. Results indicated that self-selected, classical, and no music led to significant increases in relaxation pre- and post-music, though not heavy metal, with the self-selected condition having the largest increase. Self-selected and classical music also led to significant decreases in state anxiety between pre- and post-music, while neither heavy metal nor silence did. It appears that when absent stressful stimuli, a participant feels near equal increases in relaxation when either sitting in silence or listening to self-selected music. However, when a stressor (such as studying for a test) is introduced, listening to self-selected music has been shown to be more effective at increasing levels of relaxation, while also reducing state anxiety, over merely sitting in silence.

Coupling the results from these studies then, it is plausible that self-selected music, an active and engaging stimulus, may function as a helpful distraction in stressful scenarios and provide much needed relief and stimulation. Therapeutic techniques known as "focused distractions" are a coping mechanism whose intent is to distract the patient from centering on negative or disruptive thought processes. The use of focused distractions has been shown to be effective across numerous contexts, each more extreme and stressful than academic studying (Hattori & Kawaguchi, 2010, Vickers & Vogeltanz-Holm, 2003; Li, DiGiuseppe, Froh, 2006; Gidron, Gal, Zahavi, 1999; Kristjánsdóttir & Kristjánsdóttir, 2010). However, Gaudrea and Blondin (2004) provided evidence that focused distractions may be advantageous even during task performance. They discovered that distraction-oriented coping coupled with elements of task-oriented coping led to better mood and increased goal achievement over distraction-oriented coping alone.

Evidence of music's potential as a focused distraction was observed in an exploratory study by Haake (2011). Reports from office workers who listened to music described that the music helped them concentrate on their daily activities that were otherwise monotonous. As referenced before, listening to music through headphones was especially beneficial as it provided familiar stimuli while blocking unfamiliar external stimuli. Moreover, this serves as an example of the dual functionality which self-selected music may assume. Haake found that music had the potential to serve as both a motivator and a focused distraction. While enabling better engagement in office workers' daily activities, music also provided a "diversion and prevented employees from engaging in other distracting [behaviors]" (p. 117). One worker specifically noted that if she had not been listening to music while working, she would have done “something unproductive [,] such as fiddling with papers or gazing out of the window” (p. 117). Additionally, Haake proposes that the music may have also served to aid in their thought processes during complex tasks more so than simple ones. This notion from Haake suggests that an active combination of listening to music and studying may be a beneficial study strategy, with music supplementing as an effective study aid. Perhaps listening to music enables one to cope with any negative feelings associated with studying (e.g., boredom, fatigue) and avoid truly distractive behaviors (e.g., leaving the study environment). Recently, it has been seen that when students are able to prevent their thoughts from wandering off, they display improved long and short-term performance (Nonis & Hudson, 2010).

This idea that music can promote on-task behavior ties back into Hallam and Price’s (1998) proposition that music is capable of satisfying some level of “stimulus hunger” in someone who becomes distracted. When music serves as a “focused distraction”, it allows task performance to continue, as opposed to other media programs. In the Beentjes et al. (1996) study, students who watched television while working on their homework felt that their performance suffered more when news, sports, talk shows, game shows, and drama programs were on, than when music programs were on. Self-selected music may be innately distinct in that it allows for a basic level of sustained attention, without become overly burdensome. One is not required to provide feedback to music, such as during a conversation with another person, nor must they process plot developments or storylines, such as when watching a drama series. Similarly, the sentiment that music with low information-load yields optimal conditions for activities such as reading comprehension tasks has also been shown (Kiger, 1989). Again, self-selected music will most always possess a low-information load, regardless of its genre and characteristics, as it is familiar to the listener, and can be chosen to meet the specific needs of the situation.

Study Habits

Just as a musical composition can be identified and analyzed via its characteristics, so too can the process of studying. In its simplest terms, studying can be classified into two categories: deep-level and surface-level study habits (Hay, 2007). Deep-level studying involves learning material by linking it with their prior knowledge of other material in a meaningful and organized way. The study habits that students utilize when engaged in deep-level study also include interpreting what they read into personally meaningful language and conceptualizing how the new material makes sense (Marton & Säljö, 1984).

Hay (2007) utilized concepts maps to demonstrate the mental representations and cognitive processes which occur when someone is engaged in either deep or surface-level studying. These concept maps, as outlined by Novak (1998), use boxes and lines to illustrate a hierarchy of connections made between different mental concepts when a person is learning. In Hay's study, 12 graduate students were required to construct concept maps before and after taking a class on interviewing techniques. By comparing the maps before and after the training, Hay found distinctions between deep-level, surface-level, and non-learning. (Here, non-learning simply refers to concepts maps which were absent of either type of learning when comparing before and after maps.) Deep level study was suggested by strong explanatory statements in the second maps such as "interviewing using different approaches including structured, semi-structured, and conversational," as compared to the first maps which simply stated that "interviewing using different types of questions." The presence of deep level study is evident due to a more precise knowledge structure in the second map which imparts increased conceptual meaning to its author. Contrastingly, surface level study was evidenced in the second maps by relatively vague clustering of various interviewing concepts such as "ethical issues; good relationships; respect; environment", without any distinct hierarchical connection. Compared to the author's first map, the only changes made pertained to vocabulary terms, yet neither of the maps illustrated any meaningful linkage between concepts.

Surface-level studying occurs when a student learns new materials but does not integrate it with their past knowledge (Hay, 2007). As seen in the simple introduction of a novel set of terms, the newly acquired knowledge does not possess the same meaningfulness as that knowledge which is learned through deep-level study (Marton & Säljö, 1984). Students primarily employ such techniques as memorization, recopying one's class notes, and extensive highlighting of the study material, rather than any type of encoding during surface-level study. A key reason for this distinction might be that surface-level studying involves merely memorizing the details about the study material, rather than making significant mental representations regarding its meaning and importance. The underlying reason for this disparity might lie in the fact that surface level study entails vastly different study habits as compared to those used during deep-level study.

The decision to engage in either deep-level or surface-level studying over the other may depend on what type of material a student feels is necessary to be familiar with in order to succeed on an exam (Marton & Säljö, 1984). Given that deep-level study leads to increased conceptual understanding and knowledge, it may be best utilized when studying for tests that require very involved and well-thought out answers. Past research has summarized that a student studying for long essay questions is more likely to use a deep-level approach, while a student will most likely use a surface-level approach when studying for multiple choice questions (Crooks, 1988; Nonis & Hudson, 2010). Davidson (2002) found that when students studied with deep-level study, they performed better on complex test questions. This did not hold true for simple test questions. Surface-level techniques, such as rote memorization, may be both an appropriate and time efficient strategy if a student is only preparing for short, fact-based questions. Indeed, students who adopt a surface-level approach are able to recall more factual and detailed information, though the information is usually not retained for longer than a week (Biggs, 1979). While both complex and simple assessments can require a mix of deep and surface-level study (Marton & Säljö, 1984), it is clear that each type study is better suited for different types of questions.

Level of processing theory adds perspective to the cognitive functioning present during deep and surface-level studying. Levels of processing (LOP) theory represents the notion that information can be encoded at various levels, or "depths" as they enter the brain for storage, and that depth of coding can affect later recall and manipulation (Craik & Lockhart, 1972). According to the theory, information which is encoded at deeper levels will be retained for longer and can be used for more complex manipulation. Semantic coding and linkage to past knowledge is indicative of deeper processing; while phonemic analysis is indicative of shallower processing. In this sense then, LOP theory can serve as a correlate to the study habits spectrum, ranging from deep to surface-level habits. Presumably, any information which is studied using deep-level techniques will be subject to deeper levels of processing also. It can then be expected that this material would be able to be recalled more efficiently and be can used for more elaborate analysis. Material which is only studied using surface-level study habits would be expected to be available only for more basic analysis.

In a study by Ross et al. (2006), it was shown that the depth of level of processing affected outcomes on various types of tests. When university students employed a deeper level of processing to prepare for an examination, they performed better on tests requiring more complex understanding of the material. Conversely, when they used a shallower level of processing while preparing, they performed better on questions based on memory and basic understanding of the material. Bugg, DeLosh, and McDaniel (2008) also revealed that undergraduate students' recall ability for newly presented words was significantly better when using semantic processing rather than phonological or orthographic processing. These findings fit well in line with those regarding the effectiveness and use of different study habits (Marton & Säljö, 1984; Crooks, 1988; Nonis & Hudson, 2010; Davidson, 2002). Attention also plays an interactive role with varying levels of processing. Focused attention, rather than divided attention, during encoding of vocabulary words led to better recall afterwards (Troyer &Craik, 2000). Mahdavian and Kormi-Nouri (2008) found a similar interaction, such that college students were better able to recall items committed to explicit memory when they were more focused and used deep processing.

Attention

Another way to think about the notion of studying while listening to music is to examine the amount of attention required by these activities. As seen above, the ability to remain attentive during a given task plays a definite role in shaping one's overall performance on the task. Deep and surface-level study habits may require differing levels of sustained attention. Deep-level study habits may require a greater amount of sustained attention in order to develop the rich connections made between concepts in the study material and link them to existing knowledge structures. With both deep and surface-level study habits being individually suited for specific types of test questions, sustained attention may be a factor in the academic outcomes. At the same time, several of the studies above include various populations which underline the noted link between concentration/attentiveness and task performance (Haake, 2011; Stainback, Stainback, & Hallahan, 1973; Tze & Chou, 2010; Martin, Wogalter, & Forlano, 1988).

One unique measure of sustained attention is transcranial Doppler sonography (TCD). TCD measures cerebral blood flow velocity CBFV) by measuring a Doppler signal in three specifically honed arteries in the brain which constitute part of the Circle of Willis: the anterior cerebral arteries (ACA), medial cerebral arteries (MCA), and posterior cerebral arteries (PCA) (Duschek & Schandry, 2003). It is the CBFVs in these arteries which are commonly used as a measure of attention and effort. Researchers have been interested in the neurophysiological underpinnings of a widely supported construct known as the “vigilance decrement” (Warm, Matthews, & Parasuraman, 2009; Warm & Dember, 1998). The vigilance decrement is characterized by a decline in performance over time that results from a loss of attention. The central idea of the vigilance decrement is that a brain performing constant attentional activities requires more oxygen to keep it active and engaged. In order to provide more oxygen to the brain, there is an increase in the speed at which blood flows to the necessary centers that control the performance of mental and cognitive tasks. Over time, a decrease is seen in the CBFVs, indicating that available resources (blood) are unable to be replenished indefinitely. As a result, one’s attention level is reduced as a function of time. The brain can only remain attentive, or vigilant, for so long, before a decremented effect is seen.

An overall view of the theory of attention highlights an understated assumption of what the experimental manipulation in this study will hopefully induce; increased motivation to allocate attentional resources. In general, the theory of attention states that the attentional resources required to perform a given task are limited and they may be allocated towards that task (Wickens, 2002). When two tasks are to be performed at once, one's attention may be allocated as needed to each task. Based on the extent to which each task taps into exclusive pools of attentional resources (also referred to as dual task interference), this in turn, can result in either successful or unsuccessful dual task performance (Keller, 2001, Posner, 1978). Whereas resource production or availability is thought to be influenced by arousal (Humphreys and Revelle, 1984; Warm et al, 1996), resource allocation is thought to be influenced by motivation (Buodo et al, 2002; Lang et al, 1997). In the current study, by allowing some participants to listen to music while studying, hopefully they will be more motivated to allocate attentional resources to the study material and thus maintain a higher level of sustained attention over time.

Though attention and related hemocranial velocities are typically measured via fMRI or PET scans, TCD offers some particular advantages over these approaches. First of all, fMRI and PET scans do excel at giving proximal measures, but fall notably short on providing accurate temporal measures (Duschek & Schandry, 2003). TCD however is capable of providing temporal measures accurate to within ± 100 ms, which illuminates more precise changes in stimuli response times (Klingelhöfer, Matzander, Wittich, Sander, & Conrad, 1996). Additionally, TCD only requires that a study participant wears an ultrasonic probe (in the form of a headband) containing a 2-MHz transducer which both emits and receives the Doppler signal for measuring the CFBVs. This technique is much less intrusive and cumbersome for the participant, while also allowing for a wider variety of stimulus manipulation (Duschek & Schandry, 2003).

In the case of the present study, TCD will enable the participants to listen to music and study material during the experiment, easier than would either fMRI or PET scans. In terms of the validity of TCD, several studies have shown it to be as valid as numerous other hemispheric and lateralization measuring techniques, namely fMRI (Schmidt et al., 1999; Knecht et al., 1998; Deppe et al., 2000).

Furthermore, the use of TCD carries relevant applications to the current study. As stated earlier in regards to the role of stimulus hunger in extraverts (Eysenck, 1967; Davies and Hockey, 1966), TCD will be helpful in determining if extraverted participants remain more vigilant while listening to self-selected music (stimulus) than do introverted participants. TCD has also been utilized in experiments where music serves as an independent variable (Matteis, Silverstrini, Troisi, Cupini, & Caltagirone, 1997; Vollmer-Haase, Finke, Hartje, & Bulla-Hellwig, 1998). Duschek and Schandry (2003) reiterate that TCD is advantageous in studies which seek to highlight cognitive processes and constructs.

It will thus be extremely worthwhile to measure sustained attention (vigilance) via TCD in the current study. As the participants study the provided academic material in the presence of music, TCD will enable the researcher to discern the amount of sustained attention they exhibit. That is, TCD will provide a measure of how vigilant the participants are while studying. If music and/or study condition promotes the participants to remain attentive, rather than succumbing to the vigilance decrement, then an increase in CBFV should be observed. Additionally, it will allow for further analytical explanation if the different conditions of participants perform uniquely on the outcome measures.

Sustained attention may serve as a mediator between studying academic material and performance scores on the outcomes; by measuring it during the experimental manipulation, the researcher will be able to better account for its effect.

Present Study

The present study will investigate whether the use of deep or surface-level study techniques and listening to self-selected music while studying have an effect on engagement level and academic performance in undergraduate students. It will be formed as a 2 x 2 mixed design. The within-factors condition will be Study Modality (Deep-level, Surface-level) and the between-factors condition will be Music (Self-selected Music, No Music)**.** To date, no other studies have attempted to measure sustained attention on specific study modalities through the use of TCD. This method will provide a unique insight as to the sustained or dynamic levels of attention yielded by deep and surface-level studying. Also distinct to this study is the use of self-selected music to study academic material on which participants will be tested on. Self-selected music is being used in this experiment largely because it inherently affords the listener personal selection over the stimulus; they may choose what they prefer to listen to while studying. For that same reason, potential participants who prefer not to listen to music while studying will be excluded from the study during sampling. The researcher is not interested in requiring participants to listen to music if they would otherwise choose not to do so. Therefore, only potential participants who already prefer to listen to music while studying will be included in the study. Random assignment to one of two music conditions (Self-selected Music and No Music) will allow for a check of randomization.

Furthermore, utilizing self-selected music will hopefully facilitate a few advantageous departures from past studies. Foremost, the use of self-selected music will allow for each participant to feel that he/she is studying under more natural conditions than a typical lab setting. Controlling for music genre and song choice has detracted from the external validity of the results in previous experiments.

The current study addresses the following research questions and specific hypotheses:

Question 1: How does studying in the presence of self-selected music affect students' ability to remain attentive?

H1: Students who listen to self-selected music while studying will show greater elevation from resting baseline (increased CBFV) during both the deep and surface-level study tasks. This expectation is consistent with results detailing the positive task-related behaviors of listening to music (Oldham, Cummings, Mischel, Schmidtke, & Zhou, 1995; Labbé, Schmidt, Babin, & Pharr, 2007) and of music's ability to keep an otherwise distracted person on task (Hallam & Price, 1998; Haake, 2011). With self-selected music functioning as a focused-distraction, students will be more able to disregard off-task tendencies and remain more attentive while studying.

Question 2: How does studying in the presence of self-selected music affect academic performance?

H2: Students who listen to self-selected music will perform better overall on the academic tasks than those students who did not listen to self-selected music. Similar to the first hypothesis (H1), music will serve as a focused-distraction which will allow the students to remain more on-task (Hallam & Price, 1998; Haake, 2011) and apply more effective study techniques. Furthermore, it is predicted that this increase in attention will serve as a mediator for stronger performance on the academic tasks given.

Question 3: How do the different modes of study affect students' ability to remain attentive?

H3: When involved in deep-level studying, students will show greater elevation from resting baseline (increased CBFV) than when involved in surface-level studying. Students make more complex and meaningful connections when utilizing deep-level studying rather than surface-level studying (Marton & Säljö, 1984; Hay 2007). As such, deep-level studying will require students to remain more vigilant than will surface-level studying.

Question 4: How do the different modes of study affect academic performance?

H4: When utilizing deep-level studying, students will perform better on the comprehension tasks than when utilizing surface-level studying and taking a more rote-memorization task. Deep-level study will allow students to draw more meaningful insights and think in-depth about the study material (Marton & Säljö, 1984; Hay 2007). Thus, they will perform better when given an academic task requiring well thought out and complex answers. Performance on surface-level tasks will be facilitated by surface-level studying, though excelling on these tasks may be less pronounced as learning surface-level material does not require strong, meaningful connections.

METHOD

Recruitment

Participants were recruited from the population of George Mason University's (Fairfax campus) undergraduate student body. These students are greatly accustomed to the routine and necessity of studying as a means to excel in their current and past classes. However, in order to maintain the focus of the study, the researcher purposefully recruited only a selective subset of students from this larger population. As the study is geared towards drawing conclusions about the effectiveness of self-selected music while studying, only those students who openly choose to listen to music while studying were recruited. A preference to regularly study without music was criterion for exemption from recruitment. The inclusion of these students as participants in the study would oppose the self-selective nature of the hypothesis, as well as combat the expected positive outcomes.

Conversely, by removing these students from the population of potential participants and only selecting those students who prefer to study while listening to music, the researcher hopes to minimize the error variability due to a preference for non-music while engaged in studying. In turn, this should lead to a strong signal to noise ratio, such that the results on the outcome variables are not muddied by participants for which the aims of the study do not readily apply.

Participants

The original sample in this study consisted of 38 students through GMU's SONA system. Due to lack in securing a sufficient TCD signal, 18 participants were dropped prior to the experimental manipulation in the study. As such, the final sample size who completed all measures consisted of 20 participants (8 males, 12 females, mean age = 20.35 years). Participants were predominantly in their freshman year (*n* =10), followed by junior (*n* = 5), senior (*n* = 4), and sophomore year (*n* = 1).

Measures and Materials

Estes/Richards Inventory of Study Habits (ERISH). The ERISH (Estes & Richards, 1985) contains 21 five-point Likert-scale items (Always (5) to Never (1)) which load onto three factors of study behavior: Distractibility, Deep-level, and Surface-level. A Study Orientation factor was calculated by subtracting Surface-level scores from Deep-level scores, indicating the relative utilization of Deep-level study over Surface-levels study. Each factor was assessed for use during analysis.

Levels of participant distractibility were assessed from responses to 7 items on the ERISH. A Distractibility composite score will then be calculated, with a range from 7 to 35. Reliability estimates from a pilot study by Richards, Curby, and Harnett (manuscript) yielded an alpha coefficient of .84 when scores from two variations of the ERISH (preparing for a test and preparing for homework) were cross-correlated. Example Distractibility items consist of "I find it hard to keep my mind on my work" and "I tend to daydream". Higher composite scores on this factor indicate a greater level of distractibility.

Participant use of deep-level study habits were assessed from responses to 7 items on the ERISH. A Deep-level composite score will then be calculated, with a range from 7 to 35. Reliability estimates from a pilot study by Richards, Curby, and Harnett (manuscript) yielded an alpha coefficient of .80 when scores from two variations of the ERISH (preparing for a test and preparing for homework) were cross-correlated. Example Deep-level items include "I try to judge how the writer's ideas make sense" and "I think of ways to apply what I learn". Higher composite scores on this factor indicate a greater use of deep-level study habits.

Participant use of surface-level study habits were assessed from responses to 7 items on the ERISH. A Surface-level composite score will then be calculated, with a range from 7 to 35. Reliability estimates from a pilot study by Richards, Curby, and Harnett (manuscript) yielded an alpha coefficient of .71 when scores from two variations of the ERISH (preparing for a test and preparing for homework) were cross-correlated. Example Surface-level items include "I try hard to remember details, such as name, dates, and technical terminology" and "I reread materials that I already understand". Higher composite scores on this factor indicate a greater use of surface-level study habits.

Music and Academic Characteristics Questionnaire. A 10-item questionnaire was created by the researcher and used to gather data on the musical preferences and academic characteristics of the participants. The items asked students to list the name, tempo, and genre of the songs they chose for the study and how frequently they listened to them, how frequently they listened to music while studying in general, their current GPA, and their SAT scores. Participant gender, age, and class year were also obtained.

This information was helpful in describing and classifying the various characteristics of the participants sampled in this study.

Big Five Inventory (BFI). The BFI (John, Naumann, & Soto, 2008; John, Donahue, & Kentle, 1991; Benet-Martinez & John, 1998) is a self-report inventory which is designed to measure the Big Five dimensions of personality: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience, all based on the Five Factor Model of personality (Costa & McCrae, 1992). It contains 44 five-point Likert-scale items (Agree Strongly (5) to Disagree Strongly (1)) which load onto these five factors. Participants will complete the entire BFI, though only the Extraversion/Introversion scale is of real interest to the researcher. By having participants complete the entire BFI, they were unaware that they were being measured on items which pertained specifically to Extraversion, which may have influenced their responses. Extraversion refers to people who tend to be more sociable, assertive, and gregarious, while introversion refers to people who tend to be more reserved, quiet and solitary. This measure was used as it has been shown that extraverts typically seek more stimuli whereas introverts typically seek less (Eysenck, 1967; Davies & Hockey, 1966). It will serve to check this notion, as well as provide for a measure of control in data analyses.

Currently, the BFI does not possess published norms. However, it has been used in a published study by Srivastava et al. (2003) with a sample size of over 132,000 participants. Example Extraversion items include “I am someone who is talkative" and “I am someone who has an assertive personality”. Scores for items across each this factor will then be averaged. Higher scores indicate a greater degree of extraversion, while lower scores indicate a greater degree of introversion. The BFI is also being used over other personality measures as it free for non-commercial research purposes.

SAT® Workbook Sections. Academic performance was assessed via the scores on two SAT practice instruments: Long Reading Comprehension and Vocabulary practice sections. The two practice sections were taken directly from the Kaplan SAT® Critical Reading Workbook, Fourth Edition. Primarily, the scores on the SAT are factored into decisions of undergraduate admissions. Therefore, it was tenable that undergraduate participants in this study were quite familiar with the format of the SAT questions. Similarly, the sections present on the SAT are reflective of what an undergraduate may expect to encounter in their classes. The content of both the Long Reading Comprehension and Vocabulary sections should be somewhat novel, but not overly difficult, to study. The instructions and proceeding questions for each section should have required accurate reproduction of deep or surface-level study techniques where necessary. Answers for all questions were provided in the back of the SAT practice booklet. Correct answer will be scored as a "1', while incorrect or otherwise missing answers will be scored as a "0". Composite scores will be generated by summing the responses for all 30 questions for both the Long Reading Comprehension and Vocabulary sections, with a score out of 30 possible points for each . A higher composite score will be indicative of greater academic performance for that section.

Taken as a whole, these practice sections served as a good representation of external validity in this study as students were likely to have recently encountered, and will continue to encounter, such study material and tests in their academic careers.

Each Long Reading Comprehension section consisted of roughly a 1 page passage on a random topic, followed by 5 questions. The questions contained 5 possible answers and were reflective of what someone can be expected to learn through deep-level studying. Participants were given up to 5 minutes each to completely study the 6 Long Reading Comprehension passages (30 minutes total). Participants chose to study until they felt ready to take the assessment. In order to replicate realistic studying and test-taking scenarios, each reading passage was removed after the student indicated that they felt are sufficiently prepared for to answer the questions. Participants were given up to 2 minutes each to complete the 6 question sections.

Each Vocabulary section consisted of a list of 5 pre-selected vocabulary terms and their definitions. Participants instructed to correctly pair each term with its definition from a choice of 5 possible answers once the list was removed. This task is reflective of what someone can be expected to learn through surface-level studying. Participants were given up to 5 minutes each to completely study the 6 Vocabulary sections (30 minutes total). Again, participants indicated when they felt sufficiently prepared to answer the questions and each reading passage was removed. As above, participants were given up to 2 minutes each to complete the 6 question sections.

Attention Assessment. Levels of sustained attention across all experimental conditions were measured using a Spencer Technologies® ST3 transcranial Doppler (TCD) machine available through George Mason's Human Factors and Applied Cognition (HFAC) program. TCD measures blood velocities (in centimeters per second) in targeted arteries in the brain. As noted, TCD is ideal for scenarios requiring greater stimulus manipulation or activity (in this case, listening to music and studying the provided materials). Hemocranial blood flow velocities (CBFV) were computed during each of the Study Modality conditions.

CBFV measurements from both the left and right MCA readings were averaged together to create an average CBFV value. These values were calculated for each time interval where studying occurred. Overall, 12 CBFV values were created (i.e., six Reading Comprehension study sections and six Vocabulary study sections). These CBFV values were then divided by the Music Baseline CBFV values on an individual basis. This provided an indication of increased or decreased attention while studying over the six Reading Comprehension workbook sections and six Vocabulary workbook sections for each participant. Deep-level studying was referenced by the Reading Comprehension CBFV values, while surface-level studying was referenced by Vocabulary CBFV values.

Other Equipment. Additional equipment included a MP3 player and a pair of earbud-style headphones to play musical playlists created by participants in the Music condition and for all participants during the Music Baseline period.

Procedures

The instructions noted that participants must prefer to study while listening to music, as music was to be present in the laboratory environment. However, participants were not informed upfront about how the music will be employed or manipulated, so as to mask them from the experimental aims of the study. Furthermore, potential participants were screened so that only native English speakers actually participated. This was necessary to ensure maximum comprehension and retention of the study materials used in the procedures and measures. Finally, in order to use the TCD machine, the researcher needed to have full access to each participant's scalp. As such, potential participants were also be screened for restricted scalp access (e.g., head coverings), and only those with unrestricted scalp access actually participated. Participants may have received research participation hours and/or class credit for taking part in the study. The study aimed to recruit at least 20 participants in order to account for some attrition rate due to unusable TCD data collected during the experiment.

Once recruited, participants were randomly assigned to either the Self-selected or No music conditions. Counterbalancing was used to ensure that half of the participants received the Surface-Level study material first and the Deep-Level study material second, while the other half of participants received the study materials in a reversed order. Participants were given the option of creating a 60 minute-long musical playlist that they naturally prefer to listen to while studying on their MP3 player, or they may create a Pandora station based on their musical preferences upon arriving to the lab. Those participants who created playlists on their MP3 players brought them to the lab with them. Pandora playlists were made on a separate MP3 player available in the lab room. The playlists or Pandora stations were played during their participation.

Upon entering the lab at their scheduled times, all participants gave informed consent to participate in the study. They were told that the experiment is examining how students perform as a result of studying in a novel environment. Each participant then completed two forms: a Music and Academic Characteristics Questionnaire, and the Big Five Inventory (BFI). Next, a brief explanation on the TCD equipment was given and the participant were be fitted with the headband. A 5 minute baseline measurement period absent of any stimuli allowed for any nervousness to dissipate and a more stable baseline attention level (without any music) to be obtained from the last minute of period. After this, music was played during a second baseline measurement period, lasting 2 minutes. This allowed for a stable measure of their baseline attention level in the presence of music. Those participants in the Self-selected Music condition then either had their created MP3 playlist or Pandora station played through a MP3 player via headphones. Participants were allowed to place the volume of the music at a desired level and the volume level was noted by the researcher. After placing the volume at the desired level, it was kept at that level throughout the remainder of the experiment.

Participants then received either the Deep-level or Surface-level study material and were asked to read the instructions and begin studying. For both the Deep-level and Surface-level study materials, participants had up to 30 minutes total to study before asking them to respond to the provided questions. After completing the first study material, the participants received the second study material. The music playlists were paused while participants answered the questions, so as to imitate an actual test-taking situation in a classroom (i.e., music was only played during the two 30 minute study periods).

After completion of each study material, participants filled out the ERISH to capture information on the particular study habits that they employ while studying. The TCD headband was removed and participants were briefed on the true aims of the study.

Two hours were allowed for full completion of the experimental procedures, with most participants finishing in approximately 90 minutes.

Results

Descriptive statistics are listed in Table 1 and frequency counts for music characteristics are listed in Table 2. The mean number of total correct Reading Comprehension responses was 16.70, while for Vocabulary responses it was 29.5. The ERISH revealed that on average, participants used both deep-level(25.0) and surface-level study habits (23.9) to the same degree as part of their normal study routines. The largest percentage of participants (25%) listened to their music at a volume level of 6, out of a possible 16, with the average volume level being 5.3. More participants chose to listen to an "other" genre of music (with specifications such as "pop" and "instrumental") than any other genre listed. Classical, rock, and hip-hop music were all tied for being the second most listened to genres. Interestingly, participants specified "instrumental" music even though classical was a choice, suggesting that the use of non-vocal music can be more diverse than conventional classical music. Only 3 participants indicated that they listened to more than one genre of music while studying. Music with a medium tempo was listened to most often, followed by slow tempo music, and then fast tempo music. There was a negative correlation between frequency of listening to music while studying and sustained attention for the Reading Comprehension section, $r = -.41$, $p < .05$ (one tailed). There were no differences in the frequency with which participants listened to music while studying between the two music conditions, $t(18) = -.32$, $p > .05$**.**

While checking assumptions during analysis, the total number of correct Vocabulary responses failed to pass the Shapiro-Wilk test and was significantly non-normal $W(20) = .41$, $p < .001$**.** Square root, $W(20) = .41$, $p < .001$, log, $W(20) = .40$, $p < .001$, and inverse, $W(20) = .39$, $p < .001$, transformations on this variable were all significantly non-normal as well. As such, the use of this variable in subsequent analyses would not produce findings which are accurate or can be generalized.

Table 1

Descriptive Statistics for Derived Variables

	M	*SD*	*Minimum*	*Maximum*	*Range*
Read. Correct	16.70	4.95	8.00	25.00	17.00
Vocab. Correct	29.50	1.43	24.00	30.00	6.00
Read. CBFV (%)	98	.04	.92	1.10	.18
Vocab. CBFV (%)	.99	.04	.91	1.08	.17
Volume Level	5.30	2.18	2.00	11.00	9.00
Extraversion	3.30	.81	2.25	4.88	2.63
Distractibility	22.80	4.91	10.00	29.00	19.00
Deep-level	25.00	4.32	17.00	34.00	17.00
Surface-level	23.90	4.35	17.00	32.00	15.00
Study Orientation	1.10	5.46	12.00	11.00	23.00

Table 2

Music Characteristics

	Number of Times Selected
Genre*	
Other	9
Classical	4
Rock	4
Hip hop	4
Country	1
Techno	1
Jazz	-
Tempo*	
Slow	7
Medium	13
Fast	5
Freq. Listen to Music in Experiment	
Less than once a week	2
Once/twice a week	4
Three/four times a week	7
Once a day	3
More than once a day	4
Freq. Listen to Music While Studying	

Not at all	-
Not very frequently	-
Somewhat frequently	5
Very frequently	11
Every time	4

*Multiple selections between choices were allowed

Hypothesis 1: Students who listen to self-selected music while studying will show greater levels of sustained attention during both the deep and surface-level study tasks.

Independent t-tests were used to test if average level of sustained attention while studying differed while listening to music or not. As stated, CBFV values collected during the deep and surface-level studying were divided by the Music Baseline CBFV values. Separate t-tests were run for both deep and surface-level studying.

Results of the t-test testing for differences in sustained attention during deep-level study mode revealed that there was no difference for participants who listened to music, (M = .99, SE = .02), and those who did not (M = .98, SE = .01), $t(18) = -.58$, $p > .05$. (Note: the values associated with *M*'s and *SE*'s are task related cerebral hemovelocity/rest-related cerebral hemovelocity). The t-test testing for differences in sustained attention during surface-levels study mode also revealed that there was no difference for participants who listened to music, (M = 1.00, SE = .01), and those who did not (M = .97, SE = .01), $t(18) = -1.42$, $p > .05$.

Multiple regression was also run in order to account for level of extraversion during studying. The first regression indicated that neither extraversion, (β = -.02, $t(17)$ = -.06, p > .05) nor music condition (β = .14, $t(17)$ = .54, p > .05; R^2 = .02, $F(2,17)$ = .16, p > .05), were significant predictors of sustained attention during deep-level studying. The second regression indicated that neither extraversion, (β = -.17, $t(17)$ = -.67, p > .05) nor music condition (β = .38, $t(17)$ = 1.55, p > .05), were significant predictors of sustained attention during surface-level studying (R^2 = .12, $F(2,17)$ = 1.21, p > .05).

Hypothesis 2: Students who listen to self-selected music will perform better overall on the academic tasks than those students who did not listen to self-selected music.

Independent t-tests were used to test if scores on the workbook sections differed while listening to music or not. This analysis was run for both the total number of correct Reading Comprehension and Vocabulary responses. Results revealed that there was no difference in the number of correct Reading Comprehension responses given by participants who listened to music (M = 16.00, SE = 1.74) than those who did not (M = 17.40, SE = 1.43), $t(18)$ = .62, p > .05. There was also no difference in the number of correct Vocabulary responses given by participants who listened to music (M = 29.40, SE = .60) than those who did not (M = 29.60, SE = .27), $t(18)$ = .31, p > .05.

Multiple regression was also run in order to account for level of extraversion. The first regression indicated that neither extraversion, (β = -.19, $t(17)$ = -.74, p > .05) nor music condition (β = -.07, $t(17)$ = -.29, p > .05), were significant predictors of Reading Comprehension scores (R^2 = .05, $F(2,17)$ = .46, p > .05). The second regression indicated that neither extraversion, (β = .28, t(17) = 1.12, p > .05) nor music condition (β = -.18, t(17) = -.71, p > .05), were significant predictors of Vocabulary scores (R^2 = .07, F(2,17) = .67, p > .05). As there was no significant relationship between correct responses and music condition, testing for mediation (via CBFV values) could not be performed.

Hypothesis 3: When involved in deep-level studying, students will show greater levels of sustained attention than when involved in surface-level studying.

A mixed-ANOVA was used to assess if the presence of self-selected music and the use of different study modalities had a significant effect on sustained attention. The between-subjects factor was represented by music condition. The within-subjects factors were deep/surface-level study modes and time (i.e., six study sections each for Reading Comprehension and Vocabulary). Again, CBFV values collected during the deep and surface-level studying were divided by the Music Baseline CBFV values. Mauchly's test indicated that the assumption of sphericity was not met for time, (X^2(14) = 27.56, p < .05), nor the interaction of study mode and time, (X^2(14) = 31.37, p < .05). The Greenhouse-Geisser correction was used to interpret the main effect of time, (ε = .60), and the interaction effect of study mode and time, (ε = .57). According to Levene’s test, variances were not different for all variables, except deep-level studying at Time 5, F(1,18) = 4.61, p < .05.

There was no significant main effect of study mode, F(1,18) = 1.29, p > .05, or music condition, F(1,18) = 1.07, p > .05, on sustained attention. There was a significant main effect of time however, F(3,53.95) = 5.70, p < .01, such that CBFV values from resting baseline decreased linearly over the course of studying (see Figure 1). There were no significant effects for the two-way interactions of study mode and music condition, $F(1,18) = 1.77$, $p > .05$., time and music condition, $F(5,90) = .95$, $p > .05$., or study mode and time, $F(2.83,50.87) = 1.66$, $p > .05$. There was no significant effect for the three-way interaction of study mode, time, and music condition, $F(5,90) = 1.43$, $p > .05$.

This mixed-ANOVA was run again including extraversion as a covariate in order to account for it. Mauchly's test indicated that the assumption of sphericity was not met for time, ($X^2(14) = 25.74$, $p < .05$), nor the interaction of study mode and time, ($X^2(14) = 32.84$, $p < .05$). The Greenhouse-Geisser correction was used to interpret the main effect of time, ($\varepsilon = .58$), and the interaction effect of study mode and time, ($\varepsilon = .56$). According to Levene's test, variances were not different for all variables, except deep-level studying at Time 5, $F(1,18) = 4.52$, $p < .05$. There was no significant main effect of study mode, $F(1,17) = 1.52$, $p > .05$, time, $F(2.87,48.87) = 1.73$, $p > .05$, music condition, $F(1,17) = 1.16$, $p > .05$, or extraversion, $F(1,17) = .14$, $p > .05$, on sustained attention. There were no significant effects for the two-way interactions of study mode and extraversion, $F(1,17) = 1.03$, $p > .05$, study mode and music condition, $F(1,17) = 2.61$, $p > .05$., time and extraversion, $F(2.87,48.87) = 1.16$, $p > .05$, time and music condition, $F(2.87,48.87) = 1.35$, $p > .05$., or study mode and time, $F(2.80,47.43) = .18$, $p > .05$. There was no significant effect for the three-way interaction of study mode, time, and extraversion, $F(2.80,47.43) = .41$, $p > .05$, or study mode, time, and music condition, $F(2.80,47.43) = 1.09$, $p > .05$.

In order to assess if any hemispheric differences occurred while studying, the above analyses were repeated, this time using CBFV values from the left and right MCA separately (rather than averaged together). These values were also divided by their respective hemispheric Baseline values to evaluate sustained attention over time. Mauchly's test indicated that the assumption of sphericity was not met for the interaction of hemisphere and time, ($X^2(14) = 51.31$, $p < .05$). The Greenhouse-Geisser correction was used to interpret the interaction effect of hemisphere and time, ($\varepsilon = .51$). According to Levene’s test, variances were not different for all variables, except deep-level studying in the left hemisphere at Time 5, $F(1,18) = 6.87$, $p < .05$.

There was a significant main effect of hemisphere, $F(1,18) = 11.54$, $p < .01$, such that the left hemisphere showed greater elevation from resting baseline than the right hemisphere (see Figure 2). There were no significant effects for the two-way interactions of hemisphere and music condition, $F(1,18) = 1.87$, $p > .05$., hemisphere and study mode, $F(1,18) = 1.08$, $p > .05$., or hemisphere and time, $F(2.53,45.58) = 2.38$, $p > .05$. There were no significant effects for the three-way interactions of hemisphere, study mode, and music condition, $F(1,18) = 1.03$, $p > .05$., or hemisphere, time, and music condition, $F(5,90) = 1.46$, $p > .05$. There was a significant effect for the three-way interaction of hemisphere, study mode, and time $F(5,90) = 2.50$, $p < .05$ (see Figure 3). Specifically, CBFV departures from resting baseline during the deep-level study mode maintained a similar trend in both the left and right hemispheres from Times 1 to 6. However, during the surface-level study mode, the two hemispheres deviate from each other in the departures from resting baseline exhibited as time progresses. This divergence is most apparent at Time 5, when left hemisphere CBFVs increase, while right hemisphere CBFVs decrease. Following up, bivariate correlations were computed for CBFV values and the length of time that participants spent studying each section. No significant correlations were found for the deep-level study mode. However, during the surface-level study mode , significant correlations were seen between CFBV values and length of study time for all times (r = .44-.56, $p < .05$) except at Time 5 (r = .41, $p > .05$). There was no significant effect for the four-way interaction of hemisphere, study mode, time, and music condition, $F(5,90) = .40$, $p > .05$.

This mixed-ANOVA was run again including extraversion as a covariate. Mauchly's test indicated that the assumption of sphericity was not met for time, ($X^2(14) = 25.74$ $p < .05$), the interaction of study mode and time, ($X^2(14) = 32.84$, $p < .05$, the interaction of hemisphere and time, ($X^2(14) = 48.62$, $p < .05$), nor the interaction of study mode, hemisphere, and time, ($X^2(14) = 25.63$, $p < .05$). The Greenhouse-Geisser correction was used to interpret the main effect of time, ($\varepsilon = .58$), the interaction effect of study mode and time, ($\varepsilon = .56$), the interaction effect of hemisphere and time, ($\varepsilon = .51$), and the interaction effect of study mode, hemisphere, and time, ($\varepsilon = .60$). According to Levene's test, variances were not different for all variables, except deep-level studying in the left hemisphere at Times 4, $F(1,18) = 4.47$, $p < .05$, and 5, $F(1,18) = 7.21$, $p < .05$.

There were no significant main effects of study mode, $F(1,17) = 1.52$, $p > .05$, hemisphere, $F(1,17) = 3.03$, $p > .05$, time, $F(2.87,48.86) = 1.73$, $p > .05$, music condition, $F(1,17) = 1.16$, $p > .05$, or extraversion, $F(1,17) = .14$, $p > .05$. There were no significant effects for the two-way interactions of study mode and extraversion, $F(1,17) = 1.03$, $p >$ .05, study mode and music condition, $F(1,17) = 2.61$, $p > .05$, hemisphere and extraversion, $F(1,17) = 1.06$, $p > .05$, hemisphere and music condition, $F(1,17) = 2.74$, p

$> .05$, time and extraversion, $F(2.87,48.86) = 1.16$, $p > .05$, time and music condition, $F(2.87,48.86) = 1.35$, $p > .05$, study mode and hemisphere, $F(1,17) = .01$, $p > .05$, study mode and time, $F(2.79,47.43) = .18$, $p > .05$, or hemisphere and time, $F(2.53,42.93) = .28$, $p > .05$.

There were no significant effects for the three-way interactions of study mode, hemisphere, and extraversion, $F(1,17) = .02$, $p > .05$, study mode, hemisphere, and music condition, $F(1,17) = .92$, $p > .05$, study mode, time, and extraversion, $F(2.79,47.43) = .41$, $p > .05$, study mode, time, and music condition, $F(2.79,47.43) = 1.09$, $p > .05$, hemisphere, time, and extraversion, $F(2.53,42.93) = .06$, $p > .05$, hemisphere, time, and music condition, $F(2.53,42.93) = 1.23$, $p > .05$, or study mode, hemisphere, and time, $F(3,50.93) = .29$, $p > .05$. There were no significant effects for the four-way interactions of study mode, hemisphere, time, and extraversion $F(3,50.93) = .35$, $p > .05$, or study mode, hemisphere, time, and music condition, $F(3,50.93) = .34$, $p > .05$.

Hypothesis 4: When utilizing deep-level studying, students will perform better on the comprehension tasks than when utilizing surface-level studying and taking a more rote-memorization task.

Hypothesis 4 would have tested to see if total correct Reading Comprehension responses differed significantly from total correct Vocabulary responses. However, due to the ceiling effect found in the Vocabulary responses there is a lack of variability which would greatly affect the interpretability of the outcomes. As such, this analysis could not be run.

Discussion

Three major findings emerged from this study, all regarding CBFV departures from resting baseline: a main effect for time; a main effect for hemisphere; and an interaction effect of study mode, hemisphere, and time. Each of these was found when analyzing Hypothesis 3 which primarily sought to show that students would exhibit greater elevations from resting baseline when utilizing the deep-level study mode than when utilizing the surface-level study mode. Interestingly, a predicted main effect for study modality was not found here; and results for Hypotheses 1, 2 and 4 were counter to what was expected.

Contrary to the first hypothesis, there were no significant differences in the amount of sustained attention exhibited between those who listened to music while studying and those who did not, for either deep or surface-level study modalities. Though past research showed positive effects in task-related behaviors, such as mood and stress (Oldham et al., 1995; Labbé et al., 2007), the experimental design in this study was concerned only with measures of attention. Clearly, musical presence did not lead to the expected boost in CBFV values during studying. It is possible that students simply did not attend to the music in a helpful or meaningful way and therefore it could not serve as a hypothetical focused-distraction.

There were also no differences in the amount of correct responses between those who listened to music while studying and those who did not, for either deep or surface-level studying. Again, musical presence may not have elicited a positive effect in the way in which participants studied and prepared for the workbook test sections; it may have had the opposite effect. Though not significant, there was a hint of an effect that those who did not listen to music performed better on the Reading Comprehension and Vocabulary sections than those who listened to music. Based on this performance, music may have actually interfered with participants' ability to properly study for the test questions. Reading comprehension measures could require direct focus absent of any outside stimuli, including self-selected music, given that deep-level study is best suited for studying this type of material. Conversely, while studying the Vocabulary measures in a surface-level manner comprised of rote repetition and memorization, the presence of music may not have overloaded mental workload or impeded learning.

Furthermore, the improved mathematical performance when background music was played, seen in Hallam and Price (1998), involved arithmetic problems solved by 9-10 year old students. It is likely that solving these problems would constitute more of a surface-level approach, given that arithmetic operations and solutions lend themselves to being memorized like facts. Additionally, the trion model put forth by Leng and Shaw (1991) primarily focuses on neuronal priming in the presence of music for spatial tasks, specifically mathematics and chess performance (Leng, Shaw, & Wright, 1990). Haake's results (2011) showed increased concentration in office workers who listened to music, but the most commonly cited tasks being performed were described as "routine" and "monotonous". Again, it is conceivable that routine, monotonous tasks would be approached in a surface-level manner as well, if they are highly familiar and repetitive to the workers.

Expectedly, there was a main effect of time on sustained attention. As time progressed, participants were not able to maintain the same level of attention that they exhibited at baseline. This finding infers that the experiment was capable of inducing the vigilance decrement and bolsters the internal and external validity of this experiment. More specifically, CBFV values at Time 1 were nearly identical (99.8%) to those seen during Baseline measurements. Yet by Time 6 those values had dropped lower (only 97.6%) than that of Baseline values. Given the absence of any effects from listening to self-selected music, it seems that participants were fatigued by studying and thus could not maintain elevated CBFV values throughout the entire experiment. In future experiments, it would be revealing to include self-report questions asking whether students were actually capable of allocating more attention to studying while listening to music, but chose not to, or if they simply exhausted all resources.

When further breaking down the CBFV data, there was a main effect for hemisphere. CBFV values (compared to Baseline) were greater in the left hemisphere than the right hemisphere, indicating that this hemisphere required more blood to replenish the attentional resources which were being depleted. Simply put, participants engaged this hemisphere to a greater degree while studying during the experiment. This finding is not surprising, given the literature on lateralized language processing in the brain. While the right hemisphere has traditionally been shown to be more vigilant towards tasks over time, the left hemisphere can adopt this role when the type of task is predominantly left lateralized (Shaw et al., 2012). The left hemisphere is more fundamentally associated with language processing (Beeman & Chiarello, 1998; Hull &

Vaid, 2006) in most people and both tasks (Reading Comprehension and Vocabulary) were centered on this type of cognitive functioning. The onset of cerebral lateralization can also be facilitated by task difficulty (Helton et al., 2010, Shaw et al., 2012). More complex tasks require that both hemispheres are equivocally active as a means of combating the vigilance decrement, yet simpler tasks may only require the primary use of a single hemisphere to contest this decrement. In this study, studying both types of materials may not have been explicitly difficult for participants, which was evidenced by augmented CBFV values from baseline in the left hemisphere alone. Though no main effect was found for the presence of music, there are also noted increases in left hemisphere CFBV when listening to music, which may be further boosted when language regions of the brain are activated (Carod-Artal, Vázquez-Cabrera, & Horan, 2004).

The interaction effect which was found for hemisphere, study modality, and time might be best examined as a strategic change in how participants studied each type of study material merited. As the Reading Comprehension questions were more difficult for participants to answer, the cooperative efforts of both hemispheres may have been facilitated during the deep-level mode. Yet as participants excelled at answering the Vocabulary questions, the dual efforts employed by both hemispheres may not have been necessary. Speaking particularly in reference to the surface-level study mode, this is clear at Time 5 as the left hemisphere displays an upswing in CBFV, while the right hemisphere shows a downswing. The fact that there was no significant correlation between the CFBV value and length of study time for this specific section may suggest that participants simply got distracted during this particular section and the longer they studied, the less attention was being exerted.

Though extraversion failed to elicit an effect on level of sustained attention, this particular experimental design may not have been able to produce such an effect. Using self-selected music as one of the independent variables is somewhat different than what Eysenck (1967) originally wrote about whereby preferences for novel tones are split along lines of extraversion and introversion. Davies and Hockey (1966) also used unfamiliar auditory stimuli in the form of high intensity white noise. However as mentioned, in the current study both extraverts and introverts alike may have been so accustomed to their self-selected music, that there was not a detectable effect for its presence. Alternatively, in such a small sample size, divergent levels of extraversion and introversion may not have been visible enough. The average score of 3.30 (on a scale from 1 to 5) for Extraversion places the sample squarely in the middle of the extraversion/introversion continuum. When considering a standard deviation of .81 for scores on this scale, all participants were within 2 standard deviations from the average. The potential effect of stimulus hunger on attention may not have been able to be tested in a sample which is neither significantly extraverted nor introverted. Participants may not have engaged in stimulus seeking (or avoiding) behaviors if they don't lie relatively enough on either end of the continuum. Moreover, other noted research (Gale, 1969; Elliot, 1971) only found small differences between extraverts and introverts when examining the concept of stimulus hunger, so it is difficult to conclude if this effect was even able to be seen in this sample.

Limitations

Although SAT workbook sections were ultimately decided to be used as the study material, they may not have been the optimal choice for preventing cross-contamination between the two study conditions. The Reading Comprehensions questions used to assess deep-level studying sometimes asked about information that could be considered more geared towards surface-level studying. For example, a workbook question may have read “The author includes a description of a cantilever (lines 33-36) in order to explain…?" As much as possible, the researcher attempted to select questions from the workbook that did not contain these types of referential information, but some workbook sections did not have enough questions to only choose five deep-level oriented questions. (In cases where this occurred, the researcher removed the line number references and changed the questions to read "The author includes a description of a cantilever in the passage in order to explain…?" This was done to avert any memorization of specific pieces of text, and because participants would not be allowed to reference back to the text after they had indicated that they had finished studying). Therefore, even though successful deep-level studying was attempting to be measured, some surface-level study techniques may also have been employed.

Additionally, the responses to the Reading Comprehension questions were multiple-choice, rather than open-ended. As noted by Crooks (1988) and Nonis and Hudson (2010), deep-level studying is best utilized for tests with intricate, well-thought out responses. The Reading Comprehension questions and responses used in this experiment attempted to induce more thoughtful answers, but the multiple choice format may not have been effective enough in mandating a purely deep-level approach. Moreover, even Marton & Säljö (1984) state that it is possible to use a combination of deep and surface-level studying for either complex or simple examinations. Study material(s) with empirically established reputations for use of either strictly deep or strictly surface-level studying would be worthwhile to use in future iterations of research in this area.

Another apparent limitation of this experiment was the ceiling effect of scores on the Vocabulary workbook questions, which left very little variance to explain and yielded data that violated assumptions of normality. It was unexpected that participants would perform this well on the measure, given that surface-level studying typically results in less meaningful connections to one's overall knowledge base. Hence, it was hypothesized that participants would perform worse on this measure as the material studied would be less relevant and encoded for them. It can now be concluded that although surface-level studying may be characterized by more discrete and temporary knowledge gains, learning does indeed occur and surface-level techniques may be a very effect method of study for tests based on this type of material.

It is worth pointing out that after participants signaled that they had efficiently studied the material, they were immediately given the workbook questions to answer. With no elapsed time between the point at which studying ended and test taking began, it is possible that the vocabulary material was immediately available for recall and use. In future studies, it would be informative to re-test the participants on both the vocabulary and reading comprehension material at a follow-up period a week later. Given the nature of deep and surface-level studying, it would be expected that the vocabulary material would not be retained over this time, while the reading comprehension material would.

Last, as is the case in empirical studies, this experiment would have benefited from a larger sample size. With a sample of only 20 participants, there was little power to detect small group differences.

Conclusion

While many of the expected results were not seen, this study helps further understanding of student performance via different approaches to studying and external stimuli in their environment. The use of music as a companion to studying was shown to be quite individualized and a departure from the classical music paradigm. TCD was also shown to be capable of measuring levels of sustained attention in experiments which seek to replicate real-world study scenarios for students. In all, it will behoove future research concerned with these topics to seek experimental designs and manipulations which will help parse apart the study habits continuum as much as possible.

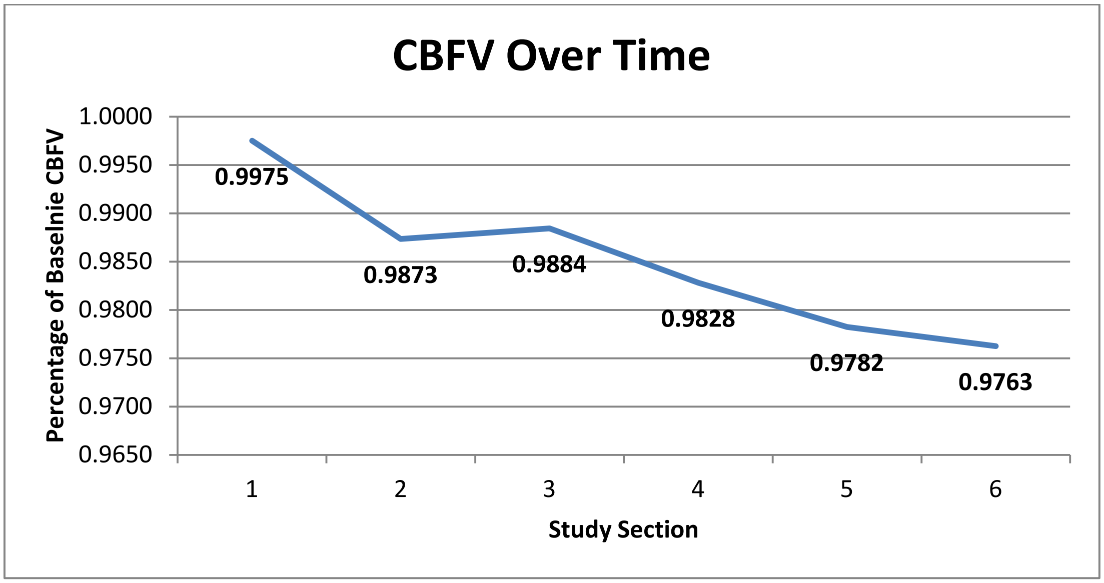

Figure 1. Main Effect of Time.

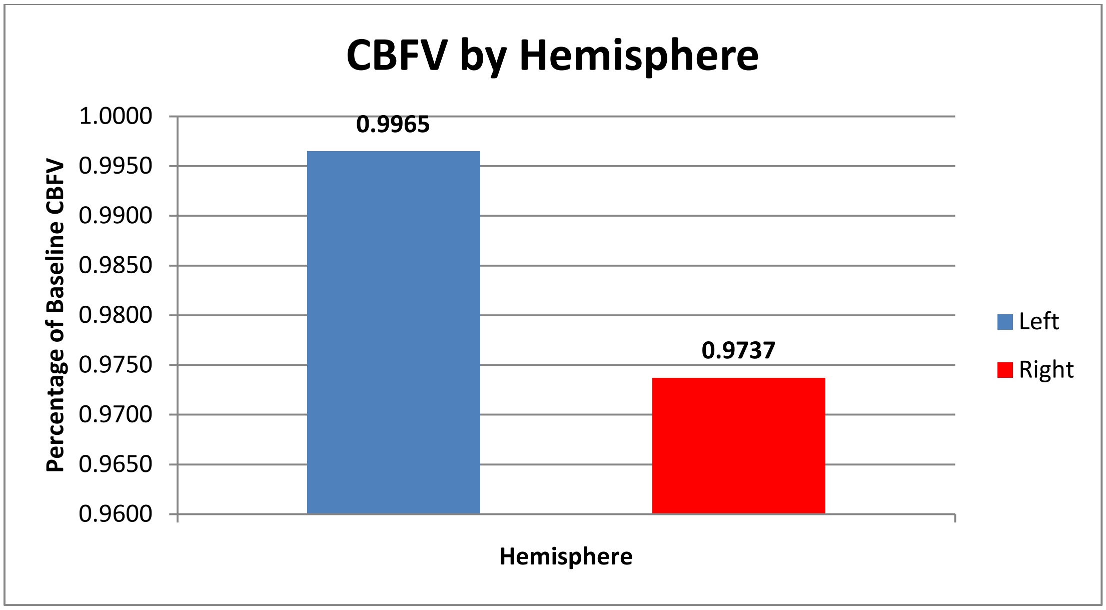

Figure 2. Main Effect of Hemisphere.

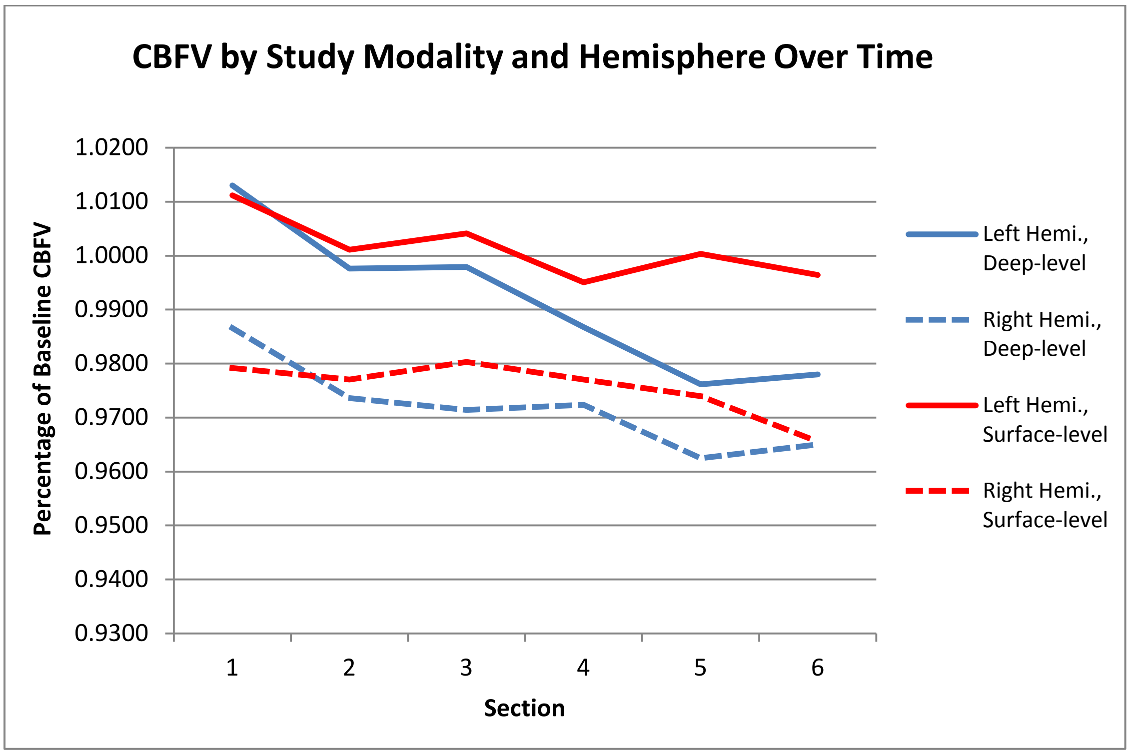

Figure 3. Interaction Effect of Study Modality, Hemisphere, and Time.

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BIOGRAPHY

Michael S. Widerman graduated from Damascus High School in Damascus, Maryland in 2004. He received his Bachelor of Arts from McDaniel College in Westminster, Maryland in 2008.