The effects of musical mood and arousal on executive function performance

By

Jerome Iruthayarajah

Honours Thesis

Honours Specialization in Neuroscience

University of Western Ontario

London, Ontario, Canada

April 8th, 2015

Thesis Advisor: Dr. Jessica Grahn

Graduate Advisor: Tram Nguyen

Psychology

University of Western Ontario

Abstract

We perform a variety of our daily tasks while listening to background music. There has been a growing interest in psychology and cognitive neuroscience to determine how certain properties of music can influence cognition, specifically the mood and arousal a piece of music induces on its listener. There has been research conducted on musical mood and arousal's effects on visuospatial, attentional and memory tasks. However the effect of musical mood and arousal on executive functions remains a novel area of investigation. In the current study, we recruited 100 undergraduate participants and assigned them to five musical listening groups: High Arousal Positive Mood (HAP) music (n=20); High Arousal Negative Mood (HAN) music (n=20); Low Arousal Positive Mood (LAP) music; Low Arousal Negative Mood (LAN) and a silent (control) condition (n=20). All participants completed three executive function tasks: the Double Stroop Task which measured conflict monitoring, the Stimulus Detection Task which measured selective attention, and the Simon Task which measured working memory and conflict monitoring. We found that participants were performed as accurately regardless of the musical listening group they were assigned to, on all three of the tasks. However participants that listened to HAP music had significantly faster reaction times on the Double Stroop Task, and the Simon Task; both of which measure conflict monitoring. The results of our study suggest that listening to HAP music may have an effect on attenuating conflict costs during conflict monitoring tasks. Future studies should explore if these results can be repeated in other conflict monitoring paradigms.

Acknowledgements

I would like to deeply express my gratitude towards Dr. Grahn for giving me the opportunity to work on this project. In the short time I have been in the Grahn lab, I have never been so impressed by the innovation, creativity and passion its citizens' display in their research; it was both inspiring and humbling. The drive and passion of the Grahn lab is just a testament to the amazing abilities you have as a leader and as a role-model for these young scientific minds. I thank you greatly for allowing me to experience this creative atmosphere and for all the feedback you have given me along my thesis journey. This experience has definitely strengthened my aspirations to pursue research and academia in the future.

I would like to thank immensely Tram Nguyen for all her help on my thesis. Whether it was helping me analyze my data, interpret my results, edit my drafts, or help me program my experiment, you have always been there to lend a helping a hand and answer my questions beyond my satisfaction. You have always been patient, understanding and considerate whenever explaining a concept or an idea to me. I know how busy your schedule must have been this past school year with all your projects and planning your wedding, but you still always managed to give me the time of day if I ever had an issue; I will always be grateful for that. I dream of one day becoming a researcher as efficient and admirable as you.

I would like to thank the Grahn lab as a whole for being always supportive and helpful throughout my thesis journey. In particular Kathrin Kuchenbach for always happily answering any of my questions and concerns, Aaron Gibbings for his one of kind sense of humour during lab meetings and his help during my photoshoot for the Neuroscience undergraduate brochure, Molly Henry for helping pilot my experiments, and Denise Soanes for helping with any issues that arose during testing.

I would like to thank Juan Chen for agreeing to be my second reader for my thesis; it was an absolute joy meeting you at my poster session and I am grateful for all the helpful feedback and comments you had on my thesis. I hope you enjoy reading the finished product.

I would like to thank deeply Dr. Sherry for being such a great course coordinator for the Neuroscience thesis course. You are by far one of my favorite professors to talk to about anything. Your teaching approach has been humorous, insightful and inspiring. It was an absolute honour and privilege to have been your student, an experience I will treasure dearly.

I would like to thank Carmen Wong, for being such an excellent TA during the Thesis course and all her helpful edits on my drafts.

` Most importantly I want to thank all my friends for being: an ear to vent to, a shoulder to lean on, and a hand to reach for. Only during completing my thesis did I see how lucky and fortunate I am to be surrounded by such compassionate and intelligent people. In particular I want to thank my fellow honours neuroscience peers. Our constant discussions, insights, and comments about our theses were the reason I was able to complete my thesis with a smile and full of positivity. You all are destined for great things.

Lastly, I want to thank the thing that inspired me to undertake this thesis in the first place: music. You have been a constant companion, a bridge to a world of memories, and a place of solace. The beauty of music is that is timeless, it can be rediscovered, and re-imagined. Reminiscing about the days of playing guitar with my friends to conversations about modern day lyricists; the connections music has made me with me are an integral part of my self-identity. For that I am truly grateful.

The effects of musical mood and arousal on executive functions

It is peculiar to imagine a world in which music does not exist. Music plays a ubiquitous role in our daily lives, providing enjoyment and pleasure to millions across the globe. The use of music is rudimentary and common amongst all known human cultures (Sacks, 2006). From driving to work, enjoying a coffee at a local café, or studying for an exam, music constantly surrounds us. What is it about music that makes its’ listener so obsessed with it? Music consists of many properties such as timbre, tempo, pitch, volume, etc. However, music is commonly used to make mundane and routine tasks more enjoyable because it can evoke various feelings and affects; as a result music can be an effective mood regulator. Additionally, music can make the listener more active and aware; such states of heightened arousal are common when listening to live music as seen in rock concerts or music festivals (Sacks, 2006). Therefore two intrinsic properties of music that this thesis will explore are: mood and arousal. There has been growing interest in the effects of music on cognition in psychology. This study will examine if the interaction between mood and arousal generated by music can influence executive functions.

Mood

Mood is a psychological construct that refers to a temporary emotional state that can last from minutes to hours (Mitchell and Phillips, 2007). There is a spectrum of affective traits used to describe moods. These affective traits are comprised of a certain degree of positive or negative valence (Feldman,1995). Examples of positive moods are happiness or contentment, whereas examples of negative moods are sadness or anxiety. Music, as a stimulus, has been used to effectively induce certain moods in its listeners. For example, fast tempo, happy sounding music can induce positive moods (McConell and Shore, 2011; Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007), while listening to slow tempo, sad sounding music can induce negative moods (Schwartz & Fouts, 2003). In fact, moods induced by music are reported to last longer, compared to traditional mood inducing stimuli (Krumhansl, 1997). Therefore, musical mood is an important regulator in the selection of music.

Arousal

Arousal refers to the physiological activation or intensity of an emotion (Sloboda & Juslin, 2001). These physiological changes can be measured by techniques such as galvanic skin responses (GSR), heart rates, and breathing patterns. Similar to the way that music can induce mood it can also cause changes in arousal. Music can evoke such strong and potent changes in arousal within a listener that cognitive neuroscientists have termed such an experience as “chills”. Chills commonly involve the following physiological changes: increased skin conductance, increased heart rate and increased blood volume corresponding with an increase in body temperature. Generally, chills have been used as a representation of the physiological response of peak emotional pleasure within research (Salimpoor, Benovov, Larcher, Dagher, & Zatorre, 2011). The pleasure response associated with chills occurs as an activation of the mesolimbic reward system in the brain (Salimpoor et al. 2011). The mesolimbic reward system releases the neurotransmitter, dopamine which is associated with feelings of reward. Arousal and the consequent reward sensations it produces contributes largely to why we listen to certain pieces of music.

The Interaction between Mood and Arousal

Mood and arousal often go hand in hand especially when discussing music; it is hard to discuss the mood of a musical piece without discussing the arousal associated with it. The two factors are co-occurring and influence one another. The Circumplex model of affect characterizes the interaction between valence, the amount a mood is positive or negative, and arousal intensity (Posner, Russell, & Peterson, 2005). The Circumplex model can be seen below in Figure 1.

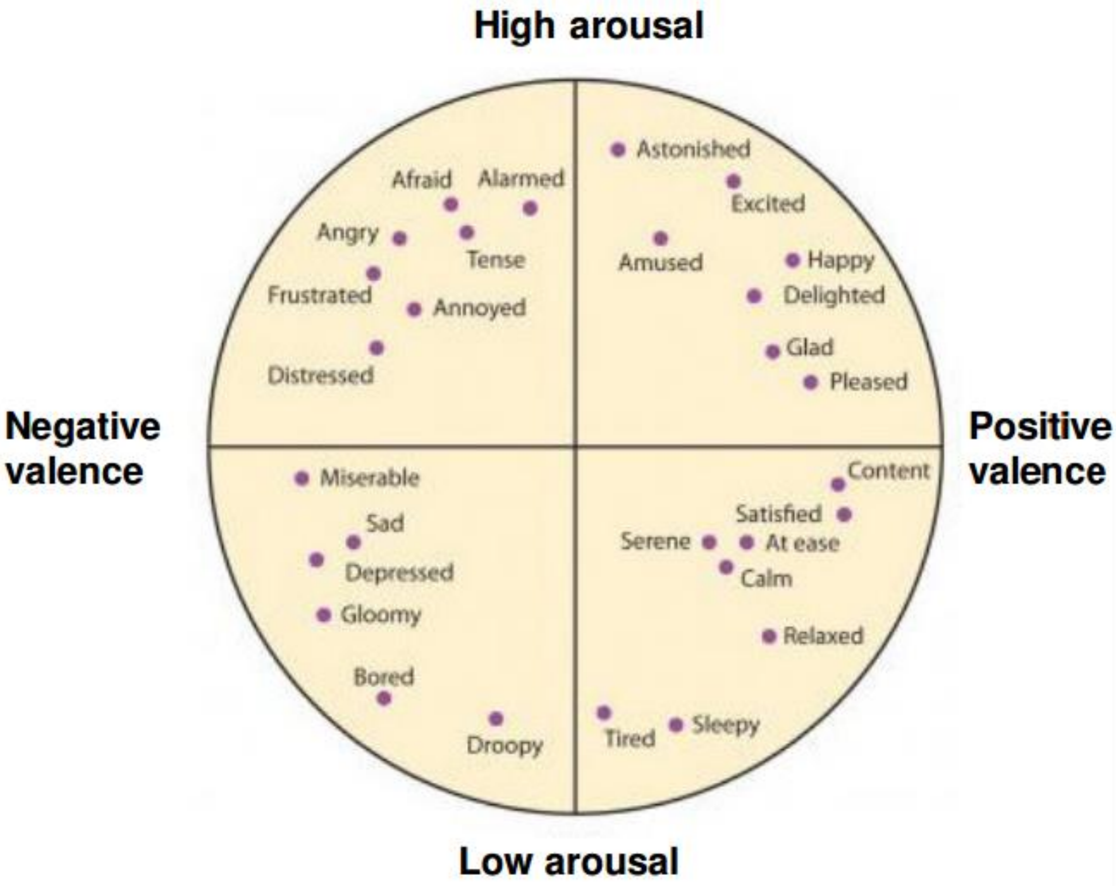

*Figure 1***.** Circumplex model of affect: describes the continuum and interaction between different valence and arousal states to create different emotional states, Adapted from Posner et al. 2005

Since music can invoke both mood and arousal, it naturally imposes this converging relationship between mood and arousal upon its listener. The interactions of mood and arousal have notable effects on cognition as well.

In the domain of music, the well-publicized *Mozart Effect* suggests that listening to Mozart's music may induce a short-term improvement on certain cognitive tasks (Rauscher, Shaw, & Ky, 1993). Media popularized versions of this hypothesis propose that listening to

Mozart makes you smarter. However, Thompson, Schellenberg, and Husain (2001) have illustrated that the *Mozart Effect* is an artifact of manipulating the listener's mood and arousal states. They compared two classical music pieces: a Mozart piece that had a pleasant (positive) mood and was energetic (high arousal) versus an Albinoni piece that had a sad (negative) mood and was slow (low arousal) on performance of a cognitive task adapted from the Rauscher et al's (1993) study. They found that performance was better when participants listened to the Mozart piece compared to the Albinoni piece. However, when mood and arousal was held constant between pre-testing and post-testing through statistical means, the advantage of the Mozart piece was eliminated (Thompson et al., 2001). The *arousal-mood effect* was later corroborated by Schellenberg and Hallam (2005). In the 2005 study, the researchers demonstrated that when a large sample of 10 and 11 year olds listened to a Mozart piece compared to a contemporary pop piece by the band Blur, performance on spatial memory testing was better after the children listened to the Blur piece. Thus, despite both pieces of music having a positive mood and high arousal, preference for a certain type of music was related to greater performance; the researchers deemed this effect satirically as the *Blur effect*. These early studies have mainly focused on spatial-temporal functioning, but it would be interesting to explore if mood and arousal induced by music can also influence other areas of cognition.

Executive Functions

We chose to examine the effects of musical mood and arousal on executive functioning to study a range of cognitive processes. Executive functions include working memory, reasoning, planning, task flexibility, vigilance, novel thinking, execution and inhibition responses, as well as problem solving (Phillips, Bull, Adams, & Fraser, 2002). Executive functioning is the reason we can mentally envision ideas, come up with answers to novel problems, stay focused and remain goal-oriented (Diamond 2013). Three main basic classes of executive functions exist: inhibition (which include: inhibitory control, selective attention), working memory and cognitive flexibility (set shifting, mental flexibility, and conflict monitoring) (Diamond 2013). From these three core classes, higher order executive functions such as reasoning, problem solving and planning are derived (Diamond 2013). The frontal and prefrontal lobes are accredited with the creation and management of executive functions (Prins et al., 2005). As a result damage to these brain areas often lead to impairments in executive functioning, as seen in strokes or acquired brain injuries (Prins et al., 2005; Ownsworth and Fleming, 2005). Since many of these cognitive processes are imperative for an assortment of activities we perform, adequate executive functioning is crucial to healthy mental functioning. Impairments in executive functioning have been implicated in addictions, attention deficit hyperactivity disorder, conduct disorder, depression, obsessive compulsive disorder, and schizophrenia (Baler & Voler, 2006; Diamond, 2005; Fairchild et al., 2009; Taylor-Tavares et al., 2007; Penades et al., 2007; Barch 2005). Poorer executive functioning has been linked to negative measures of physical health such as obesity, overeating, and substance abuse (Crescioni et al., 2011; Miller et al.,2011; Riggs, Spruijt-Metz, Sakuma, Chou, & Pentz, 2010). Better quality of life has been reported in people with greater executive function control (Brown & Landgraf, 2010; Davis, Marra, Najafzadeh, & Liu-Ambrose, 2010). Executive function performance has well been a predictor of mathematic and reading competency throughout schooling for children and adolescents (Borella , Carreti, & Pelegrina, 2010; Duncan et al., 2007; Gathercole, Pickering, Knight, & Stegmann 2004). Research has shown that poorer executive functioning leads to lower job success due to poor productivity, and difficulties in maintaining a job (Bailey, 2007). Finally in terms of public safety, individuals with poor executive functions have been correlated with greater prevalence of crime, reckless behavior, violence and emotional outbursts (Broidy et al., 2003; Denson, Pederson, Frise, Hahm, & Roberts, 2011). The above results illustrate how important healthy executive functioning is in our lives. If music can mediate executive functions, it proves to be a worthwhile area of investigation.

Mood and Executive Functions

It is easy to recall scenarios in our everyday lives where we felt a mood we were experiencing might have influenced our productivity and performance on a task. This basic behavioral interest has generated research examining the effects of mood and executive functions. Being in a positive mood has been shown to improve executive functions (Isen, 1999). Positive moods act as facilitators for innovation and task flexibility, through the reminiscence and creation of positive memories and thoughts (Isen, 1999). The enhancement of executive functions by positive mood has also been reported in tasks like the Wisconsin Card Sort test, where novel problem solving skills are required to be successful (Dreisbach & Goschke, 2006). A neurophysiological reason as to why this occurs is that positive moods increase dopamine levels, in the frontal cortex, and the anterior cingulate cortex which has a role in decision making (Ashby and Isen, 1999). Increases in dopamine in these regions are accredited with decreases in impulsivity and higher attentional regulation (Arnsten, & Li, 2005).

However, being in a positive mood can also hamper performance in cognitive tasks. Oaksford and colleagues (1996) found that participants in a positive mood had lower performance on the Tower of London Task, which is a traditional measure of executive function, specifically planning. Spies and colleagues (1996) also found positive mood to impair participants’ performance for a working memory span task. This may occur because being in a positive mood tends to increase the prevalence of positive thoughts which can interrupt processing on a given cognitive task or increase cognitive load with rumination about non-task relevant information (Phillips et al., 2002; Mitchell and Phillips, 2007). A proposed neurophysiological explanation as to why this may occur is that discernible areas within the anterior cingulate are involved in both cognitive control and emotional regulation; the interplay between the two perhaps can be inhibitory to executive functioning (Bush, Luu & Posner, 2000).

Philips et al. (2002) tested to see whether a positive mood served as an enhancer or an inhibitor to executive functioning. The authors induced half of their participants into a happy mood by telling participants to remember a time when they felt extremely happy, and the other half into a neutral mood by asking participants to remember an average day in their lives. All participants were then given a Stroop Task, and a verbal fluency task, both of which have been confirmed by neuroimaging and behavioral studies to be effective indicators of executive function (Philips et al., 2002). The Stroop Task is a task in which participants name the text colour a colour word is written in, this can be the same colour (congruent) or a different colour (incongruent) as the name of that colour word (van Veen & Carter, 2005). The executive functions this task measures are conflict monitoring, planning and cognitive flexibility. While the verbal fluency task measures creative and novel problem solving by asking participants to generate novel uses for an object such as a cup. They found that for the Stroop Task positive mood impaired performance, while for the verbal fluency task positive mood increased performance. The results of the Stroop Task agree with aforementioned theories that positive moods can, impede cognitive processing by increasing cognitive load or restrict cognitive flexibility caused by heightened emotional stature. The results of positive mood increasing verbal fluency suggest that positive moods can enhance creative problem solving.

The effects of negative mood and executive function have not been as extensively studied as positive affect and executive function. Clinical studies of early stage Parkinson's patients with depressed moods are reported to have lower executive functions (Uekerman et al. 2003). However negative mood has been also reported to enhance analytical processing, as it takes a less heuristic approach and uses a more localized or focused scope to solve a problem (Mitchell and Phillips 2007). Negative moods could promote acute stressful environment which have been demonstrated to be conducive to memory formation and learning (Joels, Pu, Wiegert, Oitzl & Krugers, 2006).

Mood and Arousal induced by Music on Executive Function

McConnell and Shore (2011) examined the effects musical mood and arousal can have on three domains of attention: alerting, orienting, and executive function. The authors using one Mozart Sonata altered the mode (mood) and the tempo (arousal) of the piece to create four music listening groups that subjects were randomly allocated to: 1) a major mode (positive valence) and fast tempo (high arousal), 2) a major mode (positive valence) and slow tempo (low arousal), 3) a minor mode (negative valence) and fast tempo (high arousal), 4) a minor mode (negative valence) and slow tempo (low arousal). Each participant listened to their assigned music piece for 10 minutes to establish the desired mood and arousal, before being administered the attentional network test (ANT). The ANT is a combination of the Posner cueing task, which measures vigilance and attentional orienting, and the Eriksen flanker task, which measures executive functions through conflict resolution, error detection and inhibitory control. The researchers found that of the three attentional domains only executive control was affected. Specifically, there was an integration of a high arousal level and a negative or positive mood that affected congruency scores on executive control portions of the task. Participants in the music condition that produced a negative valence and a high arousal were found to have a more efficient and accurate responses. Notably, no effects on executive function were seen in negative or positive valence music conditions if the arousal was low. This study demonstrates an important result, that certain combinations of mood and arousal can elicit optimal executive function performance. However since there are so many executive functions, this implores investigation if these combinations of mood and arousal can likewise affect other executive functions.

Current Study

Similar to the methodology employed by McConnell and Shore (2011), the current study will examine if the interaction of a mood and arousal induced by music can influence executive functioning. Specifically, this study will examine if certain mood and arousal combinations influence executive functions more than other combinations. Four musical listening groups will be produced that examine the extremes of mood and arousal: 1) a high arousal and positive mood group (HAP), 2) a high arousal and negative mood group (HAN), 3) a low arousal and positive mood group (LAP), 4) a low arousal and negative mood group (LAN). The music for these groups will be derived from instrumental music clips that have been previously rated in a pilot study that will meet the specification for arousal and mood (Nguyen & Grahn, 2013).

Three executive functions tasks are administered to participants measuring a range of cognitive abilities. We chose to focus on tasks that measure conflict monitoring, which is the conscious detection of errors or conflicts while processing information. Conflict monitoring was chosen because of its usefulness in a variety of our daily activities. A simple example would be driving down a familiar highway and seeing a lane ending sign that was not previously there, you are able to adaptively change your regular behaviour of driving down this lane now in relation to this new conflict. The effects of musical mood and arousal on conflict monitoring have not been previously investigated in the literature. Working memory and selective attention were also examined because their effects have also been previously studied (Greene, Bahri, & Soto, 2010; Jefferies, Smilek, Eich & Enns, 2008). A brief summary of the tasks are presented below:

1) Double Stroop Task: In this task three words appear on the screen, one word on top while two are on the bottom. Participants have to correctly click one of the two words at the bottom of the screen that correctly describes the colour the word at the top of the screen is written in, irrespective of the colour the bottom word is written in. The executive functions it measures conflict monitoring and reasoning.
2) Stimulus Detection Task: A series of 16 arrows are presented in a 4 by 4 array on the screen. Participants are to indicate if all the arrows are in the same direction or if one of the arrows is in a direction opposite relative to the other arrows. The executive functions it measures are vigilance, and selective attention.
3) Simon Task: Participants are instructed to remember three shapes of a certain colour. Anytime one of these three specified shapes appear participants are to hit a right hand response key; any other shapes participants are to hit a left hand response key. Shapes are presented individually and can appear on either the right or left of the screen. The Simon Task measures both conflict monitoring and working memory.

Based on previous literature, it is hypothesized that the interplay between mood and arousal will affect executive function performance (Thompson et al., 2001). Specifically we predicted that music of a high arousal (because of the arousal effect found in McConnell & Shore (2011)’s study) and a positive mood (because of the *positive affect hypothesis*) will lead to better performance on all executive function tasks than musical conditions of a low arousal or not of a positive mood.

Methods

Participants

One hundred undergraduate students (30 males and 70 females) from the University of Western Ontario (M_{age} = 18.42 years, *SD* = 0.84 years) participated in the study. Participants were recruited from the Psychology Research Participation Pool through the use of a sign-up poster (Appendix A). All participants were compensated with one research credit for participating. They all had normal hearing, normal or corrected-to-normal vision, and high proficiency in English. Participants were tested individually and did not have any prior exposure to or experience with the study. All participants provided informed consent in accordance with the guidelines approved by the University of Western Ontario Psychology Research Ethics Board.

Participants were randomly assigned to one of five experimental conditions for testing (4 music conditions and one silent control condition; n = 20 participants per group): high arousal positive music (HAP), high arousal negative music (HAN), low arousal positive music (LAP), low arousal negative music (LAN), and a silent condition (control).

Materials

Musical Stimuli. Twenty-four musical excerpts were used in the study (Table 1 in Appendix B). The musical excerpts were selected based on previous rating studies on musical mood and musical arousal (Nguyen & Grahn, 2013). The excerpts consisted of 90-second instrumental clips from a variety of musical genres: electronica, rock, classical, jazz, and etc. The six songs rated with the lowest arousal and the highest negative mood produced the LAN condition; the six songs rated with the highest arousal and the highest negative mood produced the HAN condition; the six songs rated with the lowest arousal and the highest positive mood produced the LAP condition; and finally the six songs rated with the highest arousal and the highest positive mood produced the HAP condition. To control for volume amongst the selected songs, the excerpts were normalized using the computer software Audacity (http://audacity.sourceforge.net).

Testing equipment. The experiment was performed on a Dell Vostro Latitude laptop with a 15 inch screen. Participants wore a pair of Bose Quiet Comfort 3 acoustic noise cancelling headphones. All the executive function paradigms were created with the computer software E-prime (2.0) (Psychology Software Tools, 2002; Schneider, Eschman & Zuccolotto, 2002).

Behavioural tasks

Double Stroop Task.

Participants were presented with two different visual stimuli during the Double Stroop Task. A fixation screen consisting of a black centered cross; and a target screen of three words displaying different combinations of the words “RED” and “BLUE”, written in different colour combinations of red and blue. All stimuli were presented on a white opaque background (Appendix C). The stimuli were displayed to participants for two seconds, while the fixation screen stimuli were presented between stimuli for one second.

During the task three words appeared on the screen: one word at the top of the screen, and two words on the bottom. Participants have to correctly identify the colour of the top word by selecting one of the two bottom words that describes that colour regardless of the bottom word’s colour. Participants pushed the “m” key with their right hand for the right bottom word and the “z” key with their left hand for the left bottom word on the keyboard. The design of this paradigm creates a double dissociation within the task. Participants have to correctly identify the colour of the top word while ignoring the colour name; while for the bottom words participants have to identify the name of the colour while ignoring the text colours. Congruent stimuli were those where the top word and the bottom word were the same name and colour. Incongruent stimuli were those in which either the top or bottom or both words differed in colour from the meaning of the word.

The Double Stroop Task during the experiment was split into six trials, each consisting of 15 stimuli. Half of the total 90 stimuli were congruent and the other half were incongruent. Participants were exposed to music or silence during the Double Stroop Task dependent on the group the participant was in. Each of the six trials had a different song playing in the background respective to the musical condition a participant was assigned to. For example a HAP participant would have a different HAP song playing for each of the trials. Trial order was randomized between participants. The task took approximately six minutes to complete.

Stimulus Detection Task.

For the Stimulus Detection Task, participants were presented with a 4 by 4 array of black arrows pointing right or left. Stimuli were presented for two seconds. Additionally a fixation screen consisting of a black centered cross was displayed between stimuli for one second. All stimuli were presented on a white opaque background (Appendix D). For some arrays, the directions of the arrows were pointing in the same direction, this was a congruent stimulus. While for other arrays, one of the arrows was pointing in a different direction relative to the other arrows, this was an incongruent stimulus. Participants were to indicate if the arrows were all pointing in the same direction or if one of the arrows was pointing in a different direction in relation to the others. If all the arrows were pointing in the same direction, participants were to use their right hand and push the “m” key; while if one of the arrows was pointing in a direction opposite to the rest of the arrows, participants were to use their left hand and push the “z” key. Any of the 16 arrows in the 4 by 4 array could be a target arrow that could be pointing in a different direction in the incongruent stimuli.

The Stimulus Detection Task was split into six trials, each consisting of 15 stimuli. Half of the total 90 stimuli were congruent and the other half were incongruent. Participants were exposed to music or silence during the stimulus detection task dependent on the group the participant is in. Each of the six trials had a different song playing in the background respective to the condition a participant was assigned to. For example a HAP participant would have a different HAP song playing for each of the trials. The trial order was randomized between participants. The task took approximately six minutes to complete.

Simon Task.

Lastly, during the Simon Task, a variety of red and blue shapes (circles, squares and triangles) were presented to participants. Stimuli were presented individually to the right or left side of the screen for two seconds. Additionally, a fixation screen consisting of a black centered cross was displayed between stimuli for one second. All stimuli were presented on a white, opaque background (Appendix E). In this paradigm, participants were instructed to respond to certain stimuli of a certain colour with one keyboard response, and respond to all other stimuli with another keyboard response. If ever a blue triangle, red square, or red circle appeared on the screen participants were to use their right hand and press the “m” key; while if any other shape of any other colour were presented participants were to use their left hand and press the “z” key. Stimuli were considered congruent if they were presented on the same side as the correct response hand, and they were considered incongruent if they were presented on the opposite side of the correct response hand.

The Simon Task was split into six trials, each consisting of 15 stimuli. Half of the total 90 stimuli were go stimuli and the other half are no-go stimuli. The stimuli were displayed to participants for two seconds, while a fixation screen was presented between stimuli for one second. Participants were exposed to music or silence during the Simon Task dependent on the musical condition group the participant was in. Each of the six trials had a different song playing in the background respective to the condition a participant was assigned to. For example a HAP participant would have a different HAP song playing for each of the trials. The trial order was randomized between participants. The task took approximately six minutes to complete.

Procedure

Prior to starting the experiment, brief verbal instructions were given to the participants regarding the nature of the tasks. After these instructions, participants were provided with a letter of information detailing the experiment (Appendix F) and asked to provide informed, written consent (Appendix G). Participants then completed in a randomized order the three experimental paradigms: the Stroop Task, the Stimulus Detection Task and the Simon Task. Participants wore a pair of acoustic noise cancelling headphones for the duration of the experiment, and all responses were made using the keyboard of a Dell laptop. The total experimental time was 33 minutes (18 minutes to complete all three tasks, and 15 minutes for experimental set-up), and at the end of the experiment a debriefing form was administered to participants (Appendix H).

Data Analysis

In all three tasks, two dependent variables were measured for each participant: their percent correct and their reaction time. Percent correct was calculated as the percentage of correct responses averaged across the 90 stimuli per task. Reaction time was calculated as the latency of a participant's response from the onset of the stimulus averaged across the 90 stimuli per task. A higher percent correct score indicated better performance, and a lower reaction time indicated better performance. Data was excluded if participants scored two standard deviations below the mean for each of the dependent variables for each of the three tasks respectively. As well any stimuli that did not elicit a response were excluded from analysis.

In all three tasks, five between-subjects conditions were analyzed based on the musical conditions participants were assigned to: HAP, HAN, LAP, LAN, and a silent c\ontrol condition. Each participant was also assessed on two within-subjects conditions based on the congruency of the stimuli presented for each of the tasks: congruent and incongruent. Performance on each of the executive function tasks was analyzed in SPSS (21.0) using a 5 (musical condition) x 2 (congruency) mixed design analysis of variance (ANOVA). A separate split plot analysis was conducted for percent correct and reaction time for each of the three tasks; therefore, a total of 6 split plot analyses were conducted.

If significant main effects or interactions were found for musical condition the between subjects variable, post-hoc paired t-tests were performed to see what was driving the effect.

Results

Double Stroop Task

Percent Correct. A total of 98 participants were analyzed, data was excluded from two participants because their overall percent correct scores were below two standard deviations of the mean (*M* = 83.533%, *SD* = 10.180%). A Levene's Test revealed that variation was equal across groups, *F*(4, 93) = 0.510, *p* = 0.729; therefore we proceeded with comparisons between groups. There was no significant main effect of musical condition, *F*(4, 93) = 0.662, *p* = 0.620.

Regardless of the music participants listened to, there was no significant difference in their percent correct scores on the Stroop task. There was a significant main effect of congruency, *F*(1, 93) = 210.210, $p < 0.001$. Participants were significantly more accurate when presented a congruent stimuli (*M* = 96.701%, *SD* = 10.184%) than an incongruent stimuli (*M* = 70.680%, *SD* = 17.762%). However, there was no significant interaction between musical condition and congruency, *F*(4, 93) =1.030, $p = 0.729$ (Figure 2).

Reaction Time. A total of 97 participants were analyzed, data was excluded from three participants because their overall reaction times were two standard deviations below the mean (*M* = 1240.805 ms, *SD* = 213.288 ms). A Levene's Test revealed that variation was equal across groups, *F*(4, 92) = 0.472, $p = 0.756$; therefore we proceeded with comparisons between groups. Similar to percent correct, there was no main effect of musical condition, *F*(4, 92) = 1.598, $p = 0.182$. Music by itself seemed to not affect participant's reaction time during the task. There was a significant main effect of congruency, *F*(1, 92) = 412.139, $p < 0.001$. Participants when presented incongruent stimuli (*M* = 1404.934 ms, *SD* = 241.000 ms) were significantly slower in responding than when presented congruent stimuli (*M* = 1076.978 ms, *SD* = 219.966 ms). There was a significant interaction between musical conditions and congruency, *F*(4, 92) = 2.710, $p = 0.035$. Post hoc tests were conducted on all condition combinations, relevant comparisons are presented in Table 1. Paired t-tests revealed that for congruent stimuli, participants who listened to HAP music (*M* = 1175.024 ms, *SD* = 161.583 ms) compared to those that listened to LAN music (*M* = 1145.651 ms, *SD* = 221.840 ms) performed significantly faster, *t*(19) = 2.214, $p = 0.039$. When presented with incongruent stimuli participants that listened to HAP music (*M* = 1316.201 ms, *SD* = 185.310 ms) responded significantly faster than participants that listened to HAN music (*M* = 1428.610 ms, *SD* = 283.120 ms), *t*(18) = 2.779, $p = 0.012$. Similarly, participants who listened to HAP music responded significantly faster than participants that listened to LAP music (*M* = 1384.418 ms, *SD* = 294.435 ms), $t(18) = 2.234$, $p = 0.039$ (Figure 3).

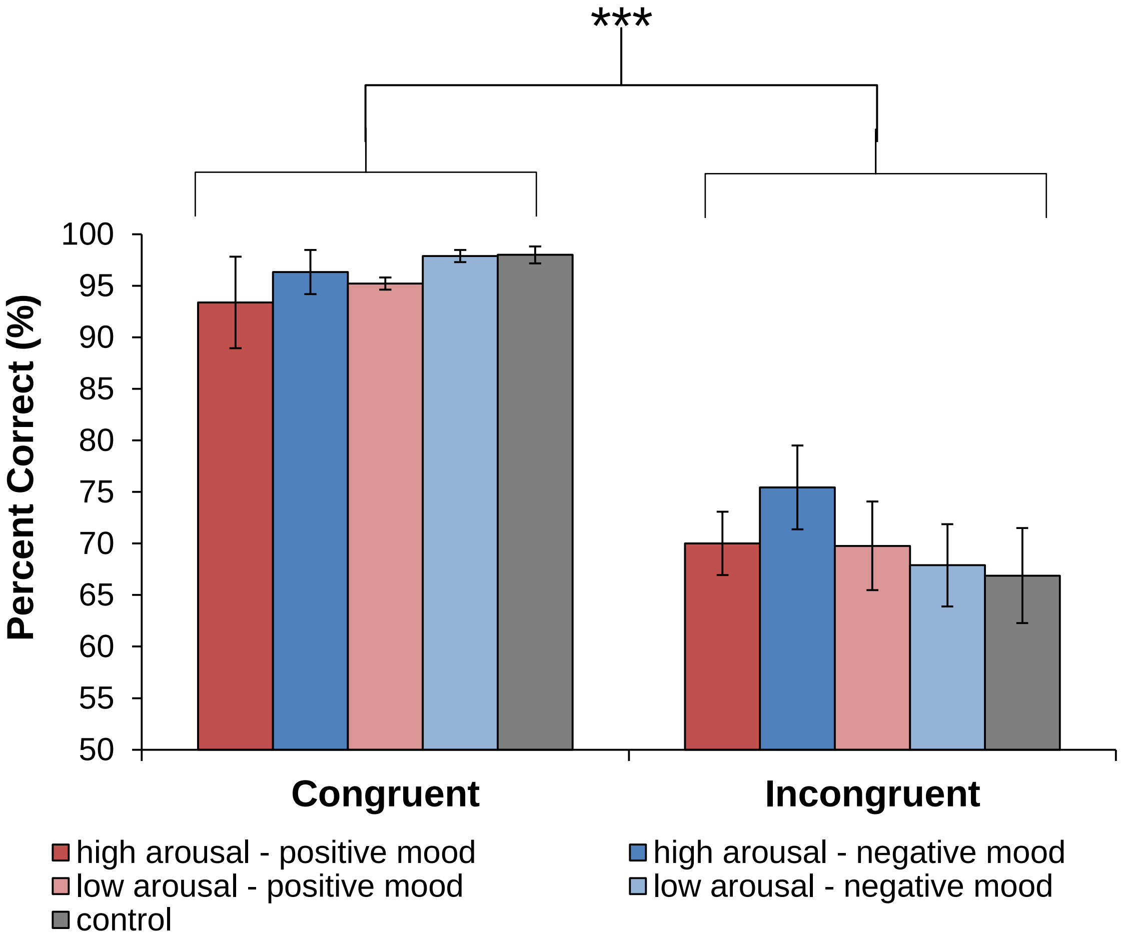

Figure 2. The interaction between musical condition and congruency on percent correct scores (%) in the Double Stroop Task. There was no main effect of musical condition on percent correct scores. There was a significant main effect of congruency. Participants performed better on the congruent stimuli than incongruent stimuli. Error bars represent standard error of the mean.

*Notes: *** $p<0.001$.*

Table 1

Post-hoc-t-tests comparing HAP congruent and incongruent condition comparisons for Double Stroop Reaction Times (ms).

Condition Comparison	df	df *t* value	Sig. (2-tailed)
LAN Congruent-HAP Congruent	19	2.214	0.039*
HAN Congruent-HAP Congruent	18	0.086	0.932
LAP Congruent-HAP Congruent	17	0.643	0.529
Control Congruent-HAP Congruent	19	1.584	0.130
LAN Incongruent-HAP Incongruent	19	2.061	0.053
HAN Incongruent-HAP Incongruent	18	2.779	0.012*
LAP Incongruent-HAP Incongruent	17	2.234	0.039*
Control Incongruent-HAP Incongruent	19	1.922	0.070

Note: * $p<0.05$

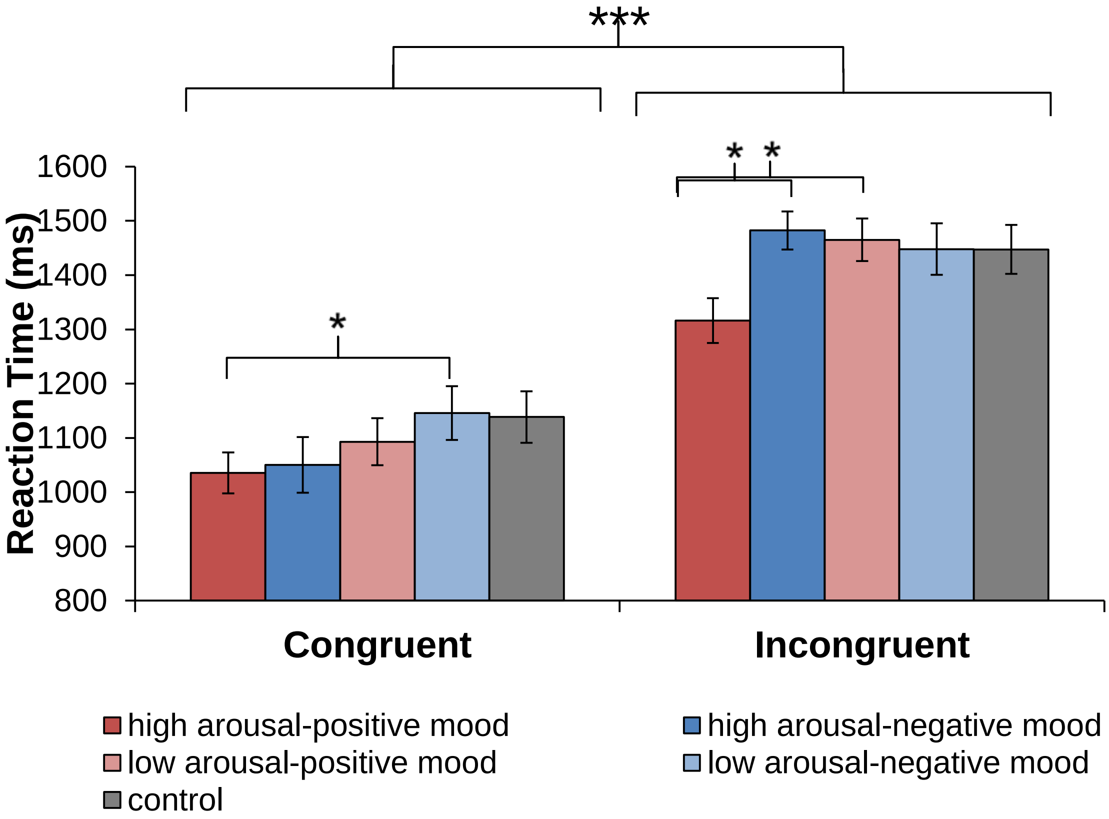

Figure 3. Interaction between musical condition and congruency for reaction times (ms) on the Double Stroop Task. There was no main effect of musical condition on reaction time. There was a significant main effect of congruency on reaction times, participants responded quicker for congruent stimuli than incongruent stimuli. There was a significant interaction between musical condition and congruency. HAP participants performed better than LAN participants when presented with congruent stimuli. While HAP participants performed better than HAN and LAP participants when presented with incongruent stimuli. Error bars represent standard error of the mean.

Notes: $* p<0.05$; $*** p<0.001$

Stimulus Detection Task

Percent Correct. A total of 97 participants were analyzed, data was excluded for three participants because their overall reaction times were two standard deviations below the mean (*M* = 93.278%, *SD* = 16.264%). A Levene's test revealed that variation was significantly different amongst groups, *F*(4, 92) = 3.817, *p* = 0.006, we still proceeded with comparisons between groups, however these results should be interpreted with caution because variance was not equal between groups. There was no main effect of musical condition on percent correct scores for the Stimulus Detection Task, *F*(4, 92) = 1.748, *p* = 0.146. Listening to music, relative to silence had no effect on participants' ability to choose the correct response on the stimulus detection task. There was a significant main effect of congruency on percent correct scores for the stimulus detection task, *F*(1, 92) = 22.533, $p < 0.001$. Participants were significantly more accurate when presented with congruent stimuli (*M* = 97.459%, *SD* = 3.205%) than incongruent stimuli (*M* = 94.638%, *SD* = 5.912%). There was no significant interaction between congruency and musical condition on percent correct scores for the Stimulus Detection Task, *F*(4, 92) = 0.717, *p* = 0.583 (Figure 4).

Reaction Time. The stimulus detection task reaction time data for all 100 participants was analyzed. A Levene's test revealed that variation was equal across groups, *F*(4, 95) = 2.257, *p* = 0.094; therefore we proceeded with comparisons between groups. There was no main effect of musical condition on participant's reaction time during the Stimulus Detection Task, *F*(4, 95) = 1.896, *p* = 0.117. Participants responded equally as fast regardless of the music they listened to. There was a significant main effect of congruency on participants' percent correct scores on the stimulus detection task, *F*(1, 95) = 5.818, *p* = 0.018. Participants responded significantly faster for congruent stimuli (*M* = 700.711 ms, *SD* = 121.830 ms) compared to incongruent stimuli (*M* = 724.324 ms, *SD* = 114.669 ms). There was no significant interaction between musical condition and congruency on participants' reaction times during the stimulus detection task, *F*(4, 95) = 1.119, *p* = 0.352 (Figure 5).

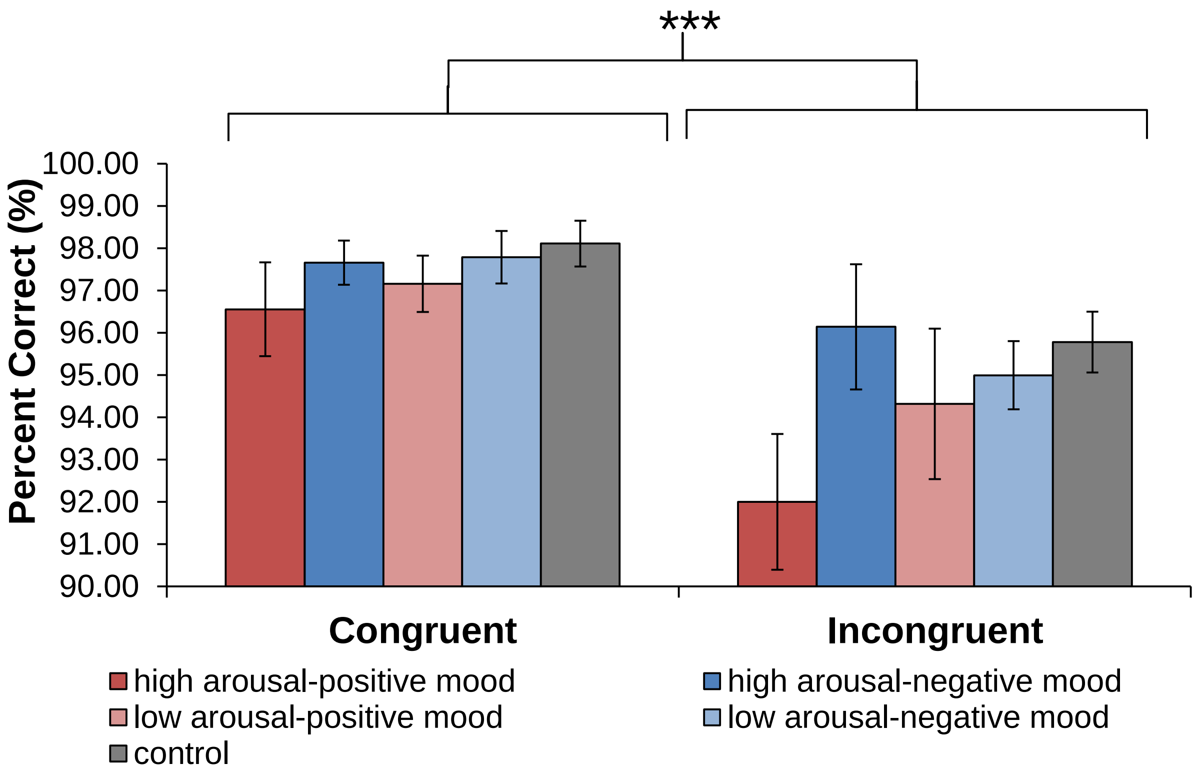

Figure 4. Interaction between musical condition and congruency for percent correct on the Stimulus Detection Task. There was no main effect of musical condition on percent correct scores. There was a significant main effect of congruency. Participants performed better on the congruent stimuli than incongruent. Error bars represent standard error of the mean.

Notes: *** $p<0.001$

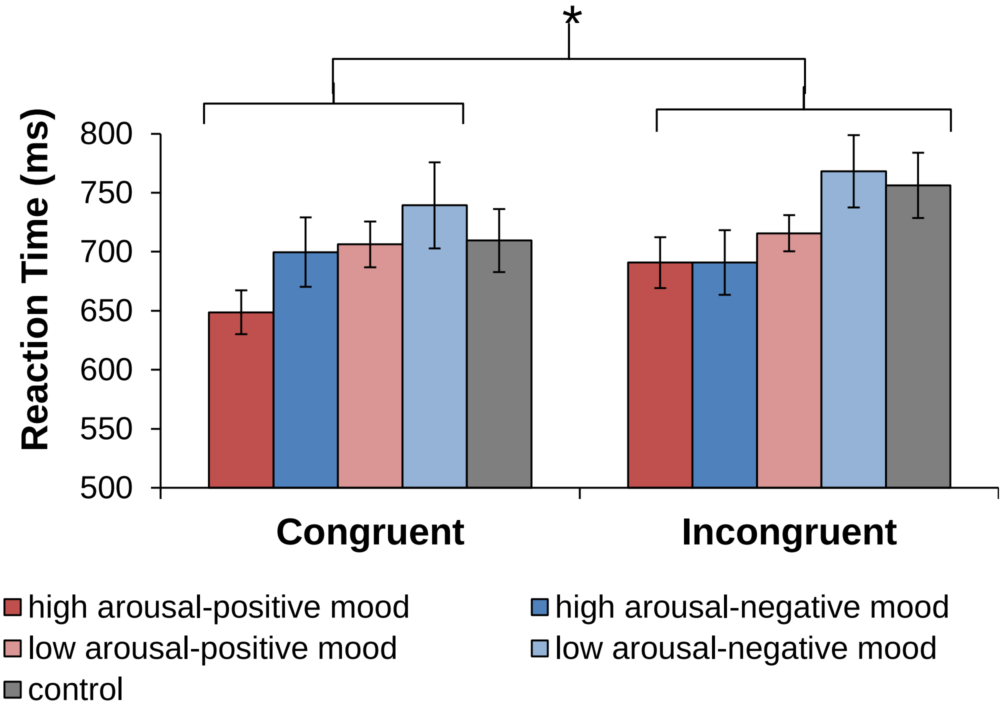

Figure 5. Interaction between musical condition and congruency for reaction times (ms) on the Stimulus Detection Task. There was no main effect of musical condition on reaction times. There was a significant main effect of congruency on reaction times. Participants performed better on congruent stimuli than incongruent. Error bars represent standard error of the mean.

Notes: * $p<0.05$

Simon Task

Percent Correct. The data for 96 participants was analyzed; the data for four participants was excluded because their overall percent correct scores were two standard deviations below the mean (*M* = 78.844%, *SD* = 27.374%). A Levene's test revealed that variation was equal across groups, *F*(4, 89) = 1.127, *p* = 0.349; therefore we proceeded with comparisons between groups. There was no significant main effect of musical condition on participants' percent correct scores for the Simon Task, *F*(4, 89) = 0.627, *p* = 0.644. The musical conditions participants listened to had no effect on their accuracy in the Simon Task. There was a significant main effect of congruency on participants' percent correct scores during the Simon Task, *F*(1, 89) = 10.021, *p* = 0.002. Participants were more accurate on congruent stimuli (*M* = 84.799%, *SD* = 19.431%) than incongruent (*M* = 82.080%, *SD* = 23.300%). There was no significant interaction between musical condition and congruency on percent correct scores during the Simon task, *F*(4, 89) = 1.796, *p* = 0.137 (Figure 6).

Reaction Time. All 100 participants' reaction times were analyzed. A Levene's test revealed that variation was equal across groups, *F*(4, 95) = 1.935, *p* = 0.111; therefore we proceeded with pairwise comparisons. There was a significant main effect of musical condition on participants' reaction times during the working memory task, *F*(4, 95) = 3.481, *p* = 0.011. Post Hoc tests were conducted on all condition combinations, relevant comparisons are presented in Table 2. Pairwise comparisons revealed that participants listening to HAP music (*M* = 764.817 ms, *SD* = 166.205 ms) compared to LAN music (*M* = 921.435 ms, *SD* = 178.636 ms) were responded significantly faster during the Simon Task, *t*(19) = 2.621, *p* = 0.017. Similarly pairwise comparisons revealed that HAP participants performed faster than participants in the control condition (*M* = 862.967 ms, *SD* = 120.727 ms), *t*(19) = 2.224, *p* = 0.038. There was a significant main effect of congruency on participants' reaction times during the working memory task, *F*(1, 95) = 10.216, *p* = 0.002. Participants had longer reaction times on incongruent stimuli (*M* = 858.093, *SD* = 174.656) than congruent stimuli (*M* = 834.559, *SD* = 158.834). There was no significant interaction between congruency and musical condition on participants' reaction times during the working memory task, *F*(4, 95) = 1.748, *p* = 0.146 (Figure 7).

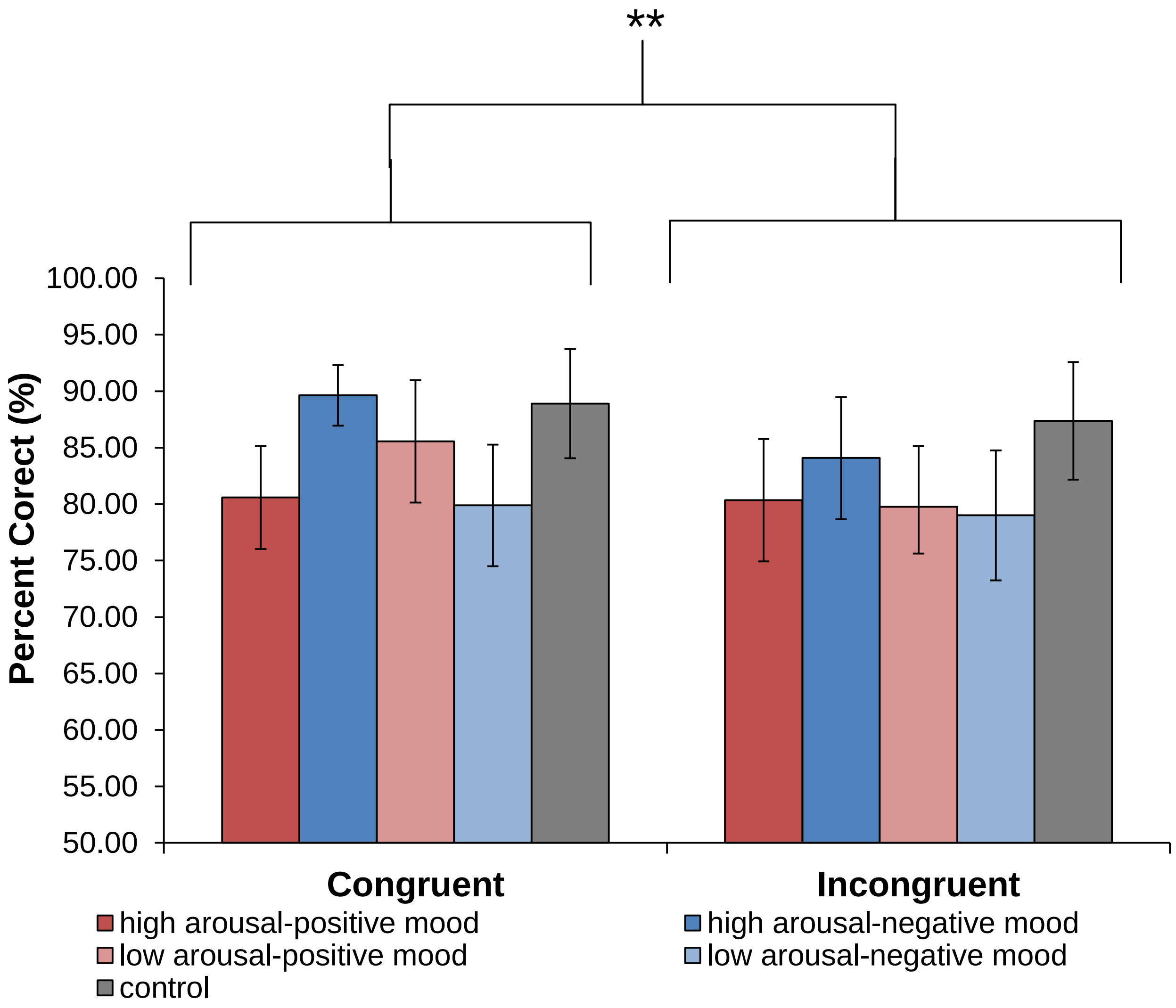

Figure 6. Interaction between musical condition and congruency for percent correct (%) on the Simon Task. There was no main effect of musical condition on percent correct scores. There was a significant main effect of congruency. Participants performed more accurately on congruent stimuli than incongruent. Error bars represent standard error of the mean.

*Notes: ** p<0.01*

Table 2

Post-hoc t-tests comparing HAP condition comparisons for Simon Task Reaction Times (ms).

Condition Comparison	df	*t* value	Sig. (2-tailed)
LAN-HAP	19	2.621	0.017*
HAN-HAP	19	0.748	0.464
LAP-HAP	19	1.695	0.106
Control-HAP	19	2.224	0.038*

Note: * $p<0.05$

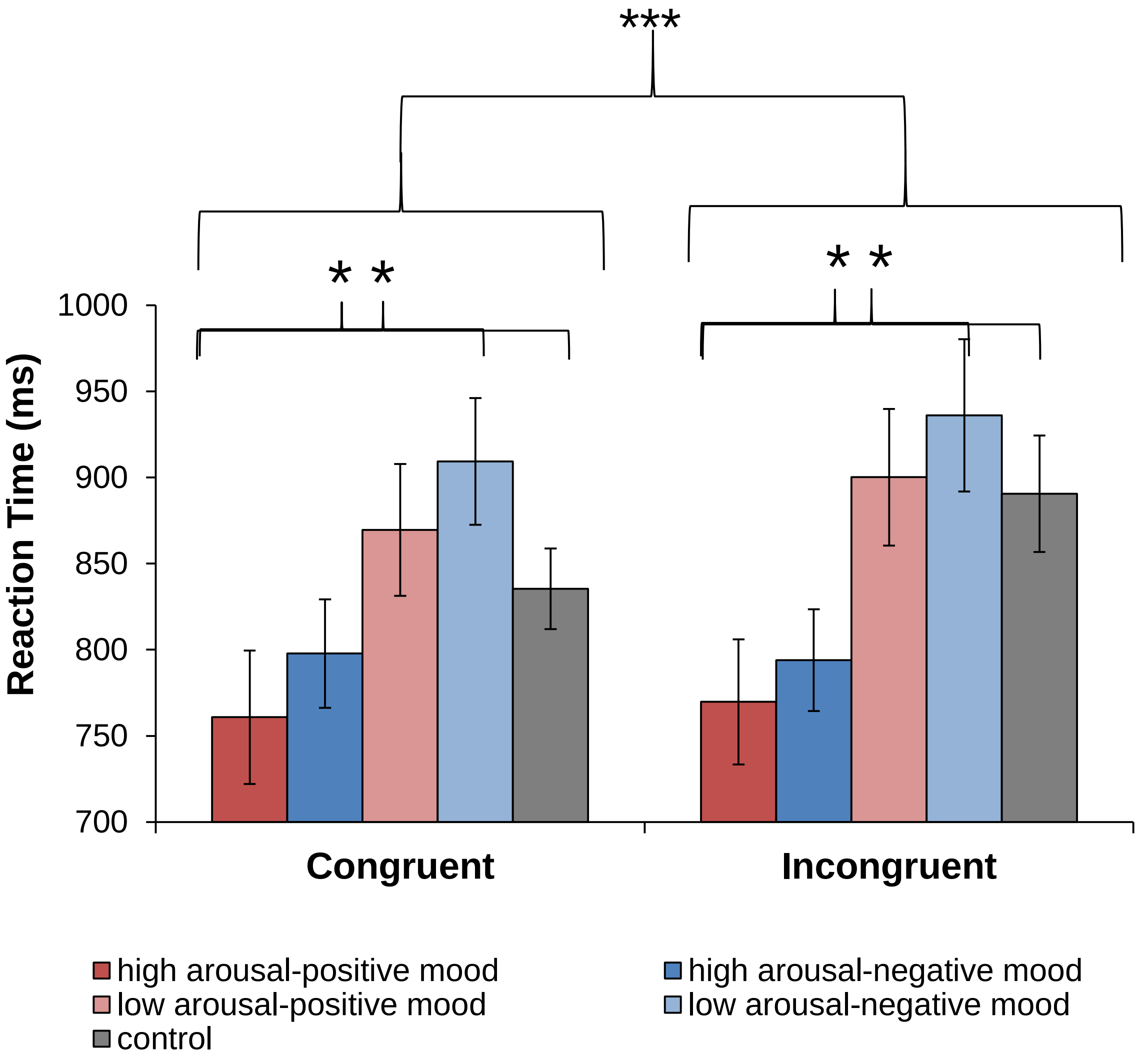

Figure 7. Interaction between musical condition and congruency for reaction times (ms) on the Simon Task. There was a significant main effect of musical condition on reaction time. Participants that listened to HAP music responded faster than participants that listened to LAN music or performed the task in silence. There was a significant main effect of congruency. Participants responded faster during the presentation of congruent stimuli than incongruent. Error bars represent standard error of the mean.

*Notes: * p<0.05; *** p<0.001*

Discussion

The goal of the current study was to determine if certain combinations of musical mood and arousal affect performance on a variety of executive function tasks. We predicted that participants listening to music that induced high arousal and positive mood would perform better on the three executive function tasks than the other musical conditions or silence. We found that music had no effect on participants' percent correct scores or their accuracy during the task, but that participants' reaction times were faster if they listened to HAP music in both the Double Stroop Task and the Simon Task. The Stimulus Detection Task reaction times however were not affected by musical condition.

For all three tasks: the Simon Task, Double Stroop Task, and the Stimulus Detection Task; performance was better for congruent stimuli compared to incongruent. This finding is consistent with previous literature regarding these tasks. For the Simon Task this result is explained by the *Simon effect*, which is that participants tend to respond more accurately and faster when the stimulus is presented to the same side as the right or left hand used to make the response (Simon & Beurbaum, 1990). The disruption in reaction times or accuracy occurs for incongruent stimuli when the spatial location of the stimulus is presented on the opposite side of the right or left hand used to make the response. In our Simon Task participants only have to remember which coloured shapes are a right or left hand responses to be successful; spatial location is irrelevant to task success. However, this spatial location congruence interferes with parallel information processing (the correct response and the type/location of stimulus presented) needed to complete the task, and hence creates a conflict when the stimulus is presented to an opposite side of the hand response, resulting in worse performance (Simon & Beurbaum, 1990).

Similarly for the Double Stroop Task, the Stroop effect explains why the congruency between the colour and name of the colour word interferes with participants' performance for incongruent stimuli. The Stroop effect is that participants respond slower to name the colour of a colour word, if the colour is incongruent with the meaning of that colour word (Cohen, Dunbar, & McClelland, 1990; Stroop, 1935). Importantly this effect disappears when the meaning of the word is the same as the word's text colour or for semantically unrelated words (e.g. window in red text) (Cambridge Brain Sciences, 2015; Scheibe, 1967). In the Double Stroop task there is an interference caused by parallel processing of the irrelevant parameters (the name of the top word, text colour of the bottom words) and the relevant parameters (text colour of the top word, name of the bottom words) making incongruent stimuli even more cognitively taxing than congruent stimuli (Macleod, 1991).

Congruency effects have been reported many times in the literature for selective attention tasks similar to the stimulus detection task used in our study (de Fockert, Rees, Frith, & Lavie, 2001). The congruent condition for the Stimulus Detection Task was whether all the stimuli were pointing in the same direction; essentially if all the stimuli were the same. The incongruent condition was whether one of the stimuli was pointing in a different direction relative to the other stimuli. It is not surprising that participants perform more accurately and respond faster for congruent stimuli as past research has demonstrated that participants use a heuristic approach in scanning rows of the same stimuli, while using a localized, systematic approach to look for different stimuli; the heuristic approach for same stimuli has been found to be more accurate and faster (Bamber, 1969). Similarly, congruent and incongruent stimuli are nearly identical except for the spatial orientation of the incongruent arrow relative to the surrounding arrows. Research has found that reaction times are longer when looking for a different stimulus amongst visually similar stimuli. This could explain why incongruent stimuli took longer to identify and why these identifications were less accurate (Nakayama and Silverman 1986).

Though percent correct scores were unaffected by musical conditions, reaction times were influenced by musical condition in both the Simon Task and the Double Stroop Task. Notably participants that listened to HAP music had faster reaction times in both of these tasks. Below are plausible reasons as to why this effect may have occurred. The *positive-affect* hypothesis suggests that being in a positive mood may facilitate enhanced performance on cognitive tasks (Olivers & Nieuwenhuis, 2006). The neurophysiological reasons as to which the *positive-affect* hypothesis may occur is that being in a positive mood increases the amount of dopamine available in areas of the brain involved in cognitive flexibility and higher order thinking like the anterior cingulate and prefrontal cortices (Ashby, 1999). Previous neuroimaging studies have implicated the activation of both the anterior cingulate cortex (ACC) and prefrontal cortex during performance in traditional Stroop and Simon Tasks (Pardo, Pardo, Janer, & Raichle, 1990; Kerns, 2006). The ACC in particular, plays an important role in successful conflict monitoring while processing information (MacDonald, Cohen, Stenger, & Carter, 2000; Van Veen, Cohen, Botvinick, Stenger, & Carter, 2001). The processing of relevant and irrelevant stimulus parameters during these conflict tasks is believed to occur by separate neural pathways. A model of the ACC's conflict monitoring role claims that the ACC strengthens the task relevant parameters and responses while simultaneously inhibiting task irrelevant parameters and responses; through projections to the dorsolateral prefrontal cortex and other areas involved in cognitive control (Mansouri, Tanaka, & Buckley 2009). This conflict monitoring model of the ACC is shown below in Figure 7.

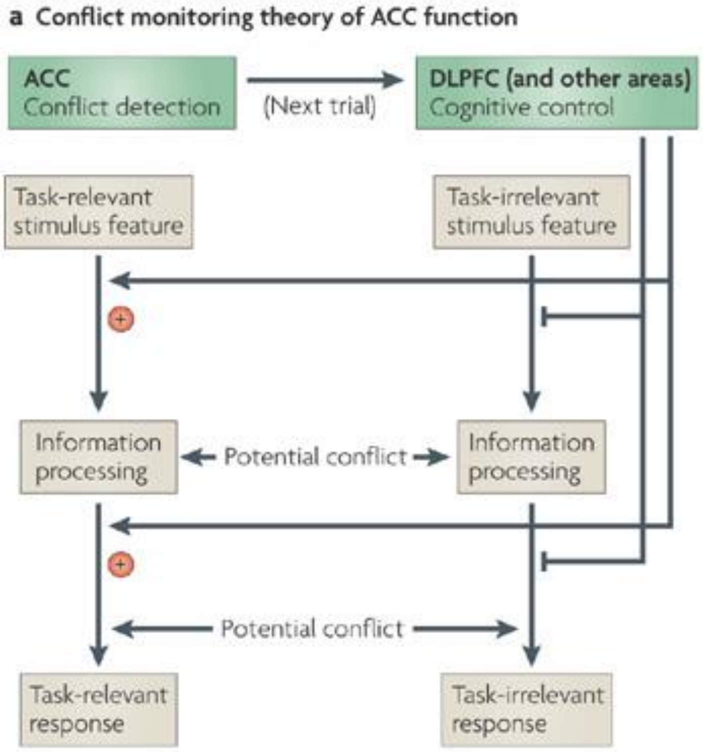

Figure 8. Conflict monitoring model of the ACC during cognitive control, Adapted from Mansouri, Tanaka, & Buckley 2009.

Conflict monitoring is an executive function that is common between both the Double Stroop and the Simon tasks; increasing activation in the anterior cingulate cortex as proposed by the *positive affect* hypothesis may explain the increase in performance seen in the current study. A study by Nadler, Rabi and Minda (2010) found that participants in positive moods were more successful than participants in negative or neutral moods on tasks that relied on following a series of rules. Both the Double Stroop and the Simon Task, have a set of rules participants must follow to be successful. For the Double Stroop Task it’s focusing on the relevant parameters while ignoring the irrelevant parameters in choosing the correct bottom word; while for the Simon task it’s remembering which shapes correspond to a right or left hand response. The stimulus detection task requires less of a rule-based procedure, but is more emphasized on selective attentional responses. In accordance with this, rule-based tasks have been found to activate different brain regions than non-ruled based tasks. Rule-based tasks (where conscious cognitive processes are required) activate areas involved in cognitive flexibility again most notably, the anterior cingulate and prefrontal cortices; while non-rule based tasks (e.g. simple attentional paradigms) activate visual cortical areas (Ashby & Got, 1988). This might explain why the stimulus detection task, a non-rule emphasized task may have not been affected by HAP music because it doesn't employ regions of the brain used in cognitive flexibility and conflict monitoring as the other two tasks do.

If being a positive mood does increase performance, then why wasn't a similar increase observed in the LAP participants' reaction times during the Double Stroop and Simon tasks? A reason to why LAP participants didn't perform as well as HAP participants is the *Yerkes-Dodson Law*. The Yerkes-Dodson law states that there exists an optimal arousal level for task performance, and over or under arousal levels reduce this performance; resulting in an inverted u parabola for arousal and performance (Cohen, 2011). Supporting this, heightened arousal states are believed to help an individual's self-focus (McConell & Shore, 2011). The increase in self-focus has been reported in high-intensity arousal states like joy and excitement (Panayiotou, Brown, & Vrana, 2007). The LAP music could simply just not be high enough in arousal to elicit as optimal a response as the HAP music does. One way to confirm this would be to make intermediate arousal levels between the HAP and LAP music conditions. We could see if there is a trend towards increasing performance the closer the arousal level is to HAP; or alternatively if there is an intermediate arousal level in which participants perform even better than HAP music. So we see that both a positive mood and a high arousal level are needed to get these faster reaction times seen during the Double Stroop Task. This result provides strong evidence for the interaction of both musical mood and arousal influencing cognition; only a certain combination of musical mood and arousal was able to increase performance during the Double Stroop Task and the Simon Task. This high arousal effect on influencing executive function performance also mirrors the arousal effect found by McConnell & Shore (2011) in their study.

Looking specifically at the Simon task, we see that musical condition by itself has a significant effect on reaction time during the task. Participants that listened to HAP music responded faster than both participants who listened to LAN music and control participants. A study by Kuhbander & Zehetleitner (2011) found that participants had better conflict adaption in tests of adaptive executive control when in a HAP mood compared to a LAN mood which mirrors our current findings in the Simon task. In their study, participants were induced into a happy, calm, sad, or anxious mood by listening to certain pieces conveying these emotions and remembering an autobiographical event specific to the emotion of the condition they were assigned. Participants were then tested on a visual search task in which they had to find a stimulus that was on an angle different that the rest of the visually identical stimuli, while ignoring distractor stimuli that would illuminate periodically. The conflict monitoring in this task is to ignore the irrelevant illuminated distractor stimuli, but focus on which stimulus is at a different angle than the rest of the stimuli. Participants were able to better perform this task when in a HAP mood compared to a LAN mood (Kuhbander & Zehetleitner 2011). However a key methodological difference between their study and ours is that participants passively listened to music while performing the executive function tasks, while in Kuhbander & Zehetleitner's study music was only listened to during the mood induction.

The Simon task as well encodes a component of working and recognition memory during the task. In a study on recognition memory, participants were found to perform better while being in a HAP mood, which supports our results. However, in that same study participants in LAN conditions performed just as well as HAP participants, contrary to our findings (Greene et al., 2010). So it's difficult to interpret if our findings on reaction time were a result of music's effect on recognition and working memory during the Simon task.

It is important to note that participants that listened to HAP music performed significantly faster than participants who performed the task in silence. This effect of certain musical moods and arousals increasing performance relative to silence has been reported for working memory (Mammarellla, Fairfield, & Cornoldi, 2007), and attentional tasks (Jefferies et al. 2008) previously. However this finding is novel for the Simon task which measures conflict monitoring. Even if this increase in performance by HAP music is temporary on cognition (Husain, Thompson, & Schellenberg, 2002), it may be worthwhile to explore the effects of pairing music listening versus silence with current executive function treatments for clinical populations where there are deficits in cognitive control. There is some research observing this interaction between passive music listening during executive function rehabilitation that has shown some merit in stroke and traumatic brain injury populations (Sarkamo et al.,2008; Thaut et al., 2009).

Focusing now on the Double Stroop Task, it is interesting that there is an interaction between musical condition and congruency, but no significant main effect of music by itself on reaction time. The congruent conditions, replicate some of the findings in the Simon Task where HAP music participants respond significantly faster than LAN participants. While, in the incongruent conditions participants listening to HAP music respond significantly faster than participants who listen to HAN and LAP music. Previous mood induction studies have demonstrated that high arousal negative moods are deemed as anxious (Eysenck, Santos, Derakshan & Calvo, 2007; Jefferies et al., 2008; Thompson, Schellenberg & Husain, 2001). Such induced anxious moods have been found to hamper cognitive performance, because being anxious creates a sensory conflict of trying to escape that anxiety that can interfere with information processing (Eysenck et al. 2007). It thus not surprising that in incongruent stimuli of the Double Stroop task where conflict is the highest, the sensory conflict of anxiety may aggregate this conflict cost in these trials and result in longer reaction times. Similarly the LAP participants may have had longer reaction times compared to the HAP participants, because as explained earlier the arousal level might be too low in the LAP condition. An optimal interaction between positive mood and arousal level seems to be needed to influence reaction time.

The fact that musical condition influenced reaction times in both the Simon and the Double Stroop task is important because both of these tasks measure conflict monitoring. A key indicator of the conflict cost during these tasks is the time it takes participants to respond when presented with an incongruent or conflict inducing stimulus. Essentially, how quickly can the participant confront the conflict and ignore the task irrelevant parameters for success. The fact that HAP music had the fastest reaction times suggests that listening to HAP music may attenuate some of these conflict costs and increase task-relevant focus during task completion. However looking at the trends in the percent correct scores for both these tasks we see HAP participants though the differences aren’t significant do perform worse than participants in the control and other musical conditions for both these tasks. Therefore it is difficult to conclude if HAP music is attenuating these conflict costs or if it’s doing so accurately.

Limitations

Although the sample size used in the current study was robust (n=100), because the study was between subjects, only 20 participants were in each group. This participant size may as a result be too small, and future experiments should replicate the experiment with larger sample sizes to see if similar results are obtained.

Music as well is a subjective experience; certain individuals prefer some types of music over others. Consequently, individuals perform tasks with the music they like while others do not listen to music at all. Since we selected the musical pieces for our study, this subjective preference of music was never considered, and as a result may have biased our results. Future studies should examine participants' personal preferences towards music, specifically if they perform cognitively demanding tasks like driving, or doing schoolwork in the presence of music.

Additionally, musical mood and arousal have been recently found to have different effects on introverts and extroverts (Cassidy & Macdonald, 2007). In their study, Cassidy & Macdonald (2007) found that high arousal negative affect music impacts introverts more than extroverts. Future studies should explore this introversion effect by administering personality questionnaires prior to testing.

Another potential bias to our results was that the majority of our sample population was first year undergraduate students, and 70% of them were females. There could potentially be some gender differences on the effects of musical mood and arousal on these executive function tasks; however such effects have not been reported or studied in the literature as of yet. As well, because our sample was mainly young adults, it would be interesting to note if these effects are reproducible in sample populations of various other age groups.

Additionally, the volume used during the study was pre-set at comfortable level and participants could adjust the volume of their accord, none of them did. Certain individuals may be responsive and perform better at certain volume levels, additionally differing volume levels may be able to convey certain arousal states more efficiently. For instance louder volumes could better induce high arousal states, and quieter volumes for low arousal states. Future studies should consider looking at differing volume levels, as well as participants' volume preferences.

Lastly an important confound to consider that may have influenced our results is beat perception. People can spontaneously reproduce certain rhythms relative to the beat they are listening to (Grahn & Brett, 2007). The HAP music used in our study was more up-tempo and had a faster beat relative to the other musical excerpts. As a result participants could have responded faster during the Simon Task and the Double Stroop Task while listening to HAP music simply because they were in sync with the faster beats in HAP music. To control for this, future experiments may want to look at using HAP music with irregular or complex metric beats that are difficult to reproduce in addition to the HAP music used in the current study.

Future Directions

The first set of follow-up experiments to this research should examine if these behavioural findings can be replicated in other executive function tasks that measure conflict monitoring. Notable examples include the Go/No-Go task, the Eriksen Flanker task, and the Wisconsin Card Sorting Test (Botvinick, Cohen, & Carter, 2004; Enriquez-Geppert, Konrad, Pantev & Hustler, 2010; Garavan, Ross, Kaufman, & Stein, 2003). If similar results are obtained in these tasks, notable that HAP music leads to the fastest reaction times we can be more confident that the results in our study were valid and not merely an artifact or chance finding.

Future experimental designs could also look at the cumulative effects of presenting different conflict situations to participants. In our study, there was an equal amount of congruent and incongruent stimuli presented to participants randomly throughout the experiment. Mansouri, Tanaka, & Buckley (2009) propose that learning of the nature and associations of these conflicts occur in these executive function tasks. Participants respond more accurately and faster on conflict stimuli if presented with a conflict stimulus immediately before. The authors propose that studies should emphasize on the stimuli order of conflict presentation, where conflicts are sequentially increasing or decreasing to study conflict monitoring effects. For example in the Double Stroop task, participants could be presented with the following stimuli ordered progressively or regressively to examine the summation of conflict effects. Firstly participants are presented with congruent stimuli where the top word and correct bottom word are the same colour and word. Secondly, they could be presented with incongruent stimuli where the top word has a different text colour than the semantics of its name, but the correct bottom word is the same text colour as the semantics of its name. Lastly, participants are presented with incongruent stimuli where both the top word and the correct bottom word have text colours that do not match the semantics of their names respectively. Thus the stimuli order would be no conflict, low conflict, and high conflict. It would be interesting to see if musical condition had an effect on the order of these conflict stimuli, especially if HAP music has the fastest reaction time, such a result would provide further evidence that HAP music may attenuate the conflict costs in these paradigms.

Finally it would be interesting to see if these behavioural observations are represented through electrophysiological recordings. In particular through electroencephalography (EEG) recordings; there exists a specific event related potential (ERP) called the N200 which is believed to measure conflict monitoring and response inhibition (Donkers & van Boxtel, 2004; Enriquez-Geppert et al. 2010). The larger the amplitude of the N200 ERP, the greater the conflict monitoring that is believed to be occurring (Folstein & Van Petten, 2008). One could hypothesize then based on the behavioural results in our study that participants that listen to HAP music would have lower amplitude N200 ERPs during conflict trials compared to other music or silent conditions. If these EEG results do coincide with our behavioural results, it would provide further evidence of background music's effect in conflict monitoring.

Conclusion

In conclusion listening to background music, particularly HAP music does seem to have some efficacy in improving performance in conflict monitoring tasks. Participants that listened to HAP music responded faster on the Double Stroop Task and the Simon Task, however they were as accurate as other participants that listened to other musical conditions. Future studies should explore if this reaction time effect of musical mood and arousal is reproducible in other conflict monitoring tasks; or other executive function tasks in general.

References

Arnsten, A. F., & Li, B. M. (2005). Neurobiology of executive functions: catecholamine influences on prefrontal cortical functions. Biological psychiatry, 57(11), 1377-1384.

Ashby, F. G., & Isen, A. M. (1999). A neuropsychological theory of positive affect and its influence on cognition. *Psychological review, 106*(3), 529.

Ashby, F. G., & Gott, R. E. (1988). Decision rules in the perception and categorization of multidimensional stimuli. Journal of Experimental Psychology: Learning, Memory, and Cognition, 14(1), 33.

Bailey, C. E. (2007). Cognitive accuracy and intelligent executive function in the brain and in business. *Annals of the New York Academy of Sciences, 1118*(1), 122-141.

Baler, R. D., & Volkow, N. D. (2006). Drug addiction: the neurobiology of disrupted self-control. Trends in molecular medicine, 12(12), 559-566.

Bamber, D. (1969). Reaction times and error rates for “same”-“different” judgments of multidimensional stimull. Perception & Psychophysics, 6(3), 169-174.

Barch, D. M. (2005). The cognitive neuroscience of schizophrenia. *Annu. Rev. Clin. Psychol., 1*, 321-353.

Borella, E., Carretti, B., & Pelegrina, S. (2010). The specific role of inhibition in reading comprehension in good and poor comprehenders. *Journal of Learning Disabilities, 43*(6), 541-552.

Botvinick, M. M., Cohen, J. D., & Carter, C. S. (2004). Conflict monitoring and anterior cingulate cortex: an update. Trends in cognitive sciences, 8(12), 539-546.

Broidy, L. M., Nagin, D. S., Tremblay, R. E., Bates, J. E., Brame, B., Dodge, K. A., ... & Vitaro, F. (2003). Developmental trajectories of childhood disruptive behaviors and adolescent delinquency: a six-site, cross-national study. *Developmental psychology, 39*(2), 222.

Brown, T. E., & Landgraf, J. M. (2010). Improvements in Executive Function Correlate with Enhanced Performance and Functioning and Health-Related Quality of Life. Postgraduate medicine, 122(5).

Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in cognitive sciences, 4*(6), 215-222.

Cohen, J. D., Dunbar, K., & McClelland, J. L. (1990). On the control of automatic processes: a parallel distributed processing account of the Stroop effect. Psychological review, 97(3), 332.

Cohen, R. A. (2011). Yerkes–Dodson Law. In Encyclopedia of clinical neuropsychology (pp. 2737-2738). Springer New York.

Crescioni, A. W., Ehrlinger, J., Alquist, J. L., Conlon, K. E., Baumeister, R. F., Schatschneider, C., & Dutton, G. R. (2011). High trait self-control predicts positive health behaviors and success in weight loss. *Journal of health psychology, 16*(5), 750-759.

Davis, J. C., Marra, C. A., Najafzadeh, M., & Liu-Ambrose, T. (2010). The independent contribution of executive functions to health related quality of life in older women. *BMC geriatrics, 10*(1), 16.

de Fockert, J. W., Rees, G., Frith, C. D., & Lavie, N. (2001). The role of working memory in visual selective attention. Science, 291(5509), 1803-1806.

Denson, T. F., Pedersen, W. C., Friese, M., Hahm, A., & Roberts, L. (2011). Understanding impulsive aggression: Angry rumination and reduced self-control capacity are mechanisms underlying the provocation-aggression relationship. *Personality and Social Psychology Bulletin, 37(*6), 850-862.

Diamond, A. (2005). Attention-deficit disorder (attention-deficit/hyperactivity disorder without hyperactivity): A neurobiologically and behaviorally distinct disorder from attention-deficit/hyperactivity disorder (with hyperactivity). Development and psychopathology, 17(03), 807-825.

Donkers, F. C., & van Boxtel, G. J. (2004). The N2 in go/no-go tasks reflects conflict monitoring not response inhibition. Brain and cognition, 56(2), 165-176.

Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: reduced perseveration at the cost of increased distractibility. Journal of Experimental Psychology:

Learning, Memory, and Cognition, 30(2), 343

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., ... & Japel, C. (2007). School readiness and later achievement. Developmental psychology, 43(6), 1428.

Ekman, P., Levenson, R. W., & Friesen, W. V. (1983). Autonomic nervous system activity distinguishes among emotions. *Science*, *221*(4616), 1208-1210.

Enriquez-Geppert, S., Konrad, C., Pantev, C., & Huster, R. J. (2010). Conflict and inhibition differentially affect the N200/P300 complex in a combined go/nogo and stop-signal task. Neuroimage, 51(2), 877-887.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. Emotion, 7(2), 336-353.

Fairchild, G., van Goozen, S. H., Stollery, S. J., Aitken, M. R., Savage, J., Moore, S. C., & Goodyer, I. M. (2009). Decision making and executive function in male adolescents with early-onset or adolescence-onset conduct disorder and control subjects. *Biological psychiatry, 66*(2), 162-168.

Feldman, L. A. (1995). Variations in the circumplex structure of mood.*Personality and Social Psychology Bulletin*, *21*(8), 806-817.

Folstein, J. R., & Van Petten, C. (2008). Influence of cognitive control and mismatch on the N2 component of the ERP: a review. Psychophysiology, 45(1), 152-170.

Garavan, H., Ross, T. J., Kaufman, J., & Stein, E. A. (2003). A midline dissociation between error-processing and response-conflict monitoring. Neuroimage, 20(2), 1132-1139.

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from national curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology, 18*(1), 1-16.

Grahn, J., & Brett, M. (2007). Rhythm and beat perception in motor areas of the brain. Cognitive Neuroscience, Journal of, 19(5), 893-906.

Greene, C. M., Bahri, P., & Soto, D. (2010). Interplay between affect and arousal in recognition memory. PloS one, 5(7), e11739.

Husain, G., Thompson, W. F., & Schellenberg, E. G. (2002). Effects of musical tempo and mode on arousal, mood, and spatial abilities. Music perception, 20(2), 151-171.

Isen, A. M. (1999). Positive affect. In T. Dalgleish, & M. Powers (Eds.),The handbook of cognition and emotion(pp. 75–94). Hillsdale, NJ: Erlbaum

Jefferies, L. N., Smilek, D., Eich, E., & Enns, J. T. (2008). Emotional valence and arousal interact in attentional control. Psychological Science, 19(3), 290-295.

Joëls, M., Pu, Z., Wiegert, O., Oitzl, M. S., & Krugers, H. J. (2006). Learning under stress: how does it work?. *Trends in cognitive sciences*, *10*(4), 152-158.

Juslin, P. N., & Sloboda, J. A. (2001). Music and emotion: Theory and research. Oxford University Press.

Kerns, J. G. (2006). Anterior cingulate and prefrontal cortex activity in an FMRI study of trial-to-trial adjustments on the Simon task. Neuroimage, 33(1), 399-405.

Kuhbandner, C., & Zehetleitner, M. (2011). Dissociable effects of valence and arousal in adaptive executive control. PloS one, 6(12), e29287.

MacDonald, A. W., Cohen, J. D., Stenger, V. A., & Carter, C. S. (2000). Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. Science, 288(5472), 1835-1838.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: an integrative review. Psychological bulletin, 109(2), 163.

Mammarella, N., Fairfield, B., & Cornoldi, C. (2007). Does music enhance cognitive performance in healthy older adults? The Vivaldi effect. Aging clinical and experimental research, 19(5), 394-399.

Mansouri, F. A., Tanaka, K., & Buckley, M. J. (2009). Conflict-induced behavioural adjustment: a clue to the executive functions of the prefrontal cortex. Nature Reviews Neuroscience, 10(2), 141-152.

Miller, H. V., Barnes, J. C., & Beaver, K. M. (2011). Self-control and health outcomes in a nationally representative sample. *American journal of health behavior*, *35*(1), 15-27.

Mitchell, R. L., & Phillips, L. H. (2007). The psychological, neurochemical and functional neuroanatomical mediators of the effects of positive and negative mood on executive functions. *Neuropsychologia*, *45*(4), 617-629.

Mitterschiffthaler, M. T., Fu, C. H., Dalton, J. A., Andrew, C. M., & Williams, S. C. (2007). A functional MRI study of happy and sad affective states induced by classical music. *Human brain mapping*, *28*(11), 1150-1162.

McConnell, M. M., & Shore, D. I. (2011). Upbeat and happy: Arousal as an important factor in studying attention. *Cognition & emotion*, *25*(7), 1184-1195.

Nadler, R. T., Rabi, R., & Minda, J. P. (2010). Better mood and better performance learning rule-described categories is enhanced by positive mood. Psychological Science, 21(12), 1770-1776.

Nakayama, K., & Silverman, G. H. (1986). Serial and parallel processing of visual feature conjunctions. Nature, 320(6059), 264-265.

Nguyen, T & Grahn, J. (2013). Musical mood and musical arousal affect different stages of learning and memory performance. University of Western Ontario - Electronic Thesis and Dissertation Repository. Paper 1390, http://ir.lib.uwo.ca/etd/1390.

Oaksford, M., Morris, F., Grainger, B., & Williams, J. M. G. (1996). Mood, reasoning, and central executive processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(2), 476.

Olivers, C. N., & Nieuwenhuis, S. (2006). The beneficial effects of additional task load, positive affect, and instruction on the attentional blink. Journal of Experimental Psychology: Human Perception and Performance, 32(2), 364.

Ownsworth, T., & Fleming, J. (2005). The relative importance of metacognitive skills, emotional status, and executive function in psychosocial adjustment following acquired brain injury. The Journal of head trauma rehabilitation, 20(4), 315-332.

Pardo, J. V., Pardo, P. J., Janer, K. W., & Raichle, M. E. (1990). The anterior cingulate cortex mediates processing selection in the Stroop attentional conflict paradigm. Proceedings of the National Academy of Sciences, 87(1), 256-259.

Panayiotou, G., Brown, R., & Vrana, S. R. (2007). Emotional dimensions as determinants of self-focused attention. Cognition and Emotion, 21(5), 982-998.

Penades, R., Catalan, R., Rubia, K., Andres, S., Salamero, M., & Gasto, C. (2007). Impaired response inhibition in obsessive compulsive disorder. *European Psychiatry*, *22*(6), 404-410.

Phillips, L. H., Bull, R., Adams, E., & Fraser, L. (2002). Positive mood and executive function: evidence from stroop and fluency tasks. *Emotion*, *2*(1), 12.

Posner, J., Russell, J. A., & Peterson, B. S. (2005). The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. Development and psychopathology, 17(03), 715-734.

Prins, N. D., van Dijk, E. J., den Heijer, T., Vermeer, S. E., Jolles, J., Koudstaal, P. J., ... & Breteler, M. M. (2005). Cerebral small-vessel disease and decline in information processing speed, executive function and memory. Brain, 128(9), 2034-2041.

Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993). Music and spatial task performance. *Nature*, *365*(6447), 611-611.

Riggs, N. R., Spruijt-Metz, D., Sakuma, K. L., Chou, C. P., & Pentz, M. A. (2010). Executive cognitive function and food intake in children. *Journal of nutrition education and behavior*, *42*(6), 398-403.

Sacks, O. (2006). The power of music. *Brain*, *129*(10), 2528-2532.

Salimpoor, V. N., Benovoy, M., Larcher, K., Dagher, A., & Zatorre, R. J. (2011). Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nature neuroscience*, *14*(2), 257-262.

Särkämö, T., Tervaniemi, M., Laitinen, S., Forsblom, A., Soinila, S., Mikkonen, M., ... & Hietanen, M. (2008). Music listening enhances cognitive recovery and mood after middle cerebral artery stroke. Brain, 131(3), 866-876.

Schellenberg, E. G., & Hallam, S. (2005). Music Listening and Cognitive Abilities in 10-and 11-Year-Olds: The Blur Effect. *Annals of the New York Academy of Sciences*, *1060*(1), 202-209.

Scheibe, K. E., Shaver, P.R. and Carrier, S.C.(1967). Colour association values and response interference on variants of the Stroop test. Acta Psychologica,26: 286-95.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002) E-Prime User's Guide. Pittsburgh: Psychology Software Tools Inc.

Schwartz, K. D., & Fouts, G. T. (2003). Music preferences, personality style, and developmental issues of adolescents. *Journal of youth and adolescence*, *32*(3), 205-213.

Simon, J. R., & Berbaum, K. (1990). Effect of conflicting cues on information processing: the 'Stroop effect'vs. the 'Simon effect'. Acta psychologica, 73(2), 159-170.

Spies, K., Hesse, F., & Hummitzsch, C. (1996). Mood and capacity in Baddeley's model of human memory. *Zeitschrift für Psychologie mit Zeitschrift für angewandte Psychologie*.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. Journal of experimental psychology, 18(6), 643.

Taylor Tavares, J. V., Clark, L., Cannon, D. M., Erickson, K., Drevets, W. C., & Sahakian, B. J. (2007). Distinct profiles of neurocognitive function in unmedicated unipolar depression and bipolar II depression. *Biological psychiatry*, *62*(8), 917-924.

Thaut, M. H., Gardiner, J. C., Holmberg, D., Horwitz, J., Kent, L., Andrews, G., ... & McIntosh, G. R. (2009). Neurologic music therapy improves executive function and emotional adjustment in traumatic brain injury rehabilitation. Annals of the New York Academy of Sciences, 1169(1), 406-416.

Thompson, W. F., Schellenberg, E. G., & Husain, G. (2001). Arousal, mood, and the Mozart effect. *Psychological science*, *12*(3), 248-251.

Uekermann, J., Daum, I., Peters, S., Wiebel, B., Przuntek, H., & Müller, T. (2003). Depressed mood and executive dysfunction in early Parkinson's disease. *Acta Neurologica Scandinavica*, *107*(5), 341-348.

van Veen, V., Cohen, J. D., Botvinick, M. M., Stenger, V. A., & Carter, C. S. (2001). Anterior cingulate cortex, conflict monitoring, and levels of processing. Neuroimage, 14(6), 1302-1308.

van Veen, V., & Carter, C. S. (2005). Separating semantic conflict and response conflict in the Stroop task: a functional MRI study. Neuroimage, 27(3), 497-504.

Welcome - Cambridge Brain Sciences. (n.d.). Retrieved April 8, 2015, from http://www.cambridgebrainsciences.com/browse/reasoning/test/double-stroop-body

Appendix A

Sign Up Poster

The Effects of Musical Mood and Musical Arousal on Executive Function

You are being invited to participate in this research study investigating the influence of music on executive function conducted by Jerome Iruthayarajah, Tram Nguyen, and Dr. Jessica Grahn. You will complete three simple executive function tasks. The executive function tasks include a Double Stroop Task which measures conflict monitoring; a Stimulus Detection Task which measures attentional prowess and vigilance; and a Simon Task which measures conflict monitoring and working memory. Viewing and active participating will be done either in silence or while listening to music. All responses will be made using a computer keypad. This study will take a little over half an hour to complete. For your time, you will be compensated one research credit.

Appendix B

Table 1. Mean ratings of mood and arousal for the music used in the experiment, adapted from Nguyen & Grahn, 2013.

Music	Condition	Arousal Rating	Mood Rating
01.Escape.wav	HAP	2.067±1.163	1.733±1.335
02.Ghosts.wav	HAP	2.467±1.125	2.133±0.990
03.SurfingAlien.wav	HAP	2.067±1.685	1.533±1.534
04.Satchboogie.wav	HAP	2.267±1.280	1.733±1.335
05.Montenegro.wav	HAP	2.333±0.617	1.667±1.047
06.Flikmachine.wav	HAP	1.867±0.915	2.333±0.617
07.Temptingtime.wav	HAN	1.667±1.356	-1.533±2.093
08.Kellot.wav	HAN	1.333±1.100	-1.267±1.877
09.TarzanFight.wav	HAN	1.333±1.335	-1.733±0.900
10.Burn1.wav	HAN	1.933±1.486	-1.267±1.534
11.SFX.wav	HAN	1.533±2.042	-1.200±1.506
12.OrbitalElements.wav	HAN	1.800±1.642	-0.867±1.699
13.ComeHomeTo.wav	LAP	-1.000±1.580	1.067±1.414
14.HelloMyLovely.wav	LAP	-1.267±1.521	0.800±1.486
15.KillerJoe.wav	LAP	-1.133±0.990	0.867±1.407
16.Akiko.wav	LAP	-0.533±1.033	0.733±1.187
17.BlessedSpirits.wav	LAP	-1.467±1.633	0.667±1.767
18.GiveYouAway.wav	LAP	-0.533±0.845	1.000±1.506
19.ChopinPreludeE.wav	LAN	-1.733±0.704	-1.933±1.335
20.SadPiano.wav	LAN	-2.200±1.767	-1.133±0.862
21.TigerDragon.wav	LAN	-2.333±1.302	-1.133±0.488
22.QuasiAdagio.wav	LAN	-1.400±1.699	-1.800±1.882
23.WhatAmI2.wav	LAN	-2.067±1.280	-1.067±1.223
24.PoliceFire.wav	LAN	-2.467±0.900	-1.333±0.743

Appendix C

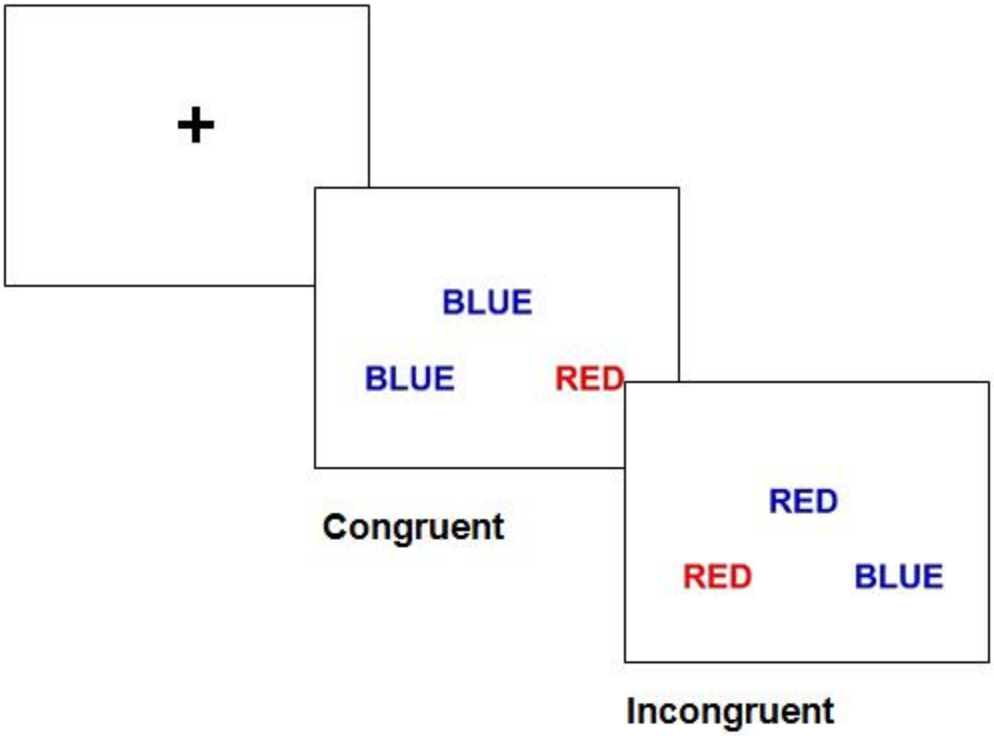

Figure 9. Examples of congruent and incongruent stimuli used during the Double Stroop Task and the fixation screen (top left image) used during testing.

Appendix D

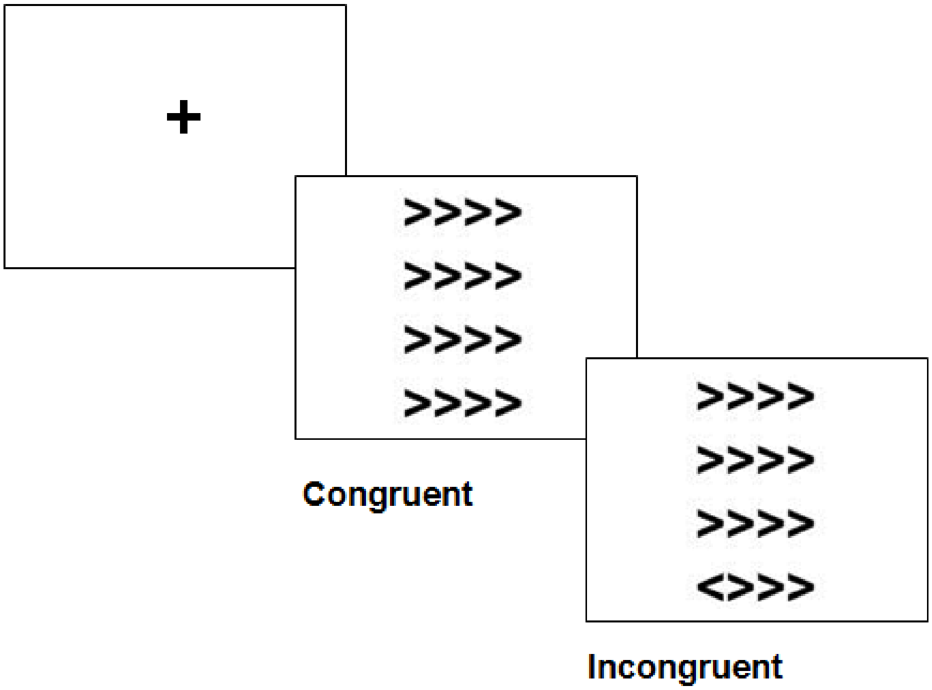

Figure 10. Examples of congruent and incongruent stimuli used during the Stimulus Detection Task and the fixation screen (top left image) used during testing.

Appendix E

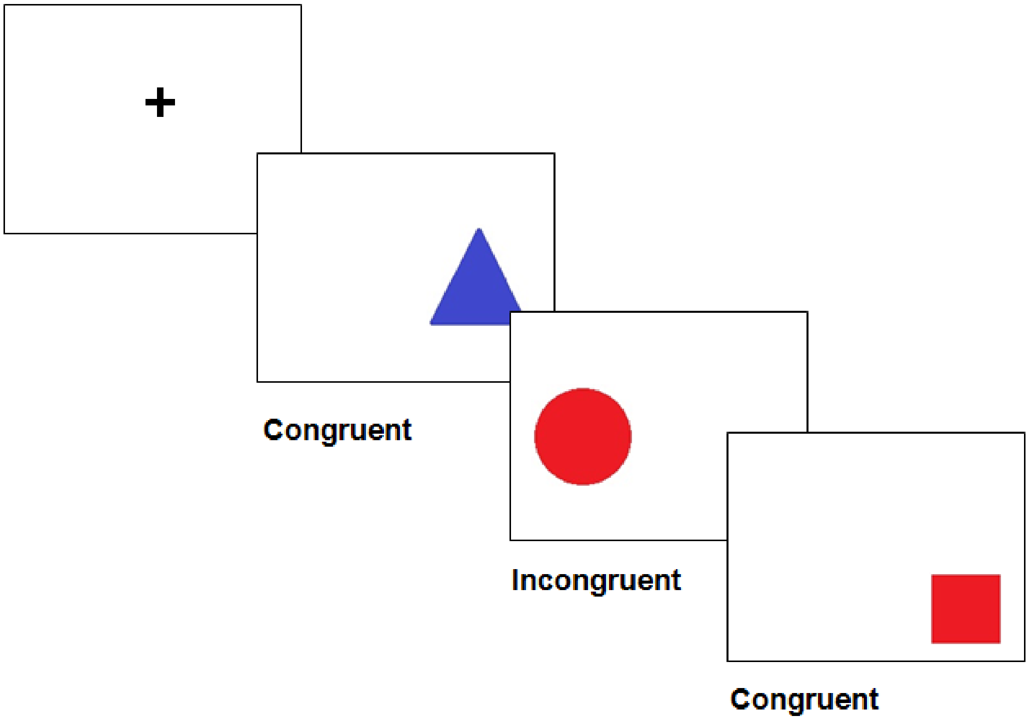

Figure 11. Examples of congruent and incongruent stimuli used during the Simon Task and the fixation screen (top left image) used during testing.

Appendix F

Letter of Information

The Effects of Musical Mood and Musical Arousal on Executive Functioning

Research Investigators:

Jerome Iruthayarajah, BSc Candidate
Student Researcher
Email: jiruthay@uwo.ca

Tram Nguyen, MSc
Student Researcher
Email: tnguye95@uwo.ca

Dr. Jessica Grahn
Principal Investigator
Brain and Mind Institute
Room 229, Natural Sciences Building
University of Western Ontario
London, Ontario, N6A 5B7
Email: jgrahn@uwo.ca
Phone: 519 661 2111 ext. 84804

Introduction:
You are being invited to participate in this research study investigating the influence of music on executive function conducted by Jerome Iruthayarajah, Tram Nguyen, and Dr. Jessica Grahn because your participation will greatly extend our knowledge of the interaction between listening to music and executive function. The purpose of this study is to determine how musical mood and musical arousal affect executive function. This letter is to provide you with information required for you to make an informed decision regarding participation in this research.

Inclusion and Exclusion Criteria:
Individuals who have normal hearing and normal or corrected-to-normal vision may participate in this research.

Research Procedures:
If you agree to participate, you will be asked to partake in the following tasks:

Executive Function Tasks:
You will complete three simple executive function tasks:

Double Stroop Task- In this task you fixate on a screen where three words will appear on the screen, one word on top while two are on the bottom. You have to then correctly click one of the two words at the bottom of the screen that correctly describes the colour of ink that the word at the top of the screen is written in, irrespective of the colour the bottom word is written in.

Simon Task- In this task you will fixate on the screen where a shape sof a certain colour will appear on the right and left of the screen. You will then be instructed at the beginning of the experiment to respond to certain stimuli by pressing a right hand key response and left hand key response for other stimuli.

Stimulus Detection Task- a series of 4 by 4 arrows are presented on screen. You are to indicate if all the arrows are pointing in the same direction. In congruent trials, the arrows all face the same direction , while in the incongruent trial the one of arrows if facing a different direction relative to the other arrows.

Viewing and active participating will be done either in silence or while listening to music. All responses will be made using a computer keypad.

It is anticipated that all three tasks will take less than an hour, over one session, to complete. The tasks will be conducted in the Natural Sciences Buildings at the Brain and Mind Institute. There will be a total of 100 participants.

Possible Risks and Benefits:
There are no known or anticipated risks or discomfort associated with participating in this study. There are also no direct benefits from participating in this study. However, the information gathered from this study may help us understand how musical valence and arousal can influence executive functioning. Results from this study may be used to contribute to existing knowledge on cognitive disorders and problems.

Compensation:
You will be compensated one research credit for your participation in this study. If you do not complete the entire study you will still be compensated for your participation.

Participation:
Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions, or withdraw from the study at any time without loss of promised credit.

Confidentiality:
All data collected will remain confidential and accessible only to the investigators of this study. If the results are published, your name will not be used. Any data resulting from your participation will be identified by a number, without any reference to your name or personal information. Data will be stored on a secure computer in a locked room. After completion of the experiment, data will be archived on storage disks and stored in a locked room for a minimum of five years and a maximum of 15 years, after which they will be destroyed. Representatives of the University of Western Ontario Non-Medical Research Ethics Board may require access to your study-related records or may follow up with you to monitor the conduct of the study.

Contact Information:
If you require any further information regarding this research project or your participation in the study you may contact: Jerome Iruthayarajah at jiruthay@uwo.ca, Tram Nguyen at tnguye95@uwo.ca, or Dr. Jessica Grahn at jgrahn@uwo.ca.

If you have any questions about your rights as a research participant or the conduct of this study, you may contact:

Office of Research Ethics
University of Western Ontario
Email: ethics@uwo.ca
Phone: 519 661 3036

Appendix G

Consent Form

The Effects of Musical Mood and Musical Arousal on Executive Function

Research Investigators:

Jerome Iruthayarajah (jiruthay@uwo.ca)

Tram Nguyen (tnguye95@uwo.ca)

Dr. Jessica Grahn (jgrahn@uwo.ca)

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Participant’s Name (please print): ______________________________

Participant’s Signature: ______________________________

Date: ______________________________

Person Obtaining Informed Consent (please print):

____

Signature: ______________________________

Date: ______________________________

Appendix H

Debriefing Form

The Effects of Musical Mood and Musical Arousal on Executive Function

Research Investigators:

Jerome Iruthayarajah, BSc Candidate
Student Researcher
Email: jiruthay@uwo.ca

Tram Nguyen, MSc
Student Researcher
Email: tnguye95@uwo.ca

Dr. Jessica Grahn
Principal Investigator
Brain and Mind Institute
Room 229, Natural Sciences Building
University of Western Ontario
London, Ontario, N6A 5B7
Email: jgrahn@uwo.ca
Phone: 519 661 2111 ext. 84804

The purpose of this study is to explore the effects of passively listening to music while simultaneously performing an executive function task. In particular the study explores if different attributes of music such as mood (positive and negative) and arousal (high and low) can modulate this effect.

Music is ubiquitous in our daily lives. Many of us listen to music to help us focus, to block out distractions, or to make a tedious task more enjoyable. However, it is unclear how this daily soundtrack affects our cognitive performance. Therefore, it is imperative to examine whether music enhances cognition, and if so, what mechanisms might be responsible. Music might positively alter the listener's internal mood and arousal levels, and these changes in emotional states are known to aid certain cognition functions.

Previous research has indicated musical training in having a beneficial effect on cognitive abilities and executive functioning (Moreno et al. 2011; Dege, Kubieck, & Schwarzer 2011). In particular the mood (negative or positive) and arousal (high or low) of a musical piece have been found to have both separate and interacting effects on cognitive performance (Thompson, Schellenberg, & Husain 2001; Phillips et al. 2002; Hallam, Price & Katsarou 2002). Notable interactions of background music on attention and memory have been discovered in past experiments. In attention tasks music with a negative or positive mood paired with low arousal conditions elicited optimal task performance (Jefferies, Smilek, Eich, & Enns, 2008); while in memory tasks positive mood and low arousal musical pieces have beneficial effects (Hallam, Price & Katsarou 2002). The effect of background music on executive function however still remains an area to be explored. Executive functioning is vital to many of our daily interactions (learning, communication, planning) and thus serves as a rewarding area of investigation.

That is why in this study, three executive function paradigms were conducted while music with a certain mood and arousal was played in the background. The three executive function tasks measure all differing domains of cognitive control. The Double Stroop Task measures conflict monitoring (West and Alain 2000), the Stimulus Detection Task measures selective attention (Fenske and Eastwood 2003), while lastly the Simon Task measures working memory and conflict monitoring.

By participating in this study, you have provided us with data to explore the effects of musical mood and musical arousal on executive functioning. Your responses will be combined with the responses of others to determine how different types of music influence these cognitive processes.

Your responses and participation were much appreciated. If you require any further information regarding this research project or your participation in the study you may contact: Jerome Iruthayarajah at jiruthay@uwo.ca, Tram Nguyen at tnguye95@uwo.ca, or Dr. Jessica Grahn at jgrahn@uwo.ca.

If you have any questions about your rights as a research participant or the conduct of this study, you may contact:

Office of Research Ethics
University of Western Ontario
Email: ethics@uwo.ca
Phone: 519 661 3036

For additional information regarding this research and associated areas of interest, you may wish to consult the following articles:

Degé, F., Kubicek, C., & Schwarzer, G. (2011). Music lessons and intelligence: a relation mediated by executive functions. Music Perception,29(2), 195-201.

Fenske, M. J., & Eastwood, J. D. (2003). Modulation of focused attention by faces expressing emotion: evidence from flanker tasks. Emotion, 3(4), 327.

Hallam, S., Price, J., & Katsarou, G. (2002). The effects of background music on primary school pupils' task performance. Educational studies, 28(2), 111-122.

Jefferies, L. N., Smilek, D., Eich, E., & Enns, J. T. (2008). Emotional valence and arousal interact in attentional control. Psychological Science, 19(3), 290-295.

Moreno, S., Bialystok, E., Barac, R., Schellenberg, E. G., Cepeda, N. J., & Chau, T. (2011). Short-term music training enhances verbal intelligence and executive function. Psychological science, 22(11), 1425-1433.

Phillips, L. H., Bull, R., Adams, E., & Fraser, L. (2002). Positive mood and executive function: evidence from stroop and fluency tasks. Emotion, 2(1), 12.

Rubia, K., Russell, T., Overmeyer, S., Brammer, M. J., Bullmore, E. T., Sharma, T., ... & Taylor, E. (2001). Mapping motor inhibition: conjunctive brain activations across different versions of go/no-go and stop tasks. Neuroimage, 13(2), 250-261.

Thompson, W. F., Schellenberg, E. G., & Husain, G. (2001). Arousal, mood, and the Mozart effect. Psychological science, 12(3), 248-251.

West, R., & Alain, C. (2000). Age-related decline in inhibitory control contributes to the increased Stroop effect observed in older adults. Psychophysiology, 37(2), 179-18