TEMPO, AROUSAL AND THE UNDERLYING MECHANISMS OF THE MOZART EFFECT

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Abstract

There is a great deal of inconsistent literature regarding the potential cognitive performance enhancement elicited by priming with music listening. This phenomenon has been coined the Mozart Effect and four theoretical models have been constructed to explain it. The first is the Neuro-priming model, which attributes performance differences to cortical firing pattern elicited by music listening. The second is the arousal model which uses arousal changes to explain performance differences. The third is the mood model which explains performance difference through changes in affect. The last is the valence model which associates performance differences to participants' level of preference to the music. This thesis describes two experiments that were conducted to determine which of these theories best explained the underlying mechanism of the Mozart Effect. The results did not support the arousal and mood models and appear to support the valence and neuro-priming models.

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Tempo, Arousal and the Underlying Mechanisms of the Mozart Effect

The mysterious power of music over its listener has long sparked the curiosity of scholars across different disciplines. In 1993, psychologist Frances Rauscher published a study showing a potential enhancement of spatial-temporal task performance brought on by simply listening to Mozart's Sonata for two pianos in D major (K. 448) for 10 minutes before performing the task. This phenomenon has since been coined the "Mozart Effect" (Rauscher, Gordon and Katherine, 1995) and has gained considerable notoriety in the public consciousness. Rauscher's research was quickly over-generalized by aspiring entrepreneurs spurring an entire industry of products including "Mozart for Babies", promising enhanced intelligence by simply listening to Mozart at an early age.

Within psychology however, there is still considerable controversy regarding the underlying nature of this effect and continuing discussion on whether it in fact exists. Although Rauscher et al. concluded that improvements in spatial-temporal performance were the result of neuro-priming caused by the complex structure of Mozart's music (1993), efforts by others to replicate these results have yielded mixed results leading to other potential explanations (e.g. Carstens, Huskins & Hounshell, 1995; Nantais & Schellenberg, 1999). Three main alternative explanations arose. The first was coined the valence model. It explains performance enhancement following exposure to music as a function of preference to the musical stimuli (Nantais & Schellenberg, 1999). Advocates of that view claim that performance improvements do not occur only when listening to music, but they can be achieved by any stimulus the individual finds appealing. The second alternative explanation uses mood changes to explain performance enhancement after listening to music (Gonzalez et al., 2003). In this, the mood model, changes resulting from music exposure occur as a result of mood enhancement caused by listening to the music. The final explanation is that the improved performance is mediated by increases in arousal (Steele, Bass & Crook, 1999). In this explanation the music simply acts as an arousing stimulus, and performance enhancement occurs as a result of the well-established link between arousal and performance (Anderson, 1990).

The arousal hypothesis has been supported repeatedly by empirical evidence (Gonzalez, Smith, Stockwell, & Horton, 2003) and research examining the impact of changes to the musical elements in Mozart's Sonata have begun to unravel the details of the relationship between mood, arousal, music and performance (Husain, Thompson & Schellenberg, 2002). Specifically, it appears that the tempo of the musical composition influences arousal, and that this increased arousal may cause improvements in performance after exposure to the Mozart sonata (Husain, Thompson & Schellenberg, 2002).

Nearly all of the abovementioned studies have used the same spatial-temporal task to measure performance enhancement. Those that have tested other cognitive mechanisms have failed to replicate the effect (e.g. Steeles, Ball & Runk, 1997; Rauscher et al., 1995). Many of these attempts, however, utilized very different experimental designs, and there are several possible explanations of their failure to replicate. These will be discussed in later sections of this thesis.

In the present study, the "Mozart Effect" was further explored and the abovementioned explanations were examined. The tempo of musical composition was altered in an attempt to determine how the musical features interact with task performance. Specifically, the proposed study attempted to determine which of the three models may best account for the performance enhancement that has been found following exposure to Mozart's Sonata. To further illuminate the impact of music on performance, a series of cognitive tasks that utilize skills other than the spatial-temporal task used in most other experiments were examined to determine if the Mozart Effect is in fact specific to spatial-temporal performance.

All the potential explanations for the Mozart Effect are outlined in the next few sections. First, the neuro-priming model will be examined more closely, followed by the three alternative explanations; the valence model, the mood model and the arousal model. The potential influence of individual differences on this effect will then be examined followed by an exploration of the potential benefits of recording physiological measures during a study of this nature. The methods and planned data analysis of the proposed experiments are then described in detail.

The Neuro-Priming Model

The neuro-priming model explains performance enhancement after listening to music with the Trion Model of cortical firing patterns. According to the Trion Model, the basic cortical neural network, called the cortical column, can be excited into symmetrical quasi-stable firing patterns that the theory assumes facilitates performance in abstract tasks like spatial tasks (Rauscher & Shaw, 1998). These firing patterns can be enhanced by gradual changes in their connection strength through Hebb's learning rule (Shaw, Silverman, & Pearson, 1985). Hebb's learning rule attempts to explain learning at the cellular level (Tsien, 2000). It holds that learning occurs through a process of neighboring neurons firing simultaneously, thereby causing a strengthening of the synaptic connections between them (Tsien, 2000). Thus, the Trion model assumes that these cortical neuronal firing patterns lead to increased cortical activity (Shaw, Silverman, & Pearson, 1985) and hence to improvements in subsequent performance on spatial-temporal tasks. As stated earlier, the Mozart effect has been found upon participants listening to the Mozart Sonata K448 for two pianos; Rauscher and his colleagues argue that it is due to these cortical firing patterns (1995).

In their first study, Rauscher and his colleagues (1993) attempted to determine if they could evoke these types of firing patterns using exposure to music, and if this type of stimulation could enhance higher brain functioning. In their study, participants were randomly assigned to one of three groups. One group sat in silence for 10 minutes; another group listened to 10 minutes of a nonmusical relaxation tape, and the final group listened to 10 minutes of Mozart's Sonata for two pianos in D major (K. 448). Participants then performed a series of tasks in which their spatial performance was tested. The researchers predicted that the complex musical structure of the Mozart sonata would excite firing patterns that would enhance abstract cognition involving mathematical operations and spatial reasoning. They recorded participants' pulse rates during the study to determine if differences in performance could be attributed to increased arousal. The results showed that participants in the Mozart group performed significantly better than both the other groups on a paper-folding and cutting task (PF&C). There was no difference between the silence group and the relaxation group. No significant differences were found in pulse rates between the groups. This led the researchers to conclude that the effect was not the result of increased arousal but rather excitement of Trion firing patterns associated with spatial-temporal cognition.

In a subsequent study using a very complex design, Rauscher et al. (1995) explored this phenomenon in further detail. In that experiment participants were tested over five consecutive days. On the first day, none of them were primed, and all were tested on the same PF&C task as in the earlier experiment as well as on a short-term memory task involving memorizing a difficult sequence of letters and symbols. Participants were then divided into three groups (Silence Group, Mozart Group and the Mixed Group) based on their performance on the PF&C task such that the mean performance level was identical in all three groups. The silence group sat in silence for 10 minutes before completing a new set of 16 PF&C tasks on each of the remaining four days. The Mozart group listened to the same Mozart sonata as in the previous study for 10 minutes before performing a new set of 16 PF&C tasks on each of the remaining four days. Treatment of participants in the mixed group differed considerably from that of the other two groups. On day 2 of the experiment, participants in the mixed group were primed with music by Philip Glass. On day 3, they listened to an audio-taped story, and on day 4, they listened to repetitive dance music before completing the same PF&C tasks as the participants in the other two groups. On day 5 they were further divided into two sub-groups based on their performance on the memory task completed on day 1 of the experiment so that each of the groups had equivalent performance on that memory task. One half of the group listened to the Mozart sonata for 10 minutes and the other half sat in silence for 10 minutes prior to completing a new version of the memory task administered on day 1.

The results showed that performance improved across the five days of the experiment in all three groups; however the Mozart group performed significantly better than the other groups on day 2. Rauscher took this to be evidence that the Mozart Effect had been replicated. On the remaining days, performance in the mixed group stayed significantly lower than that of the other groups. Most importantly, however, there was no difference between the Mozart- and the silence group on days 3-5. The researchers suggested that the improvement in the silence- and the mixed groups were the result of normal learning. They further claimed that performance in the Mozart group reached a ceiling effect on day 2, which made it impossible to measure additional improvements in that group after the second day. They suggested that, with a more difficult task, the Mozart group may have continued to improve and retain its advantage over the other groups' performance. The researchers' interpretation of the data signaling a ceiling effect is problematic. On average, participants in the Mozart group answered 12 of the 16 items correctly (i.e. 75%) on the second day. Clearly, this is not representative of a ceiling effect. An alternative explanation for the lack of performance difference after day 2 could be that the participants habituated to the music exposure. The proposed study will adopt a between-subjects design to avoid any carry- over effects.

Concerning the memory task, results were only analyzed for performance in the mixed group on day 5. Although all participants had completed the memory task on day 1, no analysis was presented for these data. Results for the mixed group revealed no difference in performance on the fifth day. Thus, it was concluded that the Mozart effect was exclusive to spatial-temporal tasks, with no transfer effect to other cognitive functions. However, the lack of significant differences between these two groups could have been the result of fatigue after being involved in the study for the previous four days. The researchers do not give a clear explanation of what the memory task involved or why they chose that particular task. Even if the Mozart Effect does not apply to short term memory functioning, there are still several other cognitive domains that it could influence and which were not tested in that study. The present research tested a wide range of cognitive functioning following exposure to the Mozart sonata to further test the specificity of the Mozart Effect.

In the conclusion of their paper, Rauscher et al. (1995) proposed that Mozart's Sonata improves performance on spatial-temporal tasks so effectively because Mozart was composing at the age of four, meaning that he was utilizing innate spatial temporal cortical firing patterns. If that were the case, the effect should only be observed in the context of people listening to Mozart's work or to music composed by other individuals who started composing at an extremely early age. More recent research has shown that the "Mozart Effect" is not specific to Mozart or to music composed by child prodigies (Nantaism & Schellenberg, 1999).

Although Rauscher et al. (1995) suggested that future investigation with EEG be conducted, no measures of arousal, either by direct physiological means or by self-report measures, were used to exclude the possible influence of arousal in their study. Therefore, it is possible that performance differences were caused by arousal changes. The authors also fail to account for the lower scores in the mixed group in which participants were exposed to music by Philip Glass that has been described by participants in a more recent study as "repetitive", "obnoxious" and "grating" (Steele, Bass & Crook, 1999). Other classical music compositions or music that the participants would find pleasing as indeed they do the Mozart sonata, would be better controls. It could be argued that a potentially aversive stimulus, such as the Philip Glass music, could actually be having the opposite effect to the Mozart sonata, thus resulting in much lower scores than in the Mozart group. With no measure of mood changes or of individual preferences for the particular stimulus, or any physiological measures, the conclusion that Mozart's music enhances spatial abilities because he was composing at age four is highly questionable.

Once the Mozart effect began to develop notoriety, other researchers attempted to replicate the study with mixed results. Several studies found no performance enhancements following exposure to the same Mozart sonata (e.g., Carstens, Huskins & Hounshell, 1995; Steele, 1997; Rideout, 1998). In response to these conflicting findings Rauscher critiqued the dependent measures of those studies and their experimental methods (Rauscher & Shaw, 1998). According to Rauscher, the Mozart Effect is specific to spatial tasks, but only to those tasks that include a temporal ordering and spatial imagery components (Rauscher & Shaw, 1998) as in the PF&C tasks. Therefore, Rauscher argues that, in experiments that use the Raven Progressive Matrices which tests abstract reasoning (e.g. Newman et al., 1995) or any other tests that target any other mental functioning (e.g. Steeles, 1997), one should not expect to find any influence of music listening. Rauscher & Shaw (1998) also cited the influence of the order of tasks in some of these studies asserting that running pretests of spatial tasks directly before exposure to the music could act as primers and thus influence the results of the study.

To further support Rauscher's neurological explanation for the Mozart Effect, Rauscher, Robinson and Jens (1998) conducted a study to test if the spatial abilities of rats could be enhanced by exposure to Mozart's Sonata. The rats were exposed to the either the Mozart sonata, Philip Glass' music or to white noise for 12 hours a day inutero, again at 60 days after birth, and on each day of testing. The rats were then tested for five days on a T-maze task intended to measure their spatial skills and learning abilities. During testing the rats were randomly assigned to one of three testing conditions (Philip Glass, Mozart or White Noise). The results suggested that the auditory stimuli during the test had no influence on performance. Those who had been exposed to the Mozart sonata before, however, showed faster learning than the other groups, as well as shorter task-completion times and fewer errors by the fifth day of testing. To ensure that these results were not due to stress induced by exposure to the noise, a further two groups of rats were tested in the same way. One was left in silence and the other exposed to white noise. No significant differences were found between the groups. The authors speculated that the rats' enhanced performance was the product of the Trion firing patterns that have been said to cause enhanced spatial-temporal performance in humans (Rauscher, Robinson & Jens, 1998). In that case early stimulation of the hippocampal region of the rat's brain was believed to affect its development, leading to smarter rats. They argue that the complex nature of Mozart's Sonata was far more stimulating than the Philip Glass' music or the white noise enhancing this effect (Rauscher, Robinson & Jens, 1998). Other research has shown that rats raised in enriching environments develop more cortical plasticity leading to enhanced learning (Greenough & Volkar, 1973).

Although these results are interesting, it is difficult to understand how they relate to the temporary, exposure-based performance enhancement that Rauscher initially discovered in humans. Researchers have tried repeatedly to find proof of music cognition by nonhuman animals with very limited success (Hauser & McDermott, 2003). Primates, birds and whales are the only nonhuman animals that have shown any evidence of discrimination of music from noise. Previous studies exposing rats to classical music have shed doubt on rats' ability to distinguish music from noise and shown better learning in silence than with music exposure (e.g. Bates & Horvath, 1971; Cross, Halcomb & Matters, 1967). By comparing the frequency range of the hearing of rats and humans, there are some considerable differences. In an analysis of Mozart's Sonata played at the sound level used in Rauscher's 1998 study, Steele determined that the rats would only be able to hear approximately 31% of the notes in the piece (2003). The rats' lack of suitable hearing and perceptual tools capable of processing music the way humans do, makes any measurable differences in the rats' performance unlikely to be related to the Mozart effect found in humans.

A meta-analysis comparing Mozart Effect studies run in Rauscher's lab with replication attempts in other labs found that main effects were almost twice as high in Rauscher's lab (Hetland, 2000). Although many other labs have still found significant differences, this finding suggests that there must be some subtle differences in Rauscher's methodology. To avoid any issues of unintentional researcher influence, participants were assigned to their groups at random using a Latin Square in the present research; nearly every aspect of the study was administered by a computer, thereby reducing the number of opportunities for the researchers to influence participants.

Although Rauscher's work uncovered an interesting phenomenon, support for the Trion model as the underlying explanation was not made evident. While adhering closely to Rauscher's procedural recommendations, the proposed study examined the Mozart Effect from a broader perspective to identify other potential underlying mechanisms. In the next section the alternative explanations for the Mozart effect proposed by other researchers will be reviewed.

Alternative Explanations for the Mozart Effect

The doubt about the claim of causal evidence linking the Mozart Effect and the Trion Model led other researchers to develop alternative explanations for the Mozart Effect. In the following sections these explanations and the supporting studies are reviewed.

Valence Model

The valence model states that performance enhancement following an auditory stimulus occurs as a product of the pleasure the stimuli elicit in individuals (Nantaism & Schellenberg, 1999). To test this theory, a study involving two between-subject experiments was conducted (Nantaism & Schellenberg, 1999). In the first, the researchers successfully replicated the results of Rauscher et.al. (1993), revealing the same effect with a similar composition by Schubert. The Schubert piece was selected from the same classical music compellation that contained Mozart's Sonata for two pianos in D major and was similar in arrangement (instrumentation), tempo (speed), complexity and style. In the second study they compared performance on a set of PF&C tasks after listening either to Mozart or to a selection from a Steven King audio book (King, 1994). In that experiment, there was no significant difference in performance between the two groups. When performance of the two groups was compared after sorting the results by individual preferences, however, preference for the stimulus was found to be associated with better performance, regardless of whether they heard the Mozart Sonata or the short story. The researchers concluded that the effect is not specific to Mozart or even to music at all. Rather they suggest that performance enhancement is a product of exposure to stimuli that the participants find appealing.

Similar to Steele, Bass and Crook (1999), Nantaism and Schellenberg suggest that the link between preference and performance is mediated by changes in arousal and mood. Without direct physiological measures, however, they were unable to measure arousal directly and therefore unable to draw any firm conclusions regarding causal relations between arousal and performance. To overcome this limitation, direct measures of physiological arousal were recorded in the present research along with self-reports of arousal and appeal to the stimulus to determine if these two factors are correlated with each other and with performance enhancement.

Mood and Arousal Model

In a meta-analysis comparing published studies of the Mozart Effect, Chabris (1999) found that studies in which the control condition was a relaxation tape, the difference in performance had a much higher effect size (d = .56 SD) than studies where silence was used as a control (d = .14 SD). This suggests that listening to a relaxation tape before performing a spatial reasoning task may actually impair performance. Findings such as these spurred the development of an alternative explanation to the Mozart Effect that linked the performance enhancements with arousal enhancements associated with music listening.

In one of the early papers that proposed the mood and arousal hypothesis, Steele, Bass and Crook (1999) attempted to replicate Rauscher's original study. They were unable to find any significant changes in performance after exposure to the Mozart Sonata for two pianos in D major (K 448). They did, however, find significant differences in mood and arousal. Participants who listened to Mozart were significantly more aroused and were in more positive moods than those who listened to music by Philip Glass or sat in silence. They concluded that the performance enhancement following exposure to music is an indirect result of mood and arousal enhancements. However, if previous findings were the result of mood enhancement and the subjects in Steele et al.'s study experienced mood enhancements as well, then why were there no performance enhancements? The experimenters offer no explanation for this absence of the original Mozart effect.

If the Mozart Effect is the result of increased arousal and mood, then one would expect that enhancing arousal and mood in other ways should influence performance in a similar manner. A study examining a sample of elementary school students, randomly assigned participants to three groups; one sat in silence, the second listened to Mozart's Sonata and the third completed a variety of active games (e.g. jumping jacks, catch with a ball) (Gonzalez et al., 2003). The students were then tested using the spatial abilities section of the Cognitive Abilities Test (Gonzalez et al., 2003), an age-specific test used to assess the suitability of students for gifted programs in schools. The results showed that students in the activity condition and the Mozart group performed significantly better than those in the silence condition (Gonzalez et al., 2003). There was no significant difference between the activity group and the Mozart group. However, it is interesting to note that the activity group performed slightly better than the control group, albeit not significantly so. It is tempting to conclude that performance in the Mozart group and the activity group was relying on the same cognitive mechanism. It is possible, however, that the performance of the activity group was enhanced by increased arousal, and the performance of the Mozart group was enhanced through neuro-priming or preference for the stimuli. In the proposed study, physiological arousal, mood enhancement and preference for the stimulus was closely monitored in an effort to identify the nature of the underlying effect. All participants were also asked to relax at the start of the study to ensure any activities they may have been doing just prior to participating in the study would not influence their performance.

Musical Features Underlying Mood and Arousal

A great deal of research has sought to isolate the features of music that contribute to its affective impact. Two primary features have been identified that affect emotional responses to music: mode (major/minor scale) and tempo (fast/slow) (Hunter, Schellenberg, & Schimmack, 2008). The mode of a musical piece refers to the scale the music is set to. In conventional western music, the major key sounds bright and happy whereas the minor key is darker and sounds sad. Tempo refers to the pace of the music. Across cultures, fast tempi have been found to be associated with happy music and slower tempi with sad music. These two features of music exist independently of each other and can even oppose one another in the same musical piece (i.e. a fast tempo in a minor key or versa slow tempo in a major key). When these factors are in opposition with one another, they can evoke both happy and sad emotions at once (Hunter, Schellenberg, & Schimmack, 2008). For example a slow song in a major key could evoke mixed feelings of happiness and sadness in the listener. Musical compositions that are both major and fast evoke the most positive emotions, and those that are minor and slow evoke the least positive emotions (Hunter, Schellenberg, & Schimmack, 2008). It is important to highlight that the Mozart Sonata used in Rauscher's original study is both in a major key and played at a moderately fast tempo (Rauscher, 1993).

To determine the influence of the mode and tempo of the famous Mozart piece, Husain, Thompson and Schellenberg (2002) compared the effects of four variations of the same Mozart Sonata. The versions were fast-major, fast-minor, slow-major and slow-minor. The fast and slow tempi (165bpm and 60bpm respectively) were based on what the researchers determined were the fastest and slowest speeds that still sounded natural. Interestingly, neither of these two speeds is near the original (120bpm). Participants were exposed to one of the four stimuli in the pre-test phase and were then tested on a PF&C task. Self-report measures of arousal and mood were taken using the Profile of Mood States (POMS) and the Affective grid (another measure of self-report mood and arousal) before and after exposure to the music. The POMS has been used in previous studies to measure changes in arousal and mood brought on by therapy, medication and mood-inducing stimuli (McNair, Lorr, & Doppleman, 1992). The Affective Grid was used as it measures mood and arousal simultaneously. This allows mood and arousal to be presented as independent, orthogonal factors to the participants (Russell, Weiss, & Mendelsohn, 1989). As the POMS a well documented and validated instrument, it was used as the mood and arousal self-report measure in the present research.

A simplified explanation of the results of this study is shown in Table 1. Via a main effect for tempo, the results showed that participants performed best in the fast music groups. A slightly smaller effect was found for mode with performance being somewhat better in the major groups. When compared to a control group from another study where participants sat in silence for 10 minutes before performing the same PF&C

task, performance in the fast-major and fast-minor group was significantly better than that of the silence group, with no difference between the slow-major, slow-minor and silence group. This suggests that the changes in tempo were related to the changes in performance on the PF&C.

Results from the self-report data showed relationships between tempo and arousal, and mode and mood. Participants who listened to the fast versions reported higher arousal and those who heard the slow versions reported lower arousal regardless of the scale in which the music was presented. Participants who listened to the versions in the major scale reported more positive mood, whereas the minor-scale groups reported more negative moods. When the two factors were congruent, (slow-minor and fast-major) participants reported higher valence (preference) than those in the incongruent groups (fast-minor and slow-major). The preference for congruent music was not reflected in performance. As the changes in tempo found to predict performance on the PF&C task, they concluded that arousal elicited by the tempo of the music was responsible for the Mozart Effect (Husain, Thompson & Schellenberg, 2002).

Table 1

Summary of results of Husain, Thompson and Schellenberg (2002)

Group	PF&C Performance (compared to silence)	Arousal	Mood	Preference
Slow Minor	Same	Lower	Same	Higher
Slow Major	Same	Lower	Higher	Lower
Fast Minor	Higher	Higher	Same	Lower
Fast Major	Higher	Higher	Higher	Higher

Husain, Thompson & Schellenberg (2002) hypothesized that this link operates under the Yerkes-Dodson Law. The Yerkes-Dodson Law states that the relationship between arousal and performance appears as an inverted-U shape with ideal performance in the center and declining performance as arousal increases above the optimal level or decreases below that ideal level (Anderson, 1990). The Yerkes-Dodson Law is illustrated in Figure 1 below.

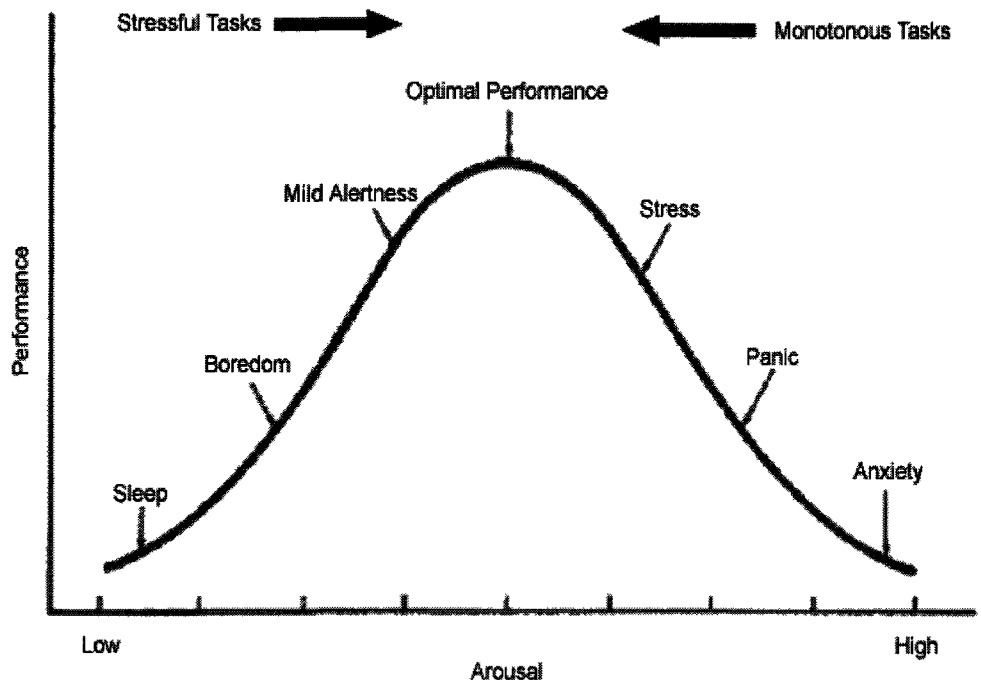

Figure 1. The Yerkes-Dobson inverted U-shaped arousal-performance function

Although the results of the Husain et al.'s (2002) study confirm the Yerkes-Dodson Law, the original tempo of Mozart's Sonata was not used. Without the original tempo as a comparison, it is impossible to determine the influence of the original composition in previous studies (e.g., Rauscher, Gordon and Katherine, 1995). To overcome this weakness, the same Mozart sonata was played at three different tempi here: slow, moderate, and fast. The moderate condition will be played at 120bpm which is the standard tempo for the piece which has been used in previous studies. If the Mozart effect is, in fact, a result of enhanced arousal, then the results should again confirm the Yerkes-Dodson Law. The slow version should impair performance due to under-arousal. The moderate should increase performance as it has in previous studies. And the fast should either increase or decrease performance depending on whether participants were over-aroused.

Spatial-Temporal Specificity

The primary issue with the arousal hypothesis is that it fails account for the spatial temporal specificity of the Mozart Effect. If music enhances performance simply by increasing arousal through the Yerkes-Dodson Law, then participants who are exposed to arousing and pleasurable music should also perform better than a control group on other measures. However several studies testing the Mozart effect on other measures have found no evidence of enhancement, for example, on backwards digit span tasks (Steeles, Ball & Runk, 1997) or on short term memory tasks (Rauscher et al., 1995). In Rauscher et al.'s study (1995), the memory task was completed on the fifth day of testing. Although the researchers concluded that a lack of performance enhancement supported the notion that the Mozart Effect was specific to spatial temporal task performance, fatigue and order effects could potentially explain the negative result. To avoid these issues, two experiments were included here. One used a selection of PF&C tasks as in earlier studies; the other used a test battery of various cognitive tasks to measure changes in performance on other cognitive dimensions following the presentation of music. If the

Mozart Effect is specific to spatial temporal tasks, then we should only see performance enhancement on the PF&C task and not on the cognitive test battery.

It is important to note that the task difficulty and participants' perception of stress associated with the task can influence arousal and subsequent performance (Anderson, 1990). Monotonous tasks can reduce arousal, and highly demanding or stressful tasks can increase arousal. Arousing stimuli could enhance performance on monotonous tasks by optimally raising arousal but impair performance on demanding tasks by raising arousal to a supra-optimal level (Anderson, 1990). It is possible that the Mozart Effect has been found to be specific to the PF&C task because the level of arousal induced by Mozart's Sonata is well matched with the task demands of the PF&C task. To address this, the present study included a second experiment in which the PF&C task was replaced with the Cognitive Drug Research (CDR) battery.

Individual Differences

Personality Differences

Although there is a great deal of research exploring the benefits of music listening on cognitive performance (e.g. Rauscher, 1993; Nantais & Schellenberg, 1999), other research has found that music can actually impair performance on cognitive tasks by distracting the individual (Furnham & Bradley, 1997). Furnham and Bradley found that test-taking can be impaired by the presence of music. Unlike Rauscher's studies, pop music was presented to participants during the task. The results showed that the impairment was less exaggerated in those who scored highly on extraversion on the Eysenck Personality Questionnaire. Their post-test questionnaires also indicated that the extroverts in the study were more likely to study in busy, noisy areas whereas the introverts preferred complete silence. This finding is consistent with Eysenck's (1955) theory of cortical arousal. This theory states that extroverts operate on a lower base-rate of cortical arousal than introverts. This causes extroverts to seek out more arousing situations and gives them a higher threshold for over-stimulation. Introverts' higher base-rate of cortical arousal lowers their threshold for over-stimulation leading them to avoid higher stimulating environments. If the Mozart effect is caused by enhanced arousal, participants' level of extroversion could potentially influence their ideal level of arousal for performance. To test this, the Eysenck Personality Questionnaire-Revised (EPQ-R) (Eysenck & Eysenck, 1975) was used to measure the participants' personality traits in the current study. A copy of the EPQ-R is not included in an appendix due to copyright laws.

Musical Preference

It is important to keep in mind the importance of participants' musical preference and background. As Nantaism and Schellenburg (1999) demonstrated, musical preference can play a large role in the effect of music on performance. To minimize the influence of musical preference, the used only one piece of music played at different tempi to reduce the influence of participants' preference to particular musical styles or composers. It is possible, however, that dramatic alterations to the tempo could make the music less enjoyable. To assess this, participants were asked to rate how enjoyable they found the musical piece at the end of the study as well as their overall preference for music.

If the Mozart Effect is stronger when the individual likes the music they are exposed to, then it is important to consider their musical preference and musical training.

The potential influence of early exposure to music, especially musical training, on cognitive areas not associated with music, has been heavily researched, and positive links between musical training and other facets of intelligence, like memory recall, have been identified (e.g., Tierney, Bergeson, & Pisoni, 2008). In most of these studies, however, it is difficult to determine if music training increases intelligence, or if more intelligent people are more likely to take music lessons (Schellenberg, 2008). Although that research is very interesting, it is beyond the scope of this thesis to pursue the potential relationship between intelligence and music training. The present research therefore focused entirely on temporary cognitive enhancement. Participants were asked about their musical background.

Physiological Measures

One of the primary drawbacks of many of the early studies examining the Mozart Effect is their lack of direct physiological measures (e.g. Rauscher et al., 1995; Gonzalez et al., 2003). Although many of these studies make assumptions about the potential influence on arousal, it is difficult to confirm any such effects without direct measures of changes in the autonomic nervous system. Studies that have used physiological measures have tended only to focus on one measure of physiology arousal at a time. The present research recorded radial pulse rates, electroencephalography and galvanic skin conductance simultaneously to measure these changes directly. A brief description of these physiological measures is presented next, together with a review of previous studies that recorded these measures in connection with the Mozart Effect.

Pulse Rates

In Rauscher's first study (1993) demonstrating the Mozart Effect, pulse rates were recorded before and after the listening conditions to record any changes in physiological arousal. The average resting heart rate of an adult is approximately 60-80 beats per minute (bpm) but can increase very quickly in the presence of an alarming or arousing stimulus (Nakahara et al., 2010). When Rauscher found no significant difference in pulse rate between the music- and silence-groups, physiological arousal was excluded as a potential explanation for the enhancement. Although an increased heart rate is commonly associated with increased arousal, it is highly variable. The human body's natural mechanisms are constantly regulating these changes in an attempt to maintain homeostasis (Malmstrom, Opton & Lazarus, 1965). With so much fluctuation, it is questionable if two samples of heart-rates as sampled in the Rauscher study would suffice to assess the impact of the music on heart rate. Studies using continuous recording methods have been much more successful at correlating heart rate and other physiological responses such as skin conductance with emotionally evoking video stimuli (Malmstrom, Opton & Lazarus, 1965). In the current study, physiological measures were recorded throughout the study and aggregated over periods of time rather than taken from a single recording. This method should ensure a more accurate indication of arousal changes brought on by the stimulus.

Rauscher (1993) does not mention a pre-experimental baseline measure of heart rate. Participants' initial state of arousal could have influenced their first heart rate recording. More recent studies have required participants to sit in silence for three minutes before measuring their arousal level to attain an adequate baseline measurement (e.g. Rideout & Laubach, 1996). To ensure that proper baseline of physiological measures, this study included a resting period of three minutes before baseline was taken.

Central Nervous System Activity

A previous study has attempted to replicate the Mozart Effect while recording participants' brain activity using electroencephalography (EEG) (Rideout & Laubach, 1996). EEG measures electrical activity on the surface of the scalp that is the result of neurons firing in the brain (Pinel, 2002). In Pinel's study, participants were asked to sit quietly while EEG readings were taken to determine their baseline pre-experimentally. The study used a repeated-measures design testing participants on two sets of 16 PF&C items. Before the first set of PF&C tasks, half the participants listened to Mozart's Sonata K. 448 for ten minutes and the other half sat in silence for ten minutes. The participants were then primed by the opposite condition (silence or Mozart) and asked to perform a second set of 16 PF&C tasks.

Even though the sample comprised only eight participants, the study found significantly higher performance on the PF&C tasks after the presentation of the music (Rideout & Laubach, 1996) as well as significant correlations between before-and-after performance in the PF&C tasks . Increased EEG power measures in several locations on the skull was correlated with improved performance after listening to music. They interpreted this as evidence that neuro-priming had occurred, which increased neural activity (Rideout & Laubach, 1996). It is possible, however, that the participants' increased arousal was responsible for the increased brain activity. It is also interesting that the recordings were taken during the test phases only. One would expect that better performance would be correlated with increased brain activity regardless of any priming that may have occurred. In the current study, EEG measures were taken during both the pre-experimental music exposure phase and during the testing phase to determine when changes occur and how long they last.

During Rideout and Laubach's (1996) study, there were also several strong negative correlations between performance enhancement and alpha peak frequencies at baseline. Performance enhancement was also positively correlated with beta peak frequency while baseline measures were taken. Put simply, this finding suggests that individuals with lower alpha peak frequencies and higher beta peak frequencies at resting may be more susceptible to the Mozart Effect. The researchers concluded that an increased frequency range would improve participants' ability to discriminate the frequencies associated with musical notes. Brains better at discriminating musical notes should therefore be better at emulating the firing patterns evoked by music and, in turn, facilitate increased performance (Rideout & Laubach, 1996). Recent studies, however, have found a relationship between resting alpha waves and extroversion (Hagmann et al., 2009). Higher amplitudes of resting alpha waves have been found to be correlated with higher levels of extroversion (Hagmann et al., 2009). As higher alpha waves have been linked with lower cortical arousal this finding is considered support for the Eysenck's arousal hypothesis (1955), that extroverts have lower baseline cortical arousal. Therefore, it is possible that the difference in performance was, in fact, the result of different levels of extroversion rather than better frequency discrimination. With no measure of extroversion in Rideout and Laubach's study (1996), this is impossible to determine.

In the current study, participants' EEG activity was recorded in an effort to determine the nature of the relationship between brain activity and music listening and performance. Specifically, alpha and beta waves were recorded as they have been found to be closely linked to arousal.

Galvanic Skin Response

Rideout and his colleges (Rideout, Fairchild & Urban, 1998) performed a follow-up to their EEG study, this time examining changes in galvanic skin response (GSR). GSR measures the skin's ability conduct electricity, which has been linked to emotional responses and to autonomic changes (Pinel, 2002). Specifically, as the autonomic nervous system becomes aroused, activity of the sweat glands increases the electro-conductivity of the skin. GSR records changes in the electro-conductivity allowing these autonomic arousal changes to be measured. Using the same procedure as in their EEG study (Rideout & Laubach, 1996), Rideout et al. (1998) attempted to replicate the Mozart effect while measuring changes in GSR. Although they followed the same procedure as their previous study with a larger sample size (n = 12), they found no performance differences between participants in the control- and the treatment conditions (Rideout, Fairchild & Urban, 1998). No correlation was found between GSR measure taken during the presentation of the music and performance on the PF&C task. If arousal is responsible for the performance enhancement as previous studies' self-report data suggest, then one would expect GSR to be related to performance enhancements (Husain, Thompson & Schellenberg, 2002). It is possible however that arousal changes would have been measurable if the effect had been replicated. Due to the within-subject design of that experiment, it is possible that a carry-over effect influenced the data. This did not appear to be an issue in their previous study (Rideout & Laubach, 1996). They did, however, find that participants with overall lower skin conductance benefited more from exposure to the music (Rideout, Fairchild & Urban, 1998). Without a significant overall performance differences between the participant-groups, it is difficult to draw firm conclusions from these results. It does highlight the subtle nature of the Mozart Effect and emphasizes the importance of strict control procedures. Recording skin conductance in a between-subject design, as in the current study, may yield more informative results.

Research Objective

The primary goal of the present research was to determine the underlying cause of the Mozart effect. This was explored through two experiments. Experiment 1 expanded on previous research (e.g. Rauscher et al. 1993) by examining the differences in spatial-temporal performance following exposure to three different tempi of the Mozart Sonata. Physiological measures were taken during the study to confirm the relation between arousal, tempo and subsequent performance. Experiment 2 examined cognitive functioning in a range of different tasks to determine if the Mozart effect is specific to spatial temporal performance as some researchers have claimed (Steeles, Ball & Runk, 1997). Both studies exposed participants to differing tempi of the same musical stimuli used in previous studies to determine the role of tempo on the Mozart effect. In addition, physiological arousal was monitored to determine its role in this effect.

Experiment 1

The purpose of Experiment 1 was to replicate the procedure of Husain, Thompson & Schellenberg (2002) using the same PF&C tasks, but including three rather than two different tempi of Mozart's Sonata. Changes in physiological arousal were measured as well. The hypotheses for Experiment 1 were as follows:

- Hypothesis 1 predicted that participants' autonomic arousal would be highest in the fast tempo group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. The control group's arousal was not expected to change following the ten minutes of silence. Following testing, autonomic arousal was predicted to return to baseline.
- Hypothesis 2 stated that participants' self-report arousal would be highest in the fast tempo group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. The control group's self-report arousal was not expected to change following the ten minutes of silence. Following testing, self-report arousal was expected return to baseline.
- Hypothesis 3 stated that participants' cortical arousal would be highest in the fast tempo group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. The control group's cortical arousal was not expected to change following the ten minutes of silence. As alpha wave amplitude has been found to be negatively correlated with high cortical arousal and beta wave amplitude has been positively correlated with high cortical arousal, changes in these measures were used to compute cortical arousal. Following testing, cortical arousal was expected to return to baseline.

- Hypothesis 4 stated that participants in the treatment groups would experience higher mood ratings than those in the control group. However, this was not expected to influence performance.
- Hypothesis 5 stated that performance on the PF&C task would be significantly better in the moderate speed group than in any of the three other groups.
- Hypothesis 6 stated that performance on the PF&C task would be lower in the groups that listened to Mozart's Sonata at the fastest and slowest speed compared to the control condition.

Method

Participants

A sample of 56 students was recruited through SONA, Carleton University's online participant sign-up system and through personal contacts. The ages of the sample ranged from 17 to 45 with an average age of 20.5. Participants were randomly assigned to one of four groups of 14 each (control, slow, moderate, fast speed) while keeping gender balanced between and within the groups, and using a Latin square design. All participants were required to have normal hearing and be fluent English speakers. Participants recruited using the SONA system received 1% course credit for their first year psychology class and the others were paid $10 for their participation. They were tested in individual sessions taking approximately one hour.

Apparatus

Physiological measures of arousal were recorded throughout the experiment using the Procomp Infiniti Encoder (SA7500) by Thought Technologies. Heart rate was measured using a blood volume pulse sensor (SA9308M) placed on the participant's middle finger of their non-dominant hand. A skin conductance sensor (SA9309M) was placed on the participant's index and ring finger of their non-dominant hand to measure skin conductance. EEG was measured using an EEG-Z sensor (T9305Z) with the ground node attached to the participants left ear lobe, the negative node attached to their right ear lobe and the positive node attached to the top of their head. All these physiological measures were recorded simultaneously using BioGraph Infiniti™ 5.0 software.

Stimuli and Measures

The same midi file of Mozart's sonata K. 448 was used as in Husain, Forde and Schellenberg's study (2002). Audio editing software (Cubase) was used to manipulate the tempo of the piece to generate three versions: slow (50bpm), fast (190bpm) and moderate (120bpm) which reflects the original speed of the piece. Although all three versions are the same in terms of pitch, mode and timbre, adjusting the tempo changed the playback duration. At the moderate tempo, the piece is six and a half minutes in length. The slow version is over fifteen minutes in length and the fast version is only be four minutes long. In the fast and moderate conditions, the piece was therefore looped; in the slow condition only the first 10 minutes was played. To avoid abrupt endings in any of the versions, they were all stopped at the end of the phrase that came after the 10-minute exposure time. The music was played from a compact disc on a stereo in front of the participants at a moderate volume (approximately 60-70 dB as used in previous studies).

Both sets of 17 PF&C items (34) constructed for Husain, Forde and Schellenberg's study were used together to assess the participants' spatial temporal abilities in the same way as has previously been assessed in at least two successful replication of the Mozart Effect (for an example see Appendix E). All 34 items were used together to increase the variability of performance. The PF&C items were presented on a computer screen and participants were required to respond by selecting the letter on a keyboard that corresponded with their answer. Direct RT software was used to present these items and record the participants' responses. All participants were asked to complete the EPQ-R to establish personality differences and self-reports of mood and arousal were taken using the POMS inventory. Participants were also asked to complete a brief demographic questionnaire before the study (Appendix C) and a follow-up questionnaire (Appendix D) at the end of the experiment.

Experimental Design

The study was a mixed-design with four groups. Table 2 illustrates the experimental design.

Table 2.

Experimental design

Group (n)	Pre-experimental	10min Stim.	Post Stim.	Task	Post Task
Control (n = 14)	Baseline, pre-experimental and self-report 1	Silence	Self-report 2	PF&C	Physiol. removed and post-exper. questionnaire
Slow (n = 14)	Baseline, pre-experimental and self-report 1	Mozart Sonata (50bpm)	Self-report 2	PF&C	Physiol. removed and post-exper. questionnaire
Moderate (n = 14)	Baseline, pre-experimental and self-report 1	Mozart's Sonata (120bpm)	Self-report 2	PF&C	Physiol. removed and post-exper. questionnaire
Fast (n = 14)	Baseline, pre-experimental and self-report 1	Mozart Sonata (190bpm)	Self-report 2	PF&C	Physiol. removed and post-exper. questionnaire

Procedure

Before the study began, participants were asked to read and sign an informed consent form outlining the details of the study (see Appendix A). The experimenter then read the experimental instructions (Appendix H) and asked if participants had any questions. With the aid of the researcher, the physiological measurement devices were then attached. Participants were asked to fill out the demographic questionnaire (Appendix C), the EPQ-R and the mood and arousal questionnaire. These were administered before the connection of the physiological equipment to avoid recording changes induced by being attached to the measurement devices. They were then asked to sit and relax for three minutes to generate a baseline measure of physiological arousal. The last minute of baseline recordings of participants' heart rate, GSR and EEG were aggregated and this measure was taken as their baseline level of physiological arousal. Participants in the three experimental groups were then exposed to ten minutes of musical stimuli (slow, moderate, fast), and the control group sat in silence for 10 minutes. The participants were then asked to retake the mood and arousal questionnaire. They were then asked to complete the 32 PF&C tasks. The participants were given a last mood and arousal questionnaire followed by a short questionnaire (Appendix D) to assess their perception of their performance, their musical background and how much they enjoyed the musical piece they listened to. Participants were then unhooked from the physiological devices, debriefed (Appendix B), asked to sign a form consenting to use their data (Appendix G), and thanked for their participation.

Results

The results are divided into six sections. The first section presents the results for physiological measures, followed by the findings from the self-report measures. The results from cortical arousal measures are presented next, followed by the results from the mood measures. The fifth section presents the performance results from the PFC task, and finally, a series of post hoc analyses conducted on the data are shown.

Physiological Measures

The first step of the data analysis was to determine if increasing the tempo of the musical piece increased autonomic nervous system arousal measured by the heart rate and galvanic skin conductance. Hypothesis 1 predicted that participants' arousal would be highest in the fast tempo subject-group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. The control group's arousal was not expected to change following the ten minutes of silence. It was expected that these differences would persist into the test-taking phase of the study but that they would be less pronounced as the influence of the music fades. To test this, two 4 x (3) mixed ANOVAs were conducted for subject-group (Control, Slow, Moderate, Fast) and time of measurement (Baseline, Treatment, Testing) for Heart Rate and GSR. The results of heart rate data, explored first, are shown in Figure 2.

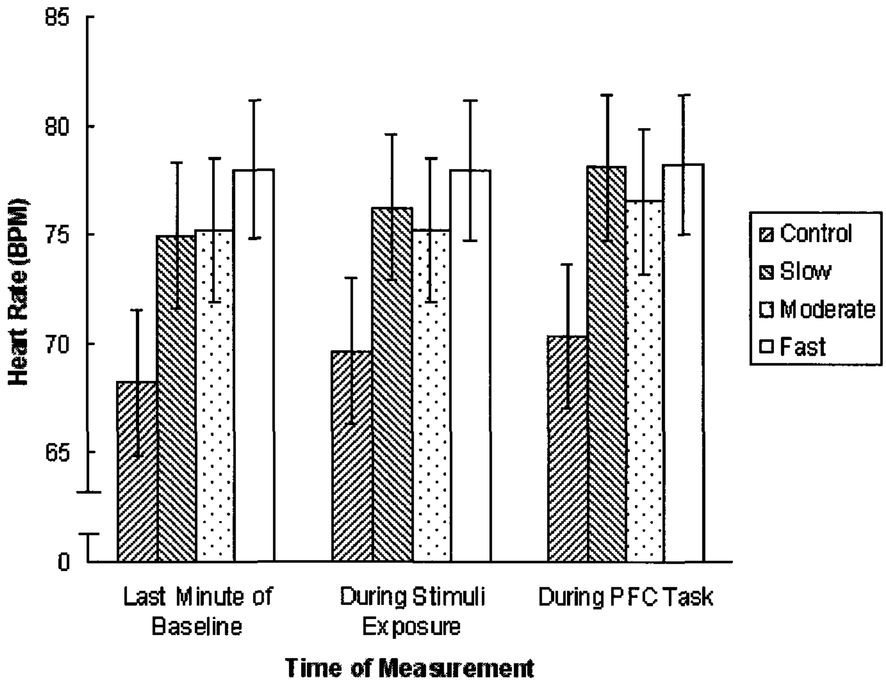

Figure 2. Heart Rate (BPM) for time of measurement (Baseline, Stimuli, Task) by condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

As the Figure shows, Heart Rate (BPM) did not appear to fluctuate much across the measurement times. It was somewhat lower in the control subject-group than in the experimental conditions, which appear to be undifferentiated.

Exploration of the data identified two potential outliers (Participants 2 and 3). Both participants' Heart Rates were above 195 bpm during the entire study, probably due to an equipment malfunction. Mauchly's test of sphericity showed that sphericity had been violated in the heart rate data (chi-square = 13.010, p <.05). Therefore the degrees of freedom were corrected using lower-bound estimate of sphericity (epsilon = .50). The 4 x (3) mixed measure ANOVA yielded no significant interaction of group and heart rate, $F(1, 49) = 1.51$, $p = .224$, $\eta_p^2 = .085$. However, there was a significant main effect for time of measurement, $F(1, 49) = 5.93$, $p < .05$, $\eta_p^2 = .108$. Bonferroni correction, used for the pairwise comparisons, showed that the heart rate was significantly higher during the stimuli exposure and while completing the task, $p < .05$, than the baseline measure. However, the HR for stimuli exposure and task-completion did not differ significantly, $p > .05$. There was no significant main effect for subject-group, $F(3, 49) = 1.39$, $p = .256$. Evidently, heart rate was not affected by the speed of the music to which the participant was exposed.

The results of GSR data, treated in the same fashion as the heart rate data, is shown for time of measurement by condition in Figure 3.

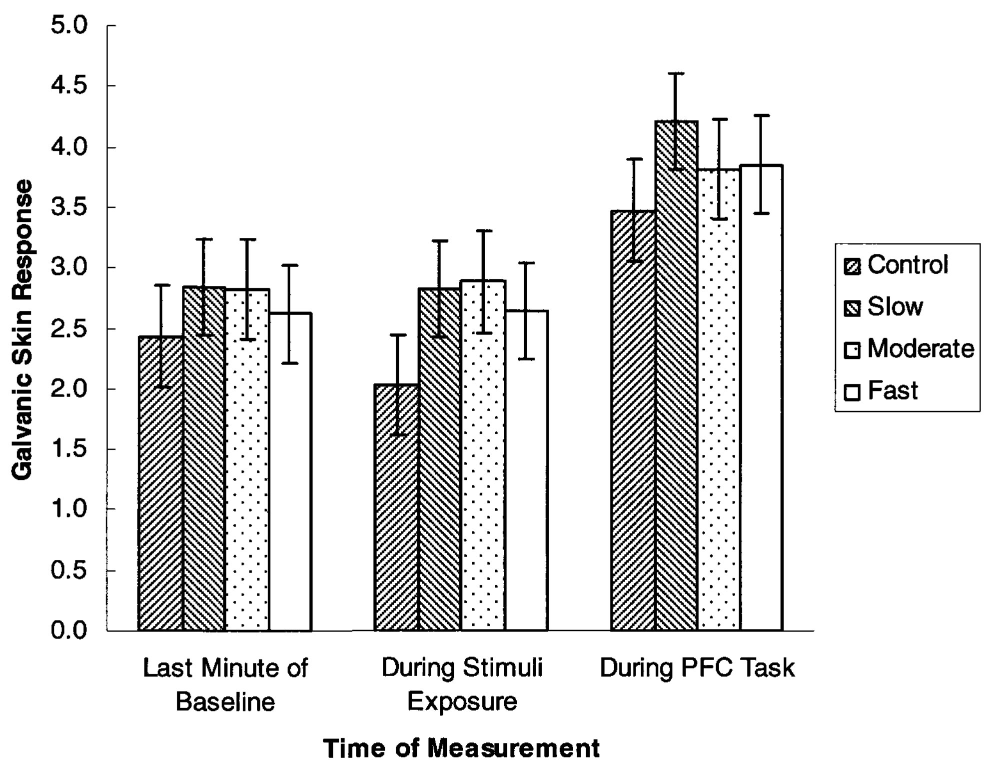

Figure 3. GSR for time of measurement (Baseline, Stimuli, Task) by condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

As the Figure shows, GSR appears lowest at the baseline time of measurement for all conditions except the control condition which has its lowest point during stimuli exposure. The other three groups appear to have slightly higher GSR at the time of stimulus exposure when compared to their baseline. GSR taken while the participants completed the task, however, appears highest regardless of condition.

Closer inspection of the GSR data revealed one possible outlier. Participant 34's GSR was three standard deviations outside of the mean of the group. This could have been due to a hardware malfunction or contamination of the skin with a conductive material. As Mauchly's test of sphericity was again significant, it indicated that the GSR data violated sphericity, (chi-square = 22.85, $p <.05$). To compensate, the degrees of freedom were corrected using lower-bound estimate of sphericity (epsilon = .50). No significant interaction was found for condition and time of measurement, $F(3, 50) = .567$, $p = .564$, $\eta_p^2 = .040$. However, there was a significant main effect for time of measurement, $F(1, 50) = 62.719$, $p <.001$, $\eta_p^2 = .556$. Fisher's LSD correction was used for pairwise tests aimed to determine the locus of these differences. The pairwise comparison showed that GSR was significantly higher while participants completed the PFC task than during both stimuli exposure, $p < .001$ and baseline, $p < .001$. Skin conductance did not differ significantly between stimuli exposure and baseline, *ns*. There was no main effect for condition, $F(3, 50) = .462$, $p = .710$. Skin conductance was thus not affected by the speed of the music to which the participant was exposed. Although participants' arousal level changed as a result of the particular activity, the different speeds with which the music was played did not affect their heart rate or skin conductance significantly. This finding refutes Hypothesis 1. Physiological arousal did not differ as a function of music listening condition.

Self-report measures of arousal. Hypothesis 2 stated that participants' self-report arousal would be highest in the fast tempo group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. The results of POMS vigor-activity self-report for time of reporting by condition are shown in Figure 4 below.

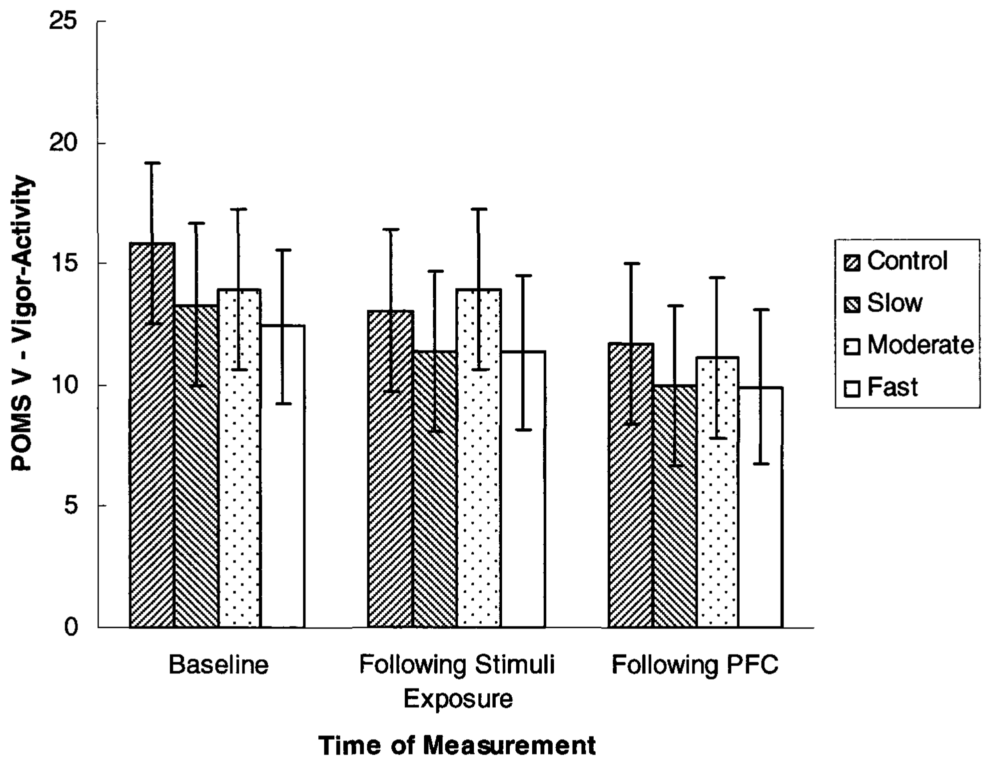

Figure 4. POMS-V for time of report (Baseline, Following Stimuli, Following Task) by condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

As the Figure shows reported POMS V was highest for all conditions at the baseline time of report. Report scores decreased following exposure and then decreased further following PFC task. This trend appears reasonably consistent across all four conditions.

An exploration of the data found no serious outliers or violations of normality. No violations sphericity (chi-square = .20, p >.05) or homogeneity of variance were found in the data. To test for differences in the POMS vigor-activity subscale, a 4 x (3) mixed ANOVA for condition (Control, Slow, Moderate, Fast) and the time of report as the within-subject factor (Baseline, Stimuli Exposure, Testing) was conducted. No significant interaction was found for condition by time of reporting for their self-reports of vigor-activity, $F(6, 100) = .494$, *ns*. There was, however, a significant main effect for the time of reporting, $F(2, 100) = 12.42$, $p < .001$, $\eta_p^2 = .199$. A Fisher's LSD correction was used, and pairwise comparisons showed that participants' reports of vigor-activity were significantly higher at baseline than following stimuli exposure, $p < .05$, and after the task, $p < .01$. Vigor-activity reports following stimuli exposure ere also found to be significantly higher than following task, $p < .05$. No main effect for condition was found, $F(3, 50) = .697$, $p = .558$. In short, it appears that self-reports of arousal reduced progressively over the course of the study. This refutes Hypothesis 2, as music exposure condition appeared to have had no influence on subjective ratings of arousal.

Cortical Arousal Measures

Hypothesis 3 predicted that participants' cortical arousal would be highest in the fast tempo group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. These differences were expected to persist into the task, however become less pronounced as the influence of the stimuli fades. No difference was expected at baseline. To calculate the relationship between cortical arousal and tempo, recordings of alpha and beta waves from the EEG taken during the last minute of baseline, during music exposure and during task-completion were compared between conditions. To test this, two 4 x (3) mixed ANOVAs for condition (Control, Slow, Moderate, Fast) by time of measurement (Baseline, Treatment, Testing) were conducted for each of the two EEG measurements, alpha and beta amplitudes. The results for alpha amplitudes for time of recoding by condition are shown in Figure 5.

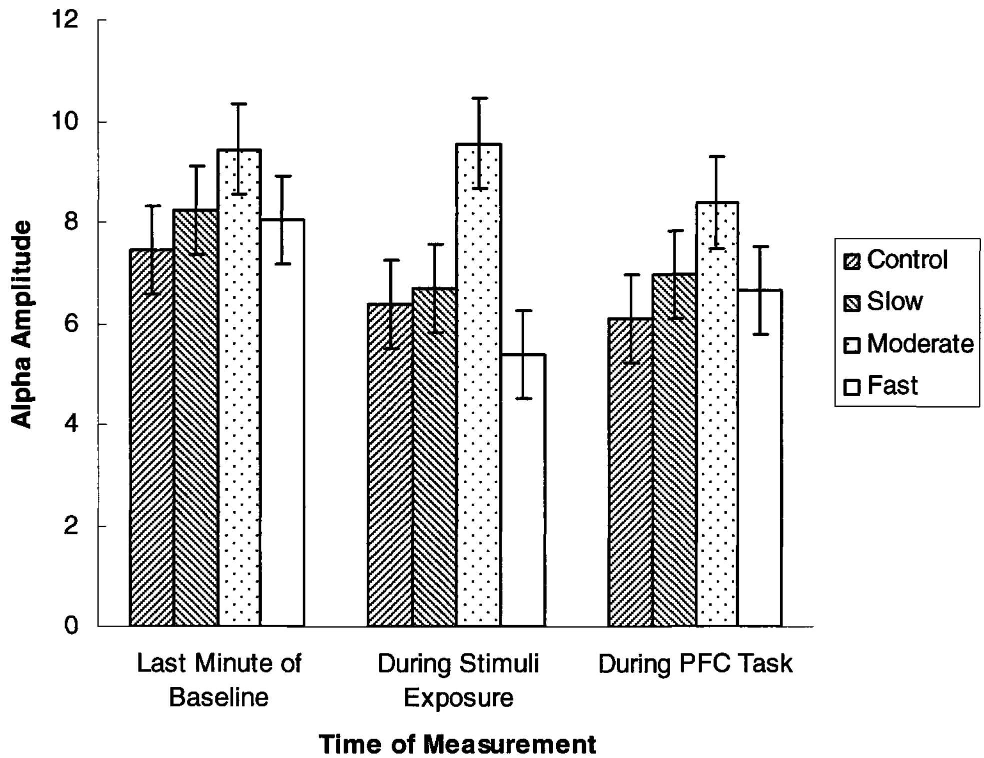

Figure 5. Alpha amplitude for time of recording (Baseline, Stimuli, Task) by condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

As the Figure shows, alpha amplitude was highest in the baseline time of recording for all conditions but the moderate. However, the pattern at stimulus exposure time of recording appears different for the moderate condition than it does for the other three conditions; it increased slightly whilst the others showed a decrease from baseline.

An exploration of the alpha amplitude data found two outliers (participants 2 and 3). These same participants' heart rate values we also identified as outliers. Both these participants' alpha amplitudes were over ten standard deviations above the mean. This supports the likelihood of a malfunction of the physiological measurements devices in these two cases and they were removed. A further exploration was conducted after these cases were removed to determine if any further outliers were present in the data. Case 29 and 39 were identified and removed. The test showed no significant interaction of condition by the time at which alpha amplitude recordings were taken, $F(6, 94) = .254$, $p = .96$. No significant main effect for time of recording, $F(2, 94) = 1.418$, $p = .25$, or subject-group, $F(3, 47) = .1.709$, $p = .178$, was found. This suggests that neither condition nor the time the recordings were taken had a significant influence on alpha wave amplitude.

The same analysis was conducted for beta amplitude. The beta amplitude data for participant 2 and 3 were once again well over ten standard deviations above the mean. These cases were identified as outliers and removed. The results for beta amplitude for condition by time of recording are shown in Figure 6.

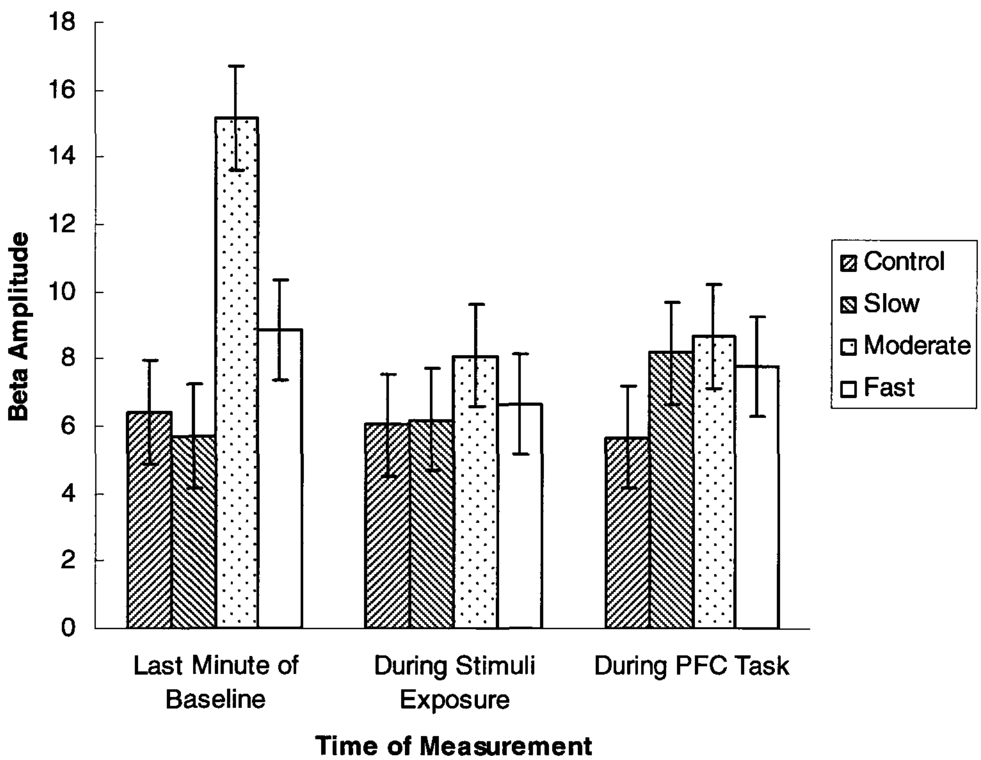

Figure 6. Beta amplitude for time of recording (Baseline, Stimuli, Task) by condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

The Figure shows that beta amplitudes for the baseline time of recording were much higher for the moderate condition than they were for the other three conditions. However, at the stimulus exposure- and the task time of recording beta amplitudes appear quite similar for all conditions.

The 4 x (3) ANOVA showed no significant interaction for condition and time of recording, $F(6, 98) = .66$, *ns,* or main effect for time of recording, $F(2, 98) = .68$, *ns.* There was also no significant main effect for subject-group, $F(3, 49) = 1.759$, $p = .167$. This suggests that neither condition nor the time the recordings were taken had a significant influence on beta wave amplitude. Together the results of both these tests refute Hypothesis 3, as no differences in cortical activity were identified between music listening conditions as a function of the time the recordings were taken.

Total mood disturbance measures. To test Hypothesis 4, stating that all participants exposed to the music would experience increased mood, the Total Mood Disturbance (TMD) score from the POMS was used as the mood measure and a 4 x (3) mixed ANOVA was conducted for condition (Control, Slow, Moderate, Fast) by time of questionnaire (Baseline, After Stimulus Exposure, After Task) for TMD score. Figure 7 shows the condition by time of questionnaire results for TMD.

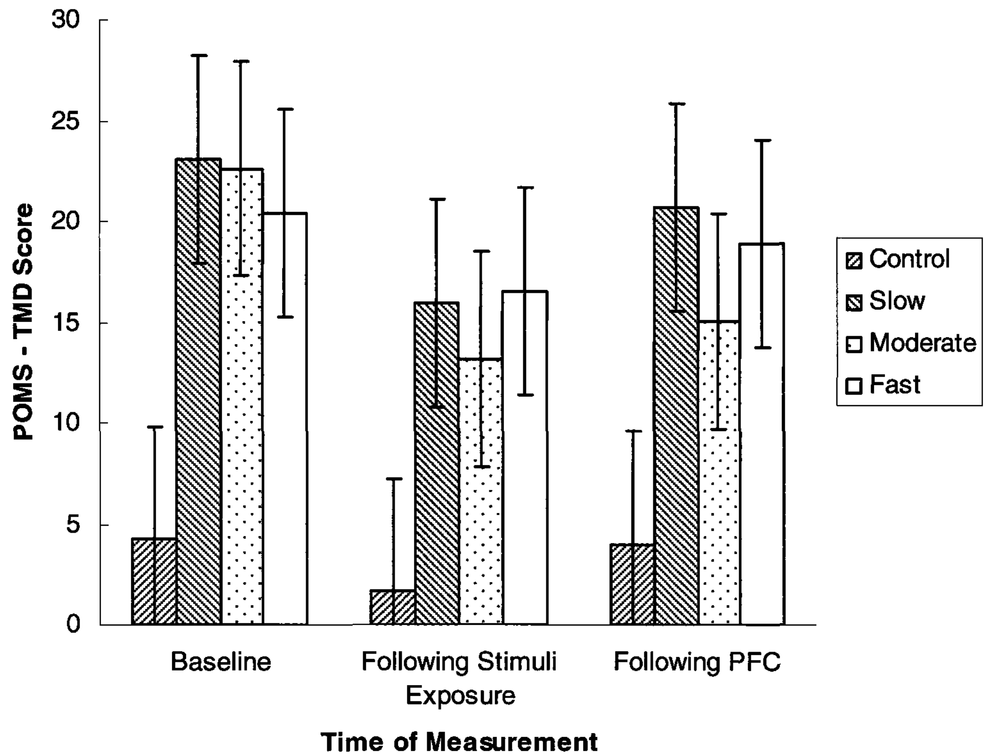

Figure 7. TMD Scores for time of questionnaire (Baseline, Stimuli, Task) by condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

When examining figure 7 it is important to keep in mind that higher TMD scores related to less positive mood and a lower score relates to happier mood. As the Figure shows, TMD scores resulted in similar patterns for all conditions. The control condition scores were quite low despite the time at which the questionnaire was administered. This is unexpected as nothing in the procedure differed between subject groups at the baseline.

An exploration of the data identified two outliers (case 19 and 40). Based on their responses it is likely these participants did not fully understand how to fill out the mood questionnaires. No significant interaction was found for condition by the time at which the questionnaire was completed, $F(6, 98) = .33$, *ns*. The main effect for time of questionnaire was marginally significant, $F(2, 98) = 3.07$, $p = .051$, $\eta_p^2 = .02$. Fisher's

LSD correction was used to analyze the pairwise comparisons of the difference between times and showed that participants' reports of TMD were significantly higher at baseline than following stimuli exposure, $p = .023$. TMD following the task was not significantly different than TMD after baseline or after exposure to the music. No main effect was found for subject-group, $F(3, 49) = 1.99$, $p = .128$. These findings refute Hypothesis 4, as no differences in mood could be found between subject-groups.

PFC Performance Measures

To test Hypotheses 5 and 6, a univariate ANOVA with condition as the independent variable (Control, Slow, Moderate, Fast) and performance on the PFC as the dependent variable was conducted. The results for the PFC task are shown for each condition in Figure 8.

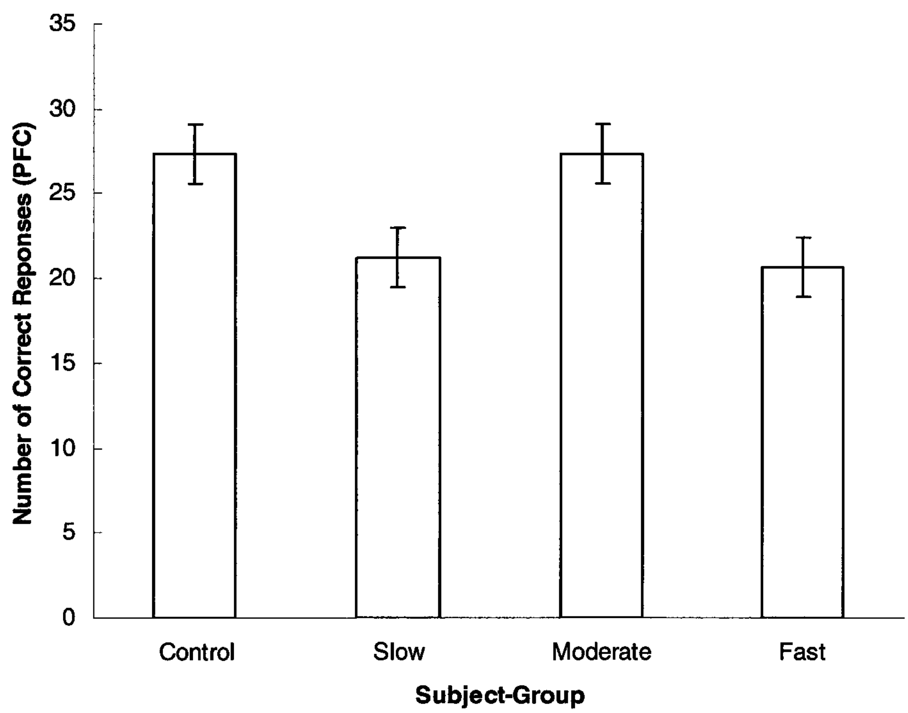

Figure 8. Performance on the PFC task for each condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

As the Figure shows, performance on the PFC task was higher for the control and the moderate conditions than it was for the slow and the fast conditions. There does not appear to be any major differences between the control and the moderate group or the slow and the fast group.

Due to violations of Shapiro-Wilk's test of normality in the control and moderate conditions ($p < .05$) four cases were removed (25, 19, 15 and 27). All these participants' scores on the PFC task were far lower than those obtained from the other participants in their groups. It is likely that variation in spatial abilities accounted for these deficits. This will be discussed in detail later. With these cases removed the normality assumption was no longer violated.

The results of the ANOVA revealed that the groups differed significantly on performance on the PFC task, $F(3, 47) = 4.574$, $p = .007$, $\eta_p^2 = .226$. The observed power was .86. As there was a control condition, Dunnett t (2-tailed) test was used to examine the pairwise comparisons. This test found that although performance of the slow group, $p < .05$, and fast group, $p < .05$, were significantly lower than the control group, $p < .05$, the moderate group did not differ significantly from the control. This finding showed no support for hypothesis 5, which stated that the moderate group would have the highest overall performance. It did, however, support hypothesis 6, stating that the slow and fast groups would have significantly lower performance than the control condition.

Post-hoc Analyses

A series of correlations were conducted to identify any other relationships that may be of interest. To test the valence model, a correlation was conducted between participants' rating of the music and performance, $r = .100$, *ns*. Each of the participants in the music conditions were asked to rate how enjoyable they found the music they listened to on a scale from one to ten at the end of the study. If preference to the stimuli leads to increased performance, a positive correlation would have been expected. The finding suggests that valence did not predict performance. However, musical ratings were positively correlated with the POMS V self-report measure of arousal following exposure, $r = .473, p < .001$. This finding suggests that the more participants enjoyed the music, the more their arousal increased following the stimulus exposure phase. Musical rating was also found to be negatively correlated with TMD from the POMS, $r = -.327, p < .05$. As higher ratings of TMD mean lower mood, this finding suggests that the more participants enjoyed the music they listened to, the more positive their mood was following exposure. By the same token, these findings could also be interpreted to indicate that participants who were in a more positive mood to begin with rated the music more positively.

To determine if music ratings differed significantly between conditions, a one-way ANOVA was conducted. The data is shown in Figure 9 below.

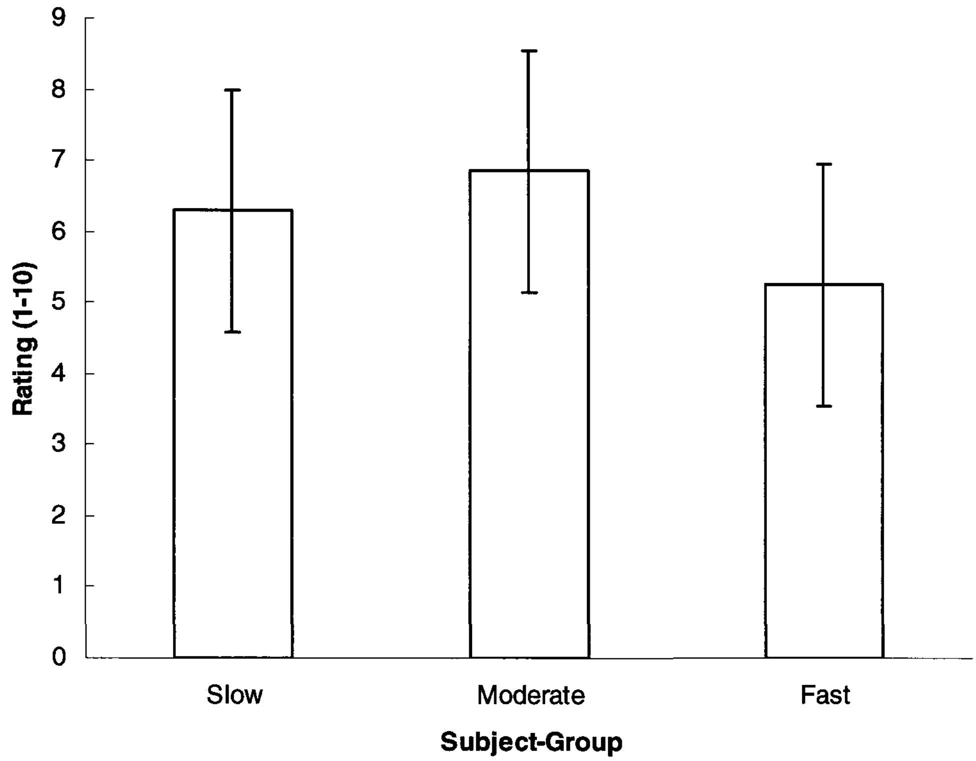

Figure 9. Music rating for each condition (Slow, Moderate, Fast). The error bars indicate the standard deviation.

The results showed that condition significantly influenced music rating, F (2, 38) = 4.109, p = .024, η_p^2 = .178. A Bonferroni correction was used for the pairwise comparison to find the locus of this difference. This test determined that there was no significant difference between the ratings in the slow group and the moderate group. However, the fast subject-group's ratings were significantly lower than the moderate subject-group, p = .02. There was no significant difference between ratings in the fast and slow conditions. This suggests that participants' found the fast music more unpleasant than the moderate music.

To determine if cortical activity influenced performance, correlations were conducted between alpha and beta amplitude during each part of the experiment and performance of the PFC task. These results can be seen in Table 3.

Table 3

Correlations Between PFC Performance and EEG Recordings

PFC Perf.	Baseline	Stimuli	Task
Alpha Amplitude	.169	.291*	.146
Beta Amplitude	-.032	.401**	.188

Note: *p = .05, **p = .01

As Table 3 shows, correlations between performance and cortical activity were only significant when taken after stimuli exposure. As this recording was taken directly before the task-completion phase, the finding suggests that the level of cortical activity before a task can influence performance. This finding supports the potential for neuro priming if indeed it is correct that the stimuli were capable of evoking cortical activity.

Discussion

The purpose of study 1 was to replicate of Husain, Thompson & Schellenberg's (2002) procedure in an effort to determine the underlying mechanism of the Mozart Effect. Hypothesis 1 and 2 were based on previous research (e.g., Gonzalez et al., 2003) claiming that performance increases following music exposure were the result of increased arousal. In the present experiment arousal was simultaneously measured through GSR, HR and self-reporting, and still, no measurable differences appeared in the data. Even if tempo did not influence changes in arousal as predicted by Husain et al.'s research (2002), one would expect differences between the control condition and the music groups. There are a few subtle differences between this study and Husain et al.'s

(2002) that may have made the influence of the tempo changes immeasurable. One potential explanation is that participants in Husain et al.'s (2002) study listened to the music on headphones in a sound attenuated booth. It is possible that listening to the music on headphone increased focus on the music and reduced distractions amplifying the effect. The music was played on normal speakers in the current study to emulate more closely normal music listening conditions. A future study comparing the impact of music listening with speakers to headphone listening on the Mozart Effect would definitively determine if way the music is listened to plays a serious role in its effect.

Each of the three measurement of arousal did change over the course of the experiment; however, each appeared to change independently of the others and in a manner that was not systematically related to the particular condition to which participants had been assigned. The baseline readings were significantly lower than readings taken during stimuli exposure and task performance. Since heart rates vary considerably both between- and within people, they are potentially more sensitive to changes in the participant's activity level (Nakahara et al., 2010). This could account for the heart rate increases both while listening to music and while completing the PFC task compared to baseline.

Although GSR is a measure of physiological arousal, it is more sensitive to changes in levels of stress. Therefore, the observation that the GSR readings increased significantly during completion of the task compared to the baseline readings and those taken while listening to the music, suggests that the task was more stressful than listening or sitting in silence. If GSR is considered as primarily a measure of stress, the absence of an interaction or main effect for subject-group is not surprising and really only suggests that music-listening was no more stressful than sitting in silence.

The trend of the POMS vigor-activity results was quite different from both the physiological arousal measures: vigor-activity was significantly lower at each of the recordings progressively over the course of the study. This may indicate an increasing level of fatigue as captured in adjectives such as 'lively', 'active', and 'energetic' assessed by the POMS. Thus, the apparent task-related excitement indicated by both the physiological measures appears to have been a rather negative experience. Since there was no main effect for subject-groups, the present results refute the arousal model as an explanation of the Mozart Effect.

Contrary to the predictions of Hypothesis 3 stating that cortical arousal would be highest in the music conditions, the EEG data yielded no significant main effects for either the beta- or the alpha waves. One possible explanation for this absence of effects may be that this study only used a single node electrode. With higher fidelity equipment, it is possible that any differences would have been more readily identified. The post hoc positive correlations between performance on the PFC task and both alpha- and beta-wave amplitude during stimuli exposure found that a positive relationship between both alpha- and beta waves during the stimuli exposure phase and performance on the PFC task. This suggests that cortical activity during priming is related to cognitive task performance. This leaves open the possibility of a neuro priming explanation of the Mozart Effect. Further studies using higher fidelity EEG will be required to learn more about this relationship.

According to Hypothesis 4, participants in the music subject-groups should experience higher moods that those in the control condition. However, analysis of the POMS scale Total Mood Disturbance (TMD) scores showed no significant differences between groups. There was however a main effect for the time the participants' filled out the questionnaire and it appeared that scores dropped below baseline following the stimuli exposure and then returned to near baseline levels following the task. As TMD is a measure of negative affect, the trend suggests that participants' mood increased overall following the stimuli exposure and returned to normal levels after the task. Although there was no difference between the subject-groups, this still suggests that overall, participants' mood increased somewhat following exposure to the music or period of silence. The POMS was intentionally administered directly following exposure to the stimuli to ensure that if any differences in mood occurred between the subject-groups, that it would be measured. As no measurable difference between the subject-groups was found in this study, it appears that the Mozart Sonata, played either fast, slow or at its normal speed, does not influence mood any differently then sitting in silence. This finding refutes the mood explanation of the Mozart Effect.

As the procedure for experiment 1 was identical to pervious research (Husain, Thompson & Schellenberg, 2002), participants in the music conditions, especially the moderate condition, were expected to perform better than those in the control condition. This was not the case. One possible explanation for the lack of a measurable difference in performance is that in the current study participants filled out a mood questionnaire directly following exposure to the music and before conducting the PFC task. In Husain et al.'s (2002) design, the participants immediately completed the PFC task following exposure to the music. The mood questionnaire was administered at this time to ensure any changes in mood related to the music listening would be measured, however this could have distracted the participants or taken long enough that the priming from the music exposure wore off before they were able to start the tasks.

A significant performance decrement did appear to occur in the fast and slow subject-group. Interestingly, participants' ratings of the pleasantness of the slow and the fast subject-groups' music was lower than the ratings of the moderate subject-group. Taken together, the above results suggest that the pleasure inherent in listening to the music may be the key to the Mozart Effect. If this finding is generalizable, a similar trend should emerge in experiment 2 reported next.

Experiment 2

The purpose of Experiment 2 was to determine if the Mozart effect can be demonstrated on tasks other than the PF&C tasks used in earlier experiments. The procedure was nearly identical to Experiment 1, but it utilized the Cognitive Drug Research (CDR) computerized test assessment battery instead of the PFC task. The hypotheses for Experiment 2 were thus as follows:

- Hypothesis 1 predicted that participants' autonomic arousal would be highest in the fast tempo group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. The control group's arousal was not expected to change following the ten minutes of silence. Following testing, autonomic arousal was predicted to return to baseline.

- Hypothesis 2 stated that participants' self-report arousal would be highest in the fast tempo group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. The control group's self-report arousal was not expected to change following the ten minutes of silence. Following testing, self-report arousal was expected return to baseline.
- Hypothesis 3 stated that participants' cortical arousal would be highest in the fast tempo group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. The control group's cortical arousal was not expected to change following the ten minutes of silence. As alpha wave amplitude has been found to be negatively correlated with high cortical arousal and beta wave amplitude has been positively correlated with high cortical arousal, changes in these measures were used to compute cortical arousal. Following testing, cortical arousal was expected to return to baseline.
- Hypothesis 4 stated that participants in the treatment groups would experience higher mood ratings than those in the control group following music exposure and during the cognitive test battery. However, this was not expected to influence performance.
- Hypothesis 5 stated that participants' performance would be highest on the monotonous tasks (speed of attention and accuracy of attention) after they had been exposed to the fast version of Mozart's Sonata, higher than control after

listening to the moderate version and lower than control after listening to the slow version.

- Hypothesis 6 stated that participants' performance would highest on the demanding tasks (speed of memory, secondary memory and working memory) after they had been exposed to the slow version of Mozart's Sonata, higher than control in the moderate condition, and lower than control in the fast condition.

Method

Participants

Experiment 2 recruited a new sample of 67 students through the same processes as in experiment 1. Five participants had to be removed before analysis due to participation in a previous study using the CDR and software crashes, leaving 62 participants for the analysis. The ages of the sample ranged from 17 to 44 with an average age of 21.6. As in Experiment 1, they were randomly assigned to one of four groups and compensated for their participation in the same manner as Experiment 1. They were tested in individual sessions that took approximately 60 minutes.

Apparatus, Stimuli, Measures, Experimental Design and Procedure

Experiment 2 was identical to Experiment 1 except the PF&C task was replaced with the CDR. The CDR is a computerized cognitive test battery that measures a wide array of well established cognitive domains. Aside from some free recall tasks, most of the CDR tasks are presented on a computer screen, and participants respond "Yes" or "No" using a response box with two buttons. This method allows time and accuracy to be reliably recorded down to the millisecond without requiring much physical involvement from the participant or risking any influence from the researcher. Through a series of nine tasks, the CDR assesses speed of attention, accuracy of attention, and quality of memory which includes working memory and secondary memory. Figure 2 shows the tasks, their outcome measures and their relationship with each of the cognitive domains. The tasks in the CDR are as follows:

Immediate word recall. A mix of 15 one-, two-, and three-syllable words are presented sequentially for one second, with one second intervals between. Participants have 60 seconds to write down as many of the words from the list they can remember. Their score on this section is calculated by the number of correct words they recalled.

Picture presentation. After the immediate word recall task, 20 photographs are shown for two seconds each. Later in the test battery participants are asked to recall these images.

Simple reaction time. During this task, the participants press the "Yes" button as quickly as possible when the word "YES" appears on the computer screen. This happens at varying intervals between 1 and 2.5 seconds for 50 trials. Reaction time is recorded in milliseconds.

Digit vigilance. 240 numbers are shown in the center of the screen, one at time, at a rate of 80 numbers per minute. During this time a single number is displayed in the top right corner of the screen. Every time the number in the center matches the number in the right hand corner, participants press the "YES" button. The numbers will match 45/80 times; response accuracy, reaction time, and number of false positives are recorded.

Choice reaction time. In this task the words "YES" or "NO" are displayed on the screen; participants press either the YES or NO button as quickly as possible when they see corresponding word. The "YES" and "NO" messages are displayed 25 times each at varying interval between 1 and 2.5 seconds. Reaction time and accuracy of response are recorded.

Spatial working memory. An image of a house with nine windows in a 3 x 3 pattern is displayed on the screen for five seconds. Four of the nine windows are illuminated. Participants are then presented with a series of 36 images of the same house, each with only one of the nine windows illuminated. They press the "YES" button if the illuminated window was one of the four lit in the original image and "NO" if it was not. Sixteen of the images show windows that were lit in the first image and 20 show images with windows that were not lit. Participants' accuracy and reaction time is recorded.

Numeric working memory. Participants are shown five digits at a rate of one per second. To ensure they remember the numbers, they say the numbers aloud to the experimenter. If the participant fails to recall the digits, they will see again to ensure they remember them. Participants are then presented with a series of 30 digits and asked to respond "YES" when the number was in the original list or "NO" if it was not. Half of the digits series were in the original list. This task includes three trials, each with their own series of five digits. Reaction time and accuracy are recorded.

Delayed word recall. During this task, participants are given 60 seconds to write down as many of the words from earlier word presentation task they can remember and the number of correct responses are recorded.

Word recognition. During this task, participants are presented with a series of 30 words. Fifteen of these are from the previous word recall task and 15 are new. Participant press the "YES" button when they recognize the word from the word presentation task and "NO" if they do not. Accuracy and reaction time are recorded.

Picture recognition. Participants are presented with 40 images. Of these, 20 were presented previously, and 20 are new. Participants press the "YES" button when they think the image is from the original set, and "NO" when they think it is a new image. Reaction time and accuracy are recorded.

Scores on the CDR tasks are grouped and analyzed in six factors four of which are labelled global (speed of attention, accuracy of attention, quality of memory and speed of memory). The quality of memory factor is split into secondary memory and working memory. The contribution of each individual task measure to each of the outcome factors is included in Figure 10 below. As the memory tasks are time-sensitive and cognitively very demanding, these are considered the demanding tasks (quality of memory, speed of memory, secondary memory and working memory). The simple nature of the attention tasks (speed and accuracy of attention) makes these well suited to classify as monotonous tasks for this study. The CDR has been used in several previous studies as a measure of cognitive functioning. It has been found to be valid, reliable, and sensitive to changes in cognitive function (Scholey et al., 1999; Wesnes et al., 1999); it is sufficiently sensitive to measure changes in performance induced by exposure to scents (Moss et al., 2002). If the superior performance found in the Mozart Effect is due to increased arousal levels, the CDR should be sensitive to measure those changes. The instructions for the CDR can be found in Appendix F.

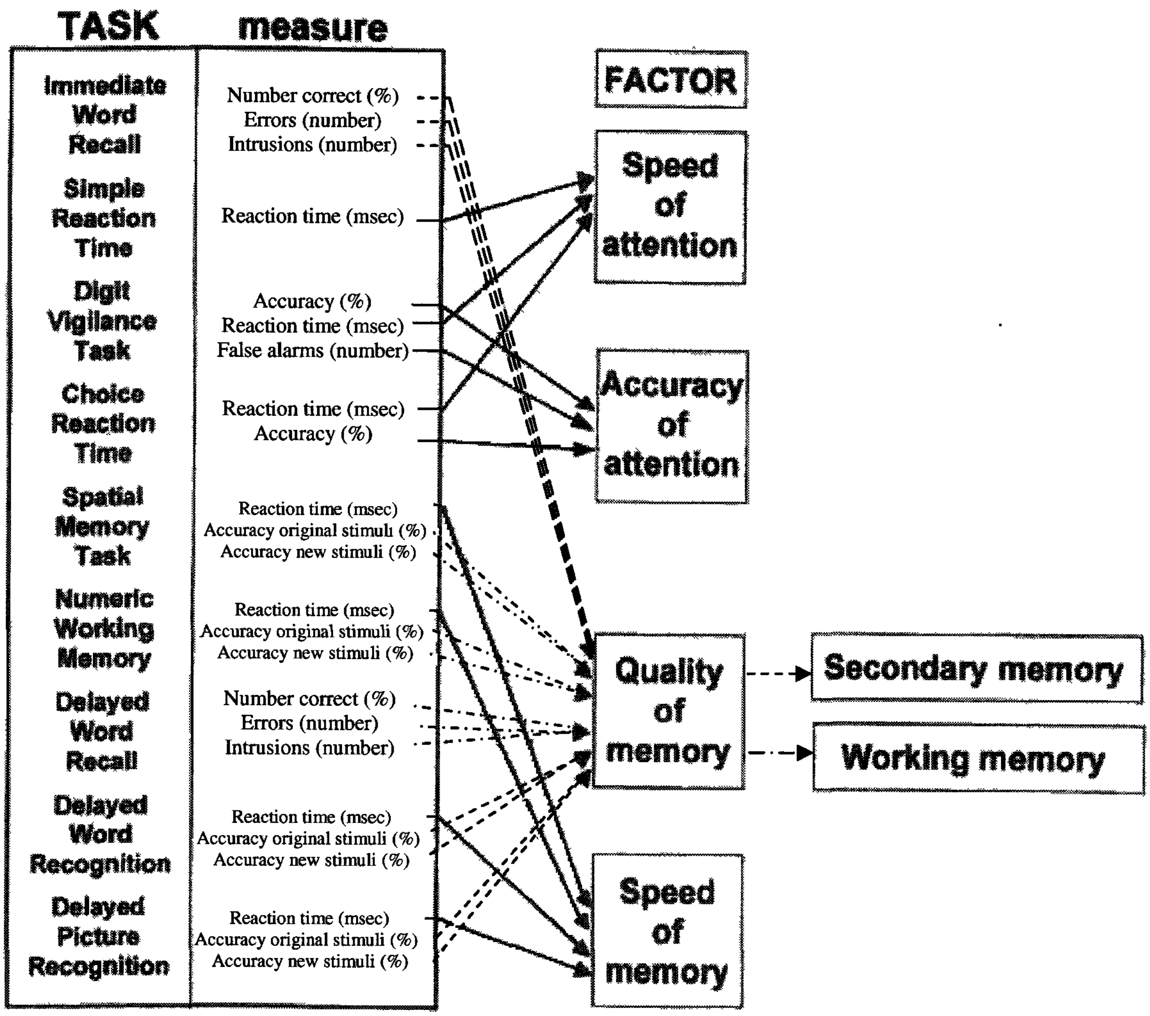

Figure 10. A visual illustration of the CDR battery showing the tasks, individual outcome measures, and the composition of the four factors derived by factor analysis. The arrows indicate which outcome measures contribute to which factors. The broken lines (- . -) contribute to "Working Memory" and the straight dashed lines (- - -) contribute to "Secondary Memory" (From: Moss et al., 2003)

Results

The results of Experiment 2 are divided into seven sections. The first section presents the results for the physiological measures of arousal, followed by a section outlining the subjective measures of arousal. The results of cortical arousal measures are presented next, followed by the results from the mood measures. The fifth section presents the performance results from the CDR monotonous tasks. A sixth section with the results of the demanding CDR tasks will follow. Finally, the last section will outline the findings from the post hoc analyses.

Physiological Measures

Hypothesis 1 predicted that participants' autonomic arousal would be highest in the fast tempo-group, higher than baseline in the moderate group and lower than baseline in the slow-tempo group following exposure to the music. It was expected that the control group's arousal would not change from baseline following the ten minutes of silence. Any differences brought on by music exposure were expected to persist into the test-taking phase of the study but the difference would be less as the effect of the music fades. To test hypothesis 1, a 4 x (3) mixed ANOVA was conducted for condition (Control, Slow, Moderate, Fast) by time of measurement (Baseline, Treatment, Testing) separately for each of the two physiological measurements, HR and GSR. The Heart rate results, explored first, are presented in Figure 11.

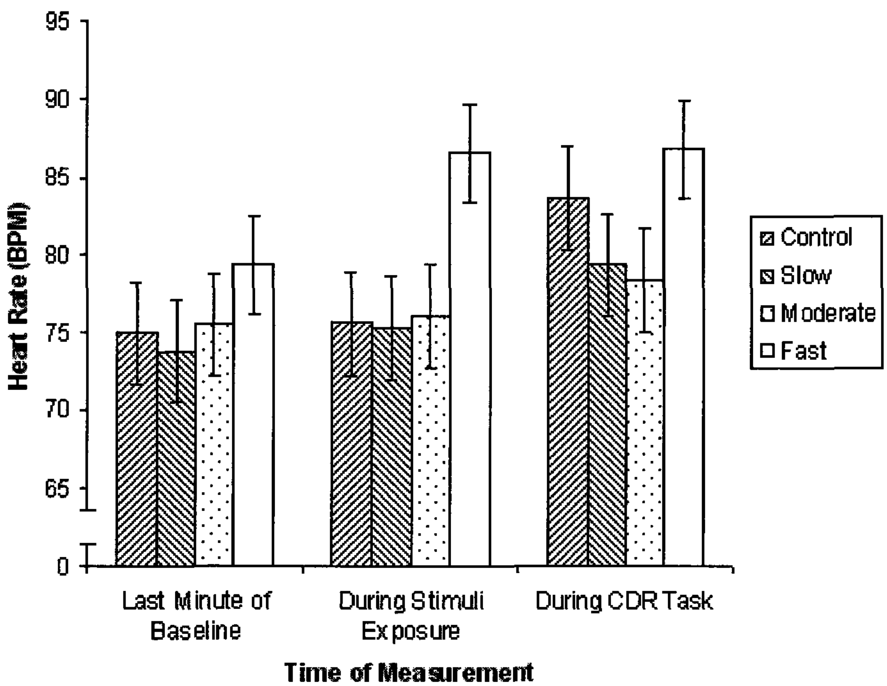

Figure 11. Heart Rate (BPM) for time of measurement (Baseline, Stimuli, CDR) by condition (Control, Slow, Moderate, Fast) with outliers removed. The error bars indicate the standard deviation.

As the Figure shows, HR was higher for all subject-groups while completing the CDR than during stimuli exposure and at baseline. The only dramatic difference between the four subject-groups, however, was the large increase for the fast-tempo group between the first and second measure.

An exploration of the Heart Rate data identified eight outliers (Participants 7, 25, 27, 35, 41, 42, 46, and 48). All of these participants' Heart Rates were above 180 bpm during the entire study, which is quite impossible. Data for these participants were therefore removed before conducting the analysis, and the problem was attributed to equipment malfunction. The ANOVA yielded no significant interaction, $F(6, 96) = .818$, $p = .558$, $\eta_p^2 = .049$. There was, however, a significant main effect for time of measurement, $F(2, 96) = 6.05$, $p = .003$, $\eta_p^2 = .112$. Fisher's LSD correction applied to the pairwise comparisons showed only that the heart rate was significantly higher during the CDR than at baseline ($p = .002$) and during stimuli exposure ($p = .043$). There was no significant main effect for subject-group, $F(3, 48) = 1.15$, $p = .339$. Thus, there was no evidence to suggest that heart rate was affected by the speed of the music to which participants were exposed. The GSR data, analyzed the in the same manner as the heart rate data, are shown in Figure 12 below.

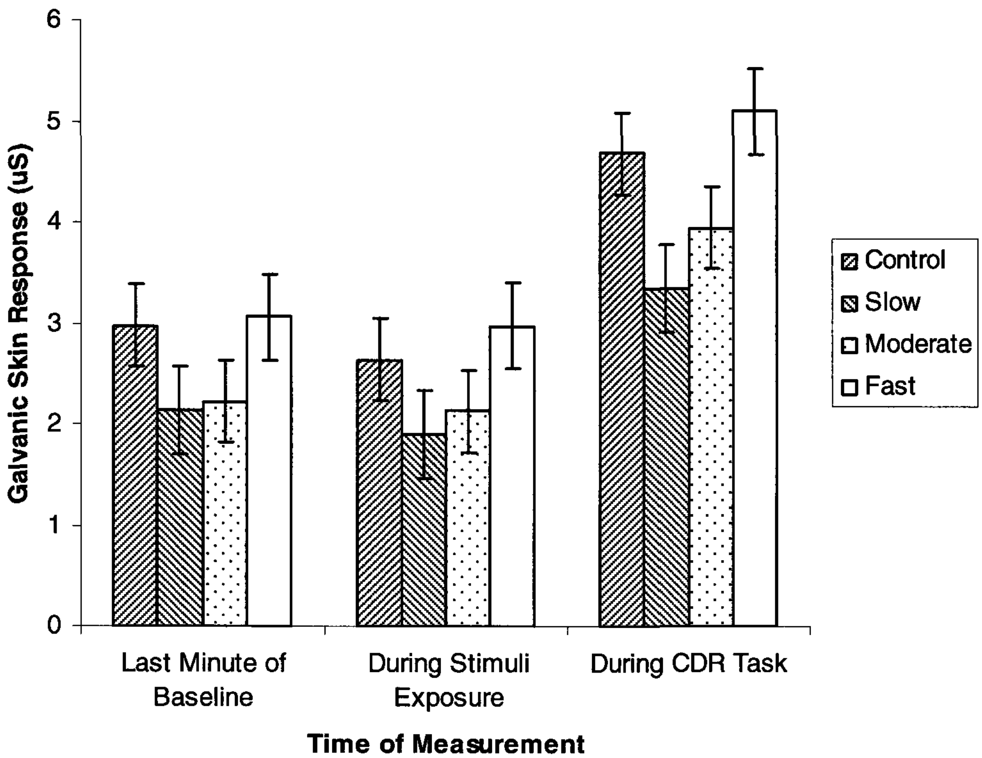

Figure 12. GSR for time of measurement (Baseline, Stimuli, CDR) by condition (Control, Slow, Moderate, Fast) with the outlier removed. The error bars indicate the standard deviation.

As the Figure shows, GSR readings were higher for all subject-groups while completing the tasks than at both the earlier times of measurement.

An exploration of the GSR data revealed one outlier. Participant 41's GSR was 3.7 standard deviations higher than the subject-group that it was in. This difference was attributed to a hardware malfunction or to contamination of the skin. Mauchly's test of sphericity was significant for the GSR data, (chi-square = 12.51, $p = .002$). The degrees of freedom were corrected using lower-bound estimate of sphericity to compensate (epsilon = .50). The analysis showed no significant interaction, $F(3, 57) = 1.325$, $p = .275$, $\eta_p^2 = .065$, but there was a significant main effect for time of measurement, $F(1, 57) = 150.26$, $p < .001$, $\eta_p^2 = .725$. Fisher's LSD correction was applied for the pairwise tests to identify the locus of the effect. GSR was significantly higher during the CDR than both baseline and during stimuli (both $p < .001$). GSR was also significantly higher during baseline than during stimuli exposure ($p = .038$). There was no main effect for subject-group, $F(3, 57) = 1.893$, $p = .141$. The results thus show that skin conductance was not affected by the speed of the music to which participants were exposed. Together these results show that participants' arousal level changed over the course of the experiment. However, music exposure did not affect heart rate or skin conductance significantly. These findings therefore refute Hypothesis 1.

Self-Report Measures of Arousal

Hypothesis 2 predicted that participants' self-report arousal would be highest in the fast tempo group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. POMS vigor-activity rating, shown in Figure 13 below, was used as a self-report measure of arousal.

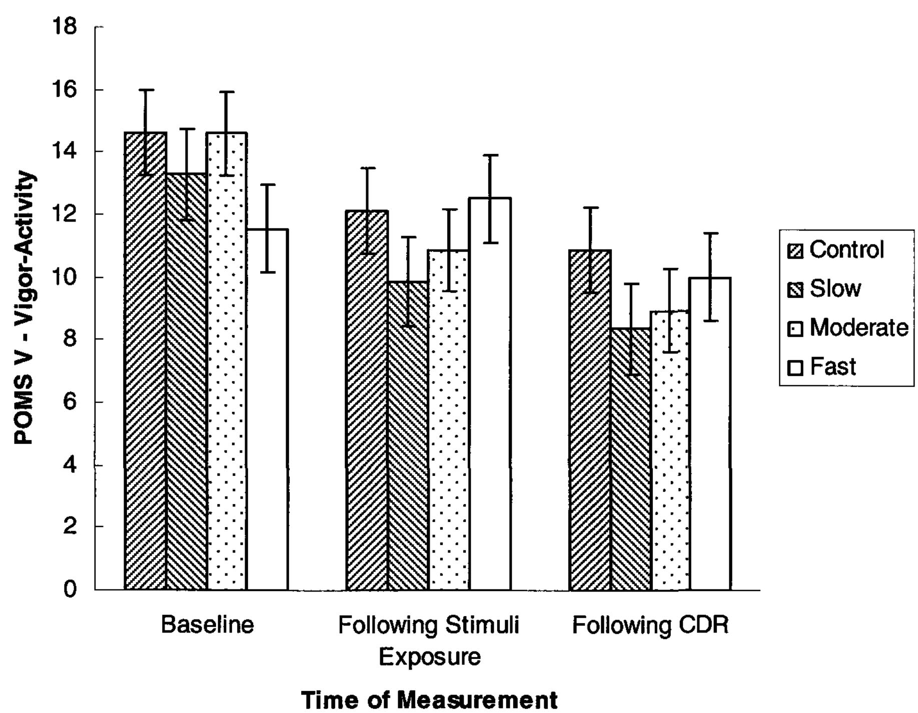

Figure 13. POMS-V for time of report (Baseline, Following Exposure, Following Task) by condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

Common to all subject-groups is the observation that vigor-activity ratings decreased from the first to the third time of measurement. While this was an almost monotonic decrease for three of the four subject-groups, only the ratings for the fast-tempo group increased somewhat from the first to the second reading.

An exploration of the data found no serious outliers or violations of normality. A 4 x (3) mixed ANOVA was conducted for condition (Control, Slow, Moderate, Fast) and the time of report (Baseline, Stimuli Exposure, Testing). The analysis showed no significant interaction, $F(6, 116) = 1.327$, $p = .271$, $\eta_p^2 = .064$. A significant main effect for time of measurement was, however, found, $F(2, 116) = 15.28$, $p < .001$, $\eta_p^2 = .209$. The fisher's LSD correction was used for the pairwise comparisons identify the locus of the effect. Ratings were significantly higher at the baseline than following both stimuli exposure ($p = .005$) and the CDR ($p < .001$). Scores following the CDR were also significantly lower than during stimuli exposure ($p = .005$). These findings show a progressive reduction in vigor-activity over the course of the experiment. No main effect for subject-group was found, $F(3, 58) = .358$, $p = .783$. These results therefore refute Hypothesis 2, as music exposure subject-group did not influence the subjective ratings of arousal.

Cortical Arousal Measures

Hypothesis 3 predicted that participants' cortical arousal would be highest in the fast tempo group, higher than baseline in the moderate group and lower than baseline in the slow group following exposure to the music. These differences were expected to persist into the task, however, also to become less pronounced as the influence of the stimuli fades. It was expect that no difference between the subject-groups would be measured at baseline. EEG recordings of alpha- and beta-waves were taken during the last minute of baseline, music exposure and during task-completion. These measure were compared between conditions using two 4 x (3) mixed ANOVAs for condition (Control, Slow, Moderate, Fast) by time of measurement (Baseline, Treatment, Testing), separately for the alpha and the beta amplitudes. The results for alpha amplitudes for time of recoding by condition are shown in Figure 14.

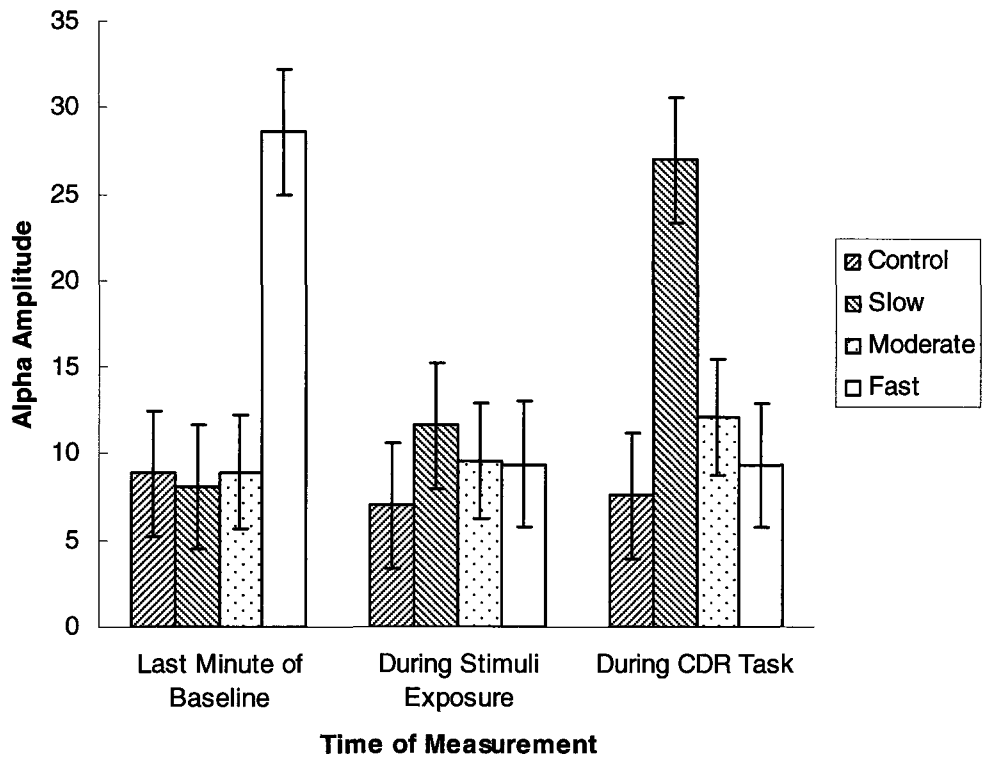

Figure 14. Alpha amplitude for time of recording (Baseline, Stimuli Exposure, CDR) by condition (Control, Slow, Moderate, Fast) with outliers removed. The error bars indicate the standard deviation.

The Figure shows that alpha amplitude did not appear to change much over the course of the study in the moderate and control conditions. Participants in the fast-tempo condition appears to have started with very high levels of alpha amplitudes at baseline, which then decreased during stimuli exposure and the CDR tasks to levels comparable to the control and moderate conditions. The slow group shows the opposite trend with low alpha amplitudes during baseline and stimuli exposure, then as dramatic increase during the CDR.

An exploration of the alpha amplitude data found that the data was extremely problematic. Some 16 outliers (participants 27, 10, 14, 15, 16, 17, 18, 20, 26, 27, 33, 35, 40, 42, 46, 47) were removed as their recordings were far higher than is actually possible. Many of these recordings were well over 800, which is over ten times the average alpha amplitude in experiment 1, $M = 7.41$, $SD = 4.74$. After removing these data, the sample sizes were reduced to 11 in the control, slow and fast subject-groups and 13 in the moderate subject-group. The ANOVA showed no significant interaction of subject-group by the time at which alpha amplitude recordings were taken, $F(6, 84) = 1.707$, $p = .171$, no significant main effect for time of recording, $F(2, 84) = .691$, $p = .504$, or subject-group, $F(3, 42) = 1.22$, $p = .314$. These findings suggest that neither subject group nor the time the recordings were taken had any significant influence on alpha wave amplitude.

This same analysis was performed on the beta amplitude data. The results for beta amplitude for condition by time of recording are shown in Figure 15.

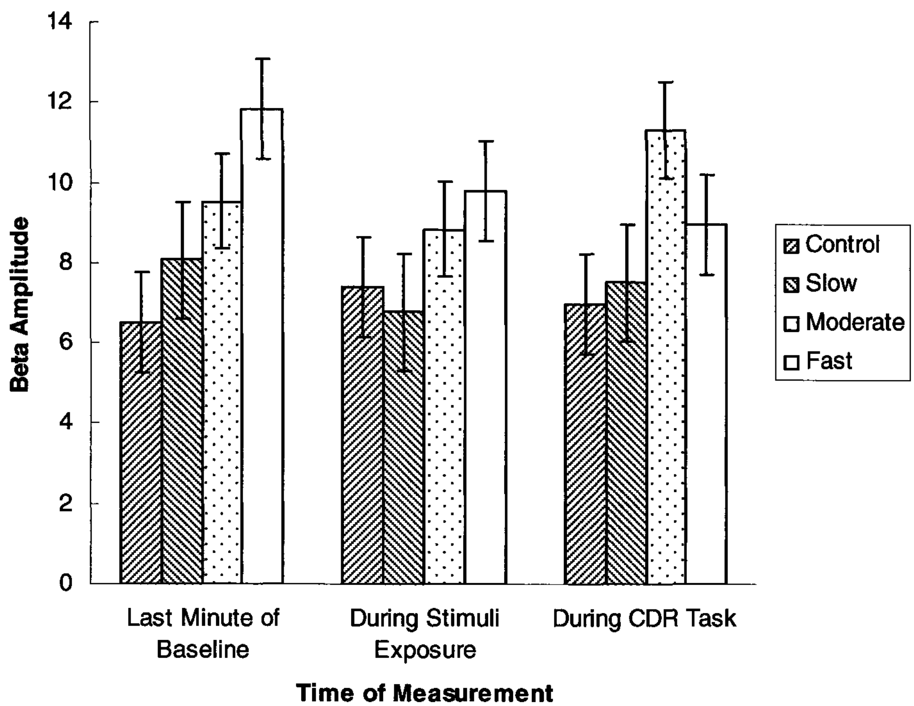

Figure 15. Beta amplitude for time of recording (Baseline, Stimuli Exposure, Task) by condition (Control, Slow, Moderate, Fast) with outliers removed. The error bars indicate the standard deviation.

No discernable trends are visible in the figure. Data for the slow-tempo and control subject-groups were quite similar throughout, but whereas the fast-tempo group was somewhat higher than those of the moderate-tempo group in the first and second readings, this was reversed in the third reading.

Exploration of the beta amplitude data revealed it to be even more problematic than the alpha amplitude data. In total 19 outliers were identified in the data (participants 3, 7, 14, 15, 16, 17, 18, 20, 25, 26, 27, 33, 35, 38, 40, 42, 46, 47, 60). Similar to the alpha amplitude data, these recordings were several times higher then common alpha wave amplitudes. After removing the outliers, 12 participants remained in the control subject-group, 10 in the slow subject group and 13 in the moderate and fast subject-groups. These data were submitted to analysis. The 4 x (3) ANOVA showed no significant interaction for condition and time of recording, $F(6, 76) = .487, p = .816$, no main effect for time of recording, $F(2, 76) = .217, p = .805$, and no main effect for subject-group, $F(3, 38) = 1.697, p = .167$. This suggests that neither condition nor the time the recordings were taken had a significant influence on beta wave amplitude. Together the results of both these tests refute Hypothesis 3, as no differences in cortical activity were identified between music listening conditions as a function of the time the recordings were taken. The number of outliers and the difficulty of collecting reasonable recordings may have contributed to this finding. It will be discussed later in the thesis.

Total Mood Disturbance Measures

Hypothesis 4 stated that all participants exposed to the music would experience increased mood. To test this, the Total Mood Disturbance (TMD) score from the POMS was used as the mood measure and a 4 x (3) mixed ANOVA was conducted for condition (Control, Slow, Moderate, Fast) by time of questionnaire (Baseline, After Stimulus Exposure, After Task) for TMD score. Figure 16 shows the condition by time of questionnaire results for TMD.

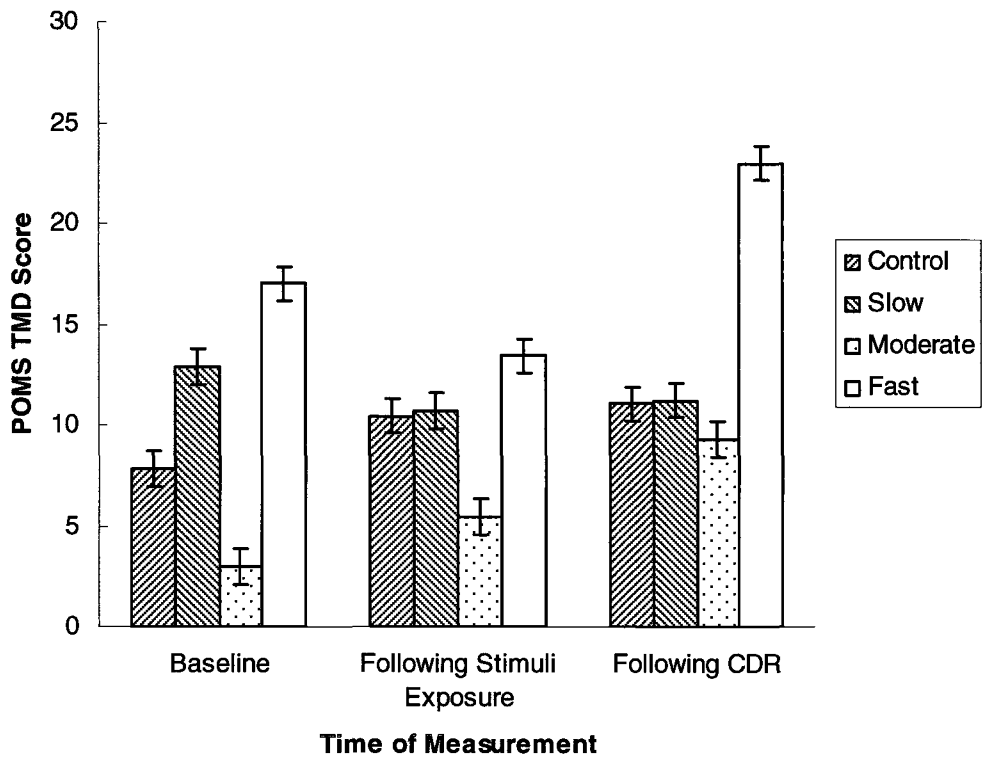

Figure 16. TMD Scores for time of questionnaire (Baseline, Stimuli Exposure, CDR) by condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

The only noteworthy observation in the figure is the steady increase in the score for the moderate-tempo group across the three readings and the large increase for the fast-tempo group in the final reading compared with the two first readings.

An exploration of the data identified no outliers. The ANOVA found no significant interaction, $F(3, 58) = 1.13$, $p = .345$. There was no main effect for the time the questionnaire was administered, $F(1, 58) = 1.76$, $p = .190$ or for subject-group, $F(3, 58) = 1.15$, $p = .336$. These findings refute hypothesis 4, as no differences in mood could be found between subject-groups.

CDR Monotonous-Task Performance

To test Hypotheses 5, two univariate ANOVA's with condition as the independent variable (Control, Slow, Moderate, Fast) and performance on the CDR as the dependent variable was conducted, one for the speed of attention measure and the other on the accuracy of attention measure. The results for the speed of attention measure are shown for each condition in Figure 17.

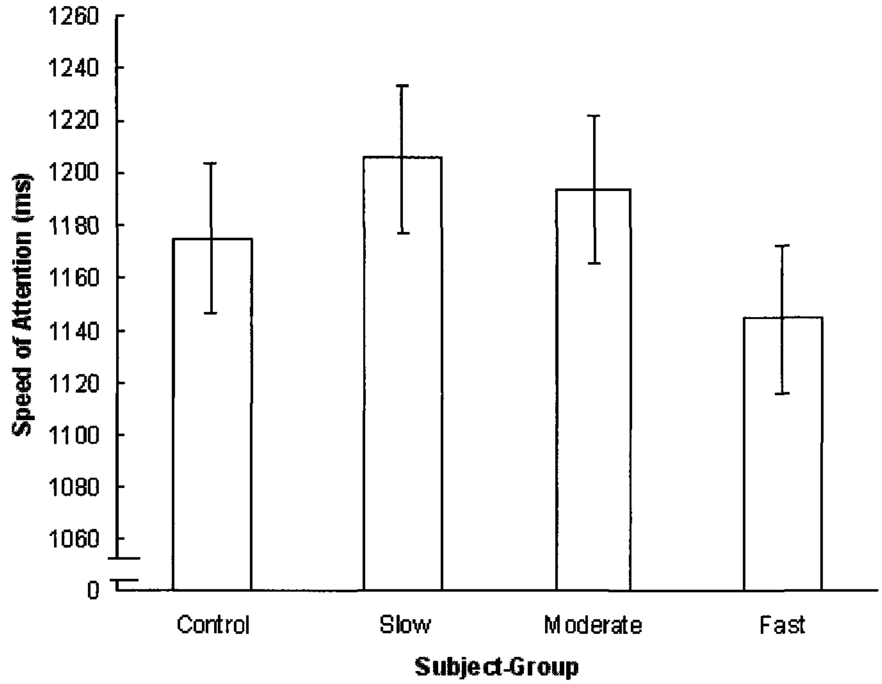

Figure 17. Speed of attention performance on the CDR for each condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

As the figure shows, the fastest responses were in the fast-tempo subject-group. The moderate condition had the second slowest performance and the slowest performance in the slow condition.

An exploration of the data showed no outliers. Despite the apparent large differences between the subject-groups, the ANOVA did not yield a significant difference for speed of attention, $F(3, 58) = .830$, $p = .483$, $\eta_p^2 = .041$.

The results for the accuracy of attention measure are shown for each condition in Figure 18.

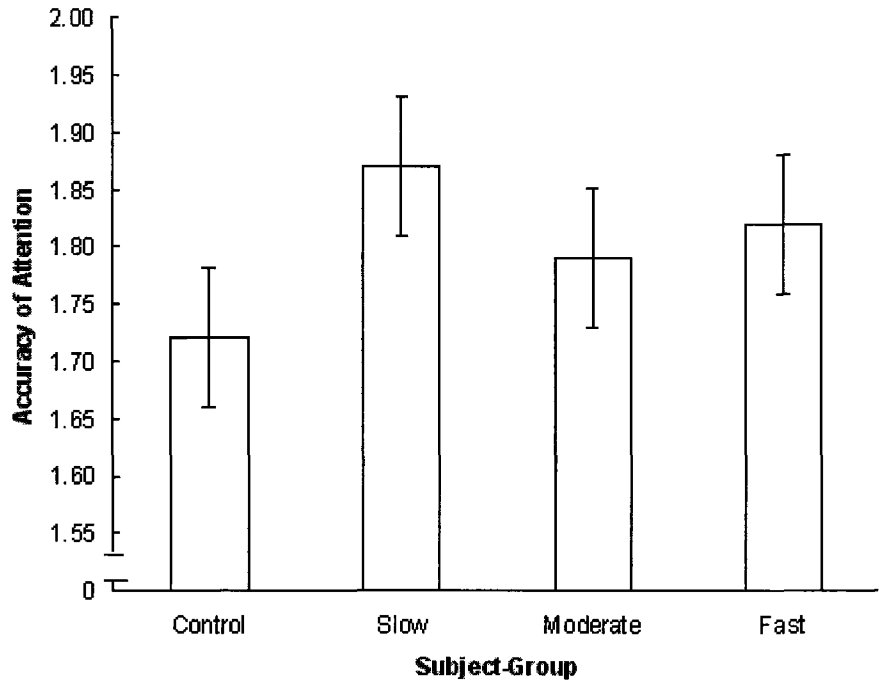

Figure 18. Accuracy of attention performance on the CDR for each condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

As the figure shows, accuracy of attention was lowest in the control subject-group and highest in the slow-tempo subject-group, with the two other groups falling between these two extremes.

An exploration of the data showed six outliers (cases 2, 3, 6, 17, 23, 30). These participants were all over four standard deviations below their group means. As with experiment 1, there was no way to control for participants' cognitive abilities. As such, these outliers were removed before the ANOVA was conducted. The ANOVA showed that there was no significant differences between any of the groups on accuracy of attention, $F(3, 52) = .972$, $p = .413$, $\eta_p^2 = .053$. The findings for speed of attention and accuracy attention show that there were no significant differences between performance on the monotonous tasks of the CDR between subject-groups.

CDR Demanding-Task Performance

To test Hypotheses 6, three univariate ANOVA's with condition as the independent variable (Control, Slow, Moderate, Fast) and performance on the CDR as the dependent variable was conducted, for the speed of memory, secondary memory and working memory. The results for the speed of memory measure are shown for each condition in Figure 19.

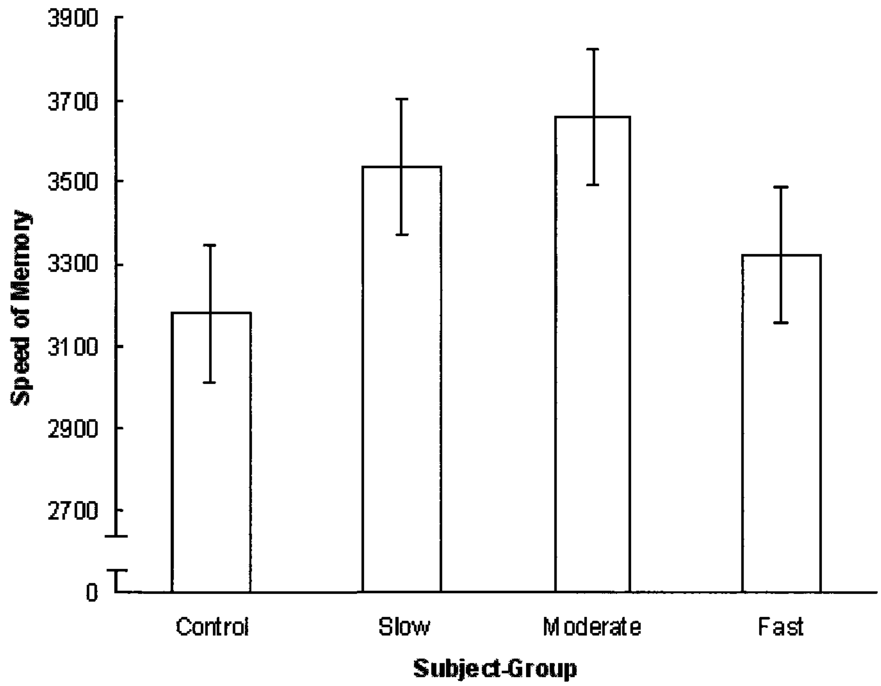

Figure 19. Speed of memory performance on the CDR for each condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

As the figure shows, the shortest response times were in the control subject-group, followed by participants in the fast-tempo subject-group. Participants in the moderate and the slow-tempo conditions took longest.

Exploration of the data showed no outliers. The ANOVA yielded no significant difference between the subject-groups on the speed of memory, $F(3, 58) = 1.707$, $p = .170$, $\eta_p^2 = .081$.

The results for the quality of secondary memory are shown for each condition in Figure 20.

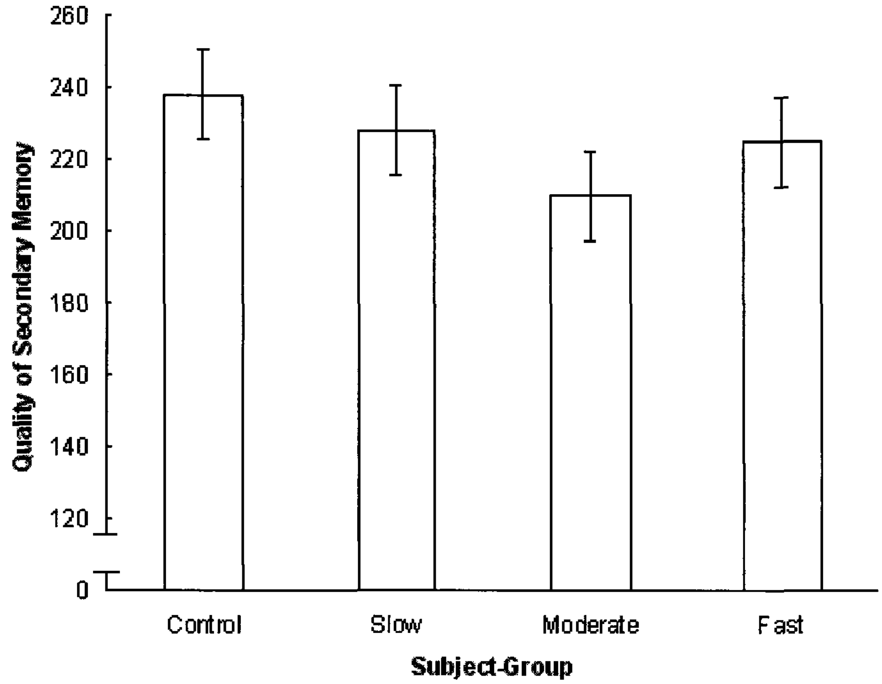

Figure 20. Quality of secondary memory on the CDR for each condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

As the figure shows, participants in the control condition performed slightly better than participants in the other subject-groups. An exploration of the data showed no outliers. The ANOVA yielded no significant differences between the subject-groups on quality of secondary memory, $F(3, 58) = .938$, $p = .428$, $\eta_p^2 = .046$.

The final demanding task measure was the quality of working memory, shown in Figure 21 below.

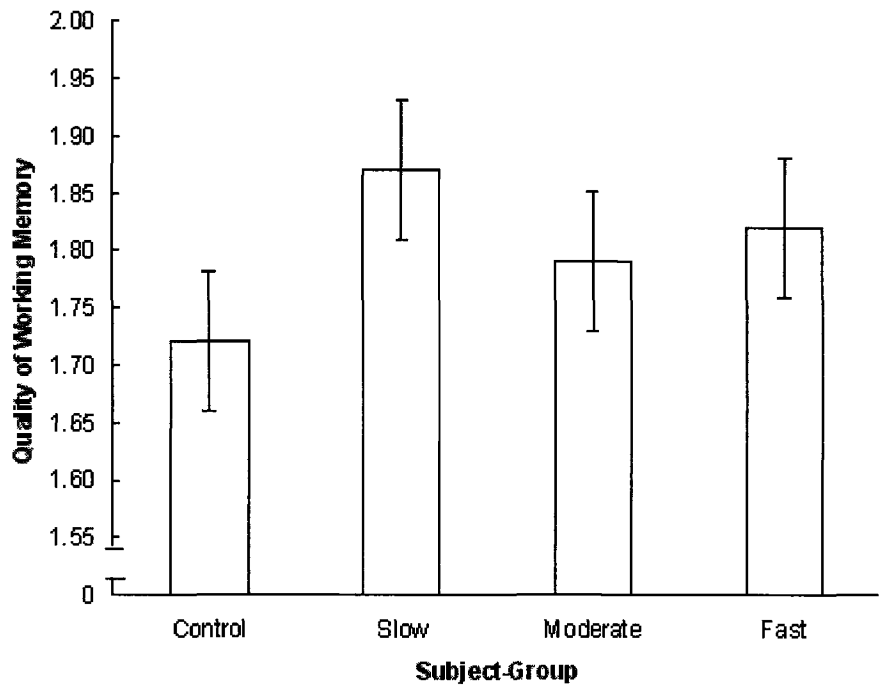

Figure 21. Quality of working memory on the CDR for each condition (Control, Slow, Moderate, Fast). The error bars indicate the standard deviation.

As the figure shows, participants in the slow-tempo subject-group performed best and the control group worst, with the other two falling between these extremes.

An exploration of the data showed six outliers (cases 2, 3, 6, 17, 23, 30), each of which was over four standard deviations above the means of their groups. These four cases were removed. The ANOVA revealed no significant differences between the subject-groups on quality of working memory, $F(3, 52) = .972$, $p = .413$, $\eta_p^2 = .050$. These three findings taken together, suggest that there was no significant difference between performance on the demanding tasks between subject groups. This finding therefore refutes Hypothesis 6.

Post-hoc analyses. Following the hypothesis testing, a series of correlations were conducted to identify any relationships with performance on the CDR. These correlations are presented in table 4 below.

Table 4

Correlations with CDR Performance

	Music Rating	POMS V-After Stimuli	POMS V- After Task	Beta Amplitude Stimuli	Task HR
Speed of Attention	-0.029	-0.218	-0.082	0.262	0.031
Accuracy of Attention	0.141	-0.111	-0.141	-0.225	**-.441****
Speed of Memory	0.117	-0.042	-0.002	**.412****	0.007
Quality of Secondary Memory	0.102	0.026	0.072	-0.232	-0.091
Quality of Working Memory	-0.225	0.058	**.266***	-0.138	0.073

Note: **p* = .05, ***p* = .01

There were no significant correlations between performance and music ratings. Thus, there was no relationship between the two on any of the cognitive tasks. There was also no relationship between subjectively assessed arousal, as measured by the POMS V, following stimuli exposure and performance on the cognitive tasks. However, self-reported arousal reported after the task did correlate positively with performance on the quality of memory sub-scale of the CDR. As for the physiological measures, the only significant correlations were a positive relationship between beta amplitude during stimuli and speed of memory; a negative relationship was uncovered between HR during the task and speed of memory performance. The implications of these relationships will be addressed in the discussion section.

To determine the effect of altering the tempo of the music on participants' ratings of the pleasantness of the stimuli, a univariate one-way ANOVA was conducted. The results are shown in Figure 22.

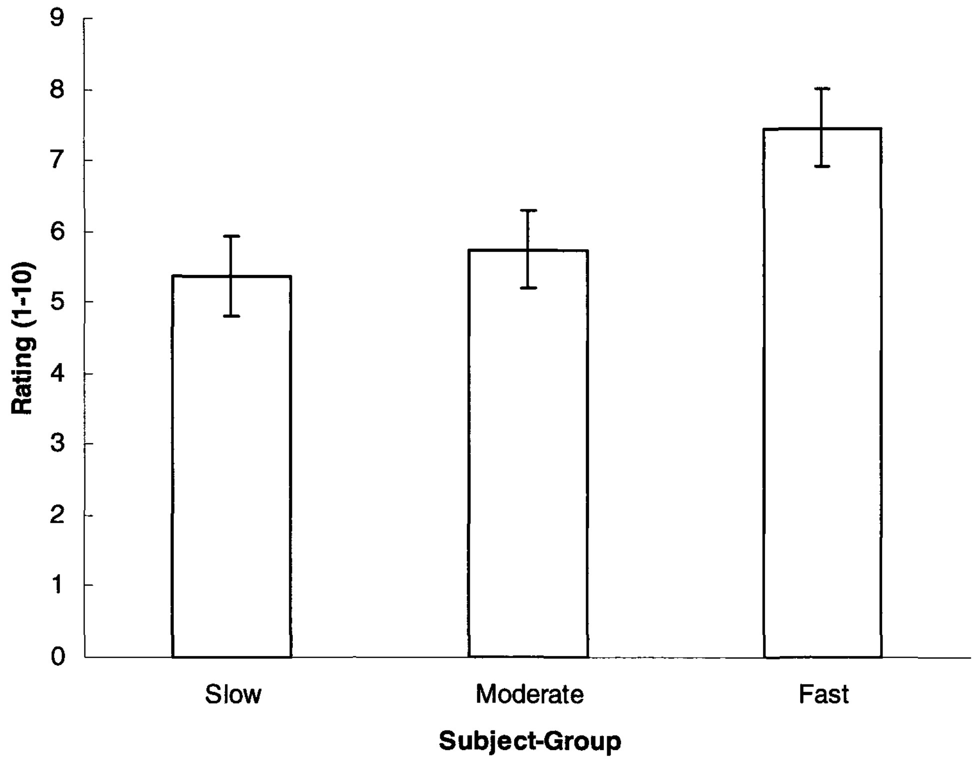

Figure 22. Ratings of the music compared for each of the music subject-groups. The error bars indicate the standard deviation.

The ANOVA showed that music ratings differed significantly between the three music subject-groups, $F\ (2, 47) = 3.99$, $p = .026$, $\eta_p^2 = .153$. A Bonferroni correction revealed that the fast-tempo conditions ratings were significantly higher than those of the slow- and the moderate-tempo group (both $p < .05$). There was no significant difference between the ratings in the slow group and the moderate group. This finding suggests that participants' found the fast music more pleasant than both the moderate and the slow version of the music.

Discussion

The purpose of Experiment 2 was to test the specificity of the Mozart Effect. Rauscher et al.'s (1995) proposed that, due to the underlying neurological nature of the Mozart Effect, it should only be observable with spatial-temporal tasks like the PFC task. As the CDR is a highly sensitive cognitive test battery covering many facets of cognition, it was expected that any cognitive enhancement induced by music listening would be evident in participants' performance. Furthermore it was expected that performance would differ by variations in task demands. Specifically, the Yerkes-Dobson law (Anderson, 1990) would predict that enhanced arousal elicited by listening to faster music should enhance performance on monotonous tasks and reduce performance on demanding tasks. The results, however, showed no differences in performance between any of the subject-groups. This finding appears to support the specificity of the Mozart Effect and refutes Hypotheses 5 and 6.

It is possible, however, that the individual differences within the groups were too large to uncover any between-group differences. If that were the case, testing a much larger sample of participants should yield larger between-group differences. Many Mozart Effect studies and studies utilizing the CDR use repeated measure designs. In the present between-subject design, adopted to avoid carry-over effects, participants' pre-experimental differences in cognitive ability could have overshadowed any potential influence attributable to the music. However, recall that Husain, et al.'s (2002) study, using the same music and a between-subject design, found measurable differences in PFC task performance. As with Experiment 1, no differences were found between subject-groups for physiological arousal or for self-report arousal. Apparently, the music did not impact participants' arousal significantly. The changes in arousal measures over the course of the experiment are difficult to explain but may be related to the nature of the arousal measures. The GSR data showed that, on average, participants' GSR decreased from its baseline level during the stimuli exposure only to increase above baseline while participants were completing the CDR. As GSR is a stress measure, one would expect that stress levels should decrease while listening to music or sitting in silence for ten minutes, and that they would increase while performing the CDR tasks. The POMS V subjective reports of arousal appeared to gradually decrease over the course of the experiment from baseline measures to the measure taken following stimuli exposure and again after the CDR. The POMS V is said to identify participants' overall fatigue (McNair, Lorr, & Doppleman, 1992). It is difficult to reconcile increasing fatigue with increasing stress levels as indicated by the GSR measures. It is noteworthy that participants who reported higher subjective arousal following the task also performed faster according to the speed of memory measure. However, as this measure was not influenced by the music listening, it provides no evidence for the Mozart Effect.

The average HR measure failed to reach a level of statistical significance between the various subject-groups. A larger sample size and more precise measure of HR may have reduced or eliminated the effects of large individual differences. The observation that HR increased significantly during the completion of the CDR tasks suggests that the tasks, and not the speed of music, induced increased physiological arousal.

The negative correlation between HR during the CDR and performance on the Accuracy of Attention subscale is interesting, as it was expected that performance on that task would improve with higher arousal, that is, with higher HR. These simple-reaction time tasks are quite monotonous, suggesting that that higher arousal would enhance performance, which was not borne out by the results. It is possible, however, that, as these tasks are time-sensitive, they may be more demanding than anticipated, resulting in poorer performance instead. However, as this evidence came from a correlation, it is also possible that those participants who were struggling with the task experienced higher arousal.

It was expected that, as within-group variability was determined with the baseline measures, differences between groups would be easily identified. However, no such differences were found on any of the arousal measures, contrary to the predictions of Hypotheses 1 and 2.

The EEG data were particularly problematic because of the need to remove so many cases, which rendered the findings unreliable. As the EEG equipment only recorded from a single sensor, it was almost impossible to derive conclusive evidence of changes to cortical arousal. Future studies utilizing high fidelity EEG will be required to conclusively rule out the neuro-priming model of the Mozart Effect.

Consistent with other measures reviewed thus far, the subjective mood reports also yielded no significant differences between the subject-groups. However, contrary to the arousal measures, they also failed to indicate differences between the times of measurement. This finding refutes hypothesis 4 stating that the participants in the music groups would experience enhanced mood when compared to the control subject-group. However, it will be recalled that the TMD score is a measure of "mood disturbance" or negative affect. Removing negative affect may not be the same as enhancing positive affect. Future studies should use a measure of positive affect as well as the POMS.

No correlation was found in the post-hoc analysis between music ratings and any of the facets of the CDR. Interestingly, a comparison of the music groups found that participants in the fast-tempo condition rated the music significantly higher than the other groups. However, these higher ratings were not reflected in their performance. Unlike the results obtained in Experiment 1, this finding failed to support the valence model, according to which higher ratings of music stimuli should predict performance.

In summary Experiment 2 found that listening to Mozart before conducting the CDR tasks did not enhance performance, and nor did it cause any changes in mood, arousal or cortical arousal. Participants' subjective ratings of pleasantness of the music did not influence performance either.

General Discussion

The purpose of this thesis was to examine the underlying causal mechanisms of the Mozart Effect. Four theoretical models seeking to explain the Mozart effect were explored: the neuro-priming model, the arousal model, the mood model and the valence model. The two experiments also attempted to examine the spatial-temporal specificity of the Mozart Effect, and the role tempo may play in the Mozart Effect. The following section outlines the salient findings from the above experiments that relate specifically to the theoretical models explored. A discussion of the theoretical implications of the study is then presented followed by a discussion of limitations and future research, culminating in an overall conclusion.

Summary of Main Findings

The central findings of this research concern the performance measures. Contrary to the hypotheses, neither of the two experiments demonstrated performance enhancements elicited by music listening. Indeed, results from Experiment 1 actually showed performance decrement in the slow- and fast-tempo subject-groups compared with the moderate-tempo and control subject-groups. Results also revealed no differences between the subject-groups on self-report arousal, physiological arousal or cortical arousal. Taken together, these findings suggest that music listening had no effect on arousal. There were, however, correlations between performance and arousal measures, suggesting that arousal may predict performance in some circumstances. Specifically, in Experiment 1 the correlation between cortical arousal during the stimuli and performance on the PFC task was significant. In Experiment 2, subjective arousal following the task was positively correlated with speed of memory, and HR was negatively correlated with accuracy of attention. Moreover, in both experiments ratings of the pleasantness of the music did differ between the subject-groups. Ratings in the fast- and slow-tempo subject-groups were lower than ratings in the moderate-tempo group in Experiment 1. By contrast, in Experiment 2 and contrary to expectations, ratings were higher in the fast-tempo group than in the three other subject-groups. As the music and the procedure in the two experiments were identical except for the task, it is reasonable to argue that the task itself may have influenced participants' rating of pleasantness.

Theoretical Implications

Since Experiment 1 utilized the same music and PFC tasks as Husain and his colleagues (2002), replication of performance enhancement was expected but did not occur. This could be attributed to subtle differences in participants' music listening experience. For example, the use of speakers rather than headphones could have reduced attention to the stimulus. If this is true, the Mozart Effect may not be very salient or robust, suggesting that the effect is too small too have any practical applications.

The relationship between cortical activity of both alpha and beta waves during priming and performance on the PFC task provides support for the neuro-priming model. The absence of any traceable effects of cortical priming on the CDR in Experiment 2 supports the specificity of the Mozart Effect to spatial-temporal tasks, which is further evidence for the neuro-priming model. As stated above, it is possible that the way in which participants listened to the music reduced its influence on their neuro-priming. Future research utilizing higher fidelity measures of cortical arousal while listening to the music in a more isolated manner will be required to determine the extent to which neuro-priming influences the Mozart Effect.

Another possible explanation for the lack of a measurable Mozart Effect, is that participants were asked to complete a mood and arousal questionnaire between music-listening and performance of the task. This was done to ensure that any differences in arousal or mood that occurred as a result of listening to the music would be accounted for. As no differences appeared between the subject-groups, it does not seem to be the case that changes in arousal or mood were elicited by the music listening. Likewise, there were no subject-group differences with respect to physiological arousal, even though HR and GSR were recorded simultaneously throughout the entire experiment. Taken together, these findings do not support the arousal- or the mood-model of the Mozart Effect.

Since changes in tempo did not affect any of the three measures of arousal, this study appears to contradict past research suggesting that increased tempo leads to increased arousal (Husain, Thompson & Schellenberg, 2002). Performance differences were, however, found on in the fast- and slow-tempo subject-groups in Experiment 1, which suggests that tempo did influence performance. It is important to note that the slow-tempo music in this study was slightly slower than the slow version, and the fast-tempo music was slightly faster than the fast music in Husain et al.'s study. This was done in an effort to determine if the effect of tempo on arousal could be enhanced by increasing the tempo differences. As the ratings of pleasantness of the fast and slow tempo were lower than the moderate-tempo music in Experiment 1, it is possible that the tempo was too extreme to remain pleasant and therefore it was unable to influence arousal.

The valence model of the Mozart effect was supported, as lower ratings of the pleasantness of the fast- and slow-tempo music are consistent with the lower performance in these two groups as found in Nantaism and Schellenburg's (1999) study. This did not occur in Experiment 2. Since participants rated the fast music the highest in Experiment 2, it suggests that the CDR influenced the ratings. As the CDR in Experiment 2 took much longer than the PFC task in Experiment 1, it is possible that there was a fatigue affect. Thus, if participants in Experiment 2 were more tired than participants in Experiment 1 by the time they rated the pleasantness of the music, one could argue that, at a lower state of arousal, the fast energetic music could have been more appealing than was the case in Experiment 1.

Although some support was provided for the valence model in the present research, it still does not explain the underlying mechanism of the Mozart Effect. The question of how musical stimuli may influence performance on the PFC task remains open. As neuro-priming was also partially supported, it is possible that stimuli deemed pleasant enhance cortical activity leading to superior performance. Future research will be required to test this theory.

Limitations and Future Work

Due to large individual differences, the relatively small sample size in the present research limited the statistical power. This may in turn have resulted in type II errors on a number of statistical tests. Although the hypothesized relationships between the subject-groups were present when examined as general trends (i.e., by examining the means in the results), they did not quite reach a level of statistical significance. Further, the need to remove a number of outliers compounded the impact of the small sample size. However, despite being small, the sample size in this study was considerably larger than in Husain, Thompson & Schellenberg's (2002) study in which only eight participants were assigned to each group. Yet, their study did yield significant between-group results. Therefore, the inability of the present performance data to reach significance cannot be attributed entirely to sample size. However, the method used in this research differed in several ways from that of Husain et al. (2002), which could explain the differences in the two sets of findings. As mentioned earlier, participants in this study listened to the music on speakers rather than via headphones, which may have reduced attention to the stimuli and thus reduced the impact of the music. Headphones were not feasible in the present study however, as participants were wearing clips on their ears for the EEG recording. Future studies utilizing EEG caps that do not require ear clips could be used with earphones to overcome these differences. In addition, the use of physiological measurement devices may have distracted participants further, thus changing the procedure and the participants' experience compared with that of Husain, Thompson & Schellenberg (2002). Likewise, the requirement to complete the mood and arousal questionnaire between the music listening and the task in the current study may have interfered with the Mozart Effect. Future studies with varying amounts of delay time between music exposure and task performance could help determine how long the influence of the Mozart Effect lasts. A shorter mood and arousal measure would also reduce the time between music exposure and the task, potentially increasing the likelihood of the occurrence of the Mozart Effect. Finally, Husain, Thompson & Schellenberg's (2002) participants listened to the music in a sound-attenuated room. As the experiment room in this study was not sound proof, sounds from outside the room could have distracted the participants. Future Mozart Effect studies should all be conducted in sound proof rooms.

This research has highlighted the need for more studies of the Mozart Effect using sophisticated cortical arousal measures. Moreover, this study suggests that multi-node EEG studies of the Mozart Effect will be crucial for determining the neurological activity that is related to the Mozart Effect. It is also clear that more research regarding the valence model of the Mozart Effect is required. If participants were able to listen to music of their choosing rather than only Mozart's Sonata, it is possible that the cognitive enhancement would be more pronounced and may carry over into other cognitive domains. If personal selections were compared to music traditionally used in Mozart Effect studies, differences in the tempo, mode and genre could be recorded. If these factors influence performance they may be more salient when they occur naturally in other music. It is possible that changes to the tempo of a musical piece intended to be played at a particular speed made it sound too artificial to still be pleasing. By using songs that are composed at different speeds, this limitation could be overcome.

Studies examining the influence of environmental factors on the Mozart Effect, like listening with headphones or the presence of another person in the room, may shed more light on why replication of the Mozart Effect has been inconsistent throughout the literature.

Conclusion

Although the Mozart Effect was not replicated in this study, it still shed some light on the nature of the effect and the influence of music on arousal. It appears that music played at different speeds may influence performance on PFC tasks, as also reflected in the pleasantness ratings in Experiment 1. Results of Experiment 1 also suggested that unenjoyable music, as noted in the pleasantness ratings, hindered performance in the fast- and slow-tempo groups. This research supports the specificity of the Mozart Effect to spatial temporal tasks, as the listening to music appeared to have no effect on any of the cognitive domains covered by the CDR tasks. Further, the research supported the potential for neuro-priming enhancing cognitive functioning. It is possible that a positive relationship exists between listening to a pleasant stimulus and neuro-priming. Future research will be required to determine not only why the Mozart Effect occurs, but why it occurs inconsistently.

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Appendix A

Informed Consent Form

The purpose of an informed consent is to ensure that you understand the purpose of the study and the nature of your involvement. The informed consent must provide sufficient information such that you have the opportunity to determine whether you wish to participate.

Research personnel:

Principal investigator: Patrick Noonan

Faculty advisor: Dr. Gitte Lindgaard (613) 520-2600 x 2255

Purpose: To assist in the evaluation of some new physiological arousal measures and cognitive tests in responses to music.

Requirements: The Experiment will take approximately 1 hour. You will be asked to complete a survey with questions asking about your background (e.g., age), their mood, their personality and various cognitive measures. During the course of the study participants' physiological activity will be recorded using several non-invasive sensors attached to the body. In compensation for taking part in this study, you will be awarded 1.0% course credit or $10.

Potential Risk/Discomfort: You are not expected to be exposed to any potential psychological or physical risks. Slight discomfort may arise from the sensors, but this happens very rarely, and there is no risk of permanent physical or psychological harm.

Anonymity/confidentiality: All the information you provide will be kept anonymous and confidential. To ensure anonymity, all data will be coded and confidentiality will be assured by restricting data access to only research personnel directly involved with this experiment.

Right to Withdraw: You have the right to refuse to answer any question /or to withdraw from this study at any time without explanation and for any reason. If you choose to do so, you will still be compensated.

Concerns: If you have any ethical concerns about how this study was conducted, you may contact Dr. Monique Sénéchal (Chair of the Carleton University Ethics Committee for Psychological Research, 613-520-2600 x 1155). If you have any other concerns about this study, you may contact Dr. Janet Mantler (Chair of the Department of Psychology, 613-520-2600 x 4173)

Signatures: My signature indicates that I understand the above description of the study and agree to participate in this study.

(Signature)	(Print Name)	(D/M/Y)
(Witness Signature)	(Witness Print Name)	(D/M/Y)

Appendix B

Debriefing

Thank you for participating in this study. You were a participant in an experiment conducted by Patrick Noonan under the supervision of his advisor Dr. Gitte Lindgaard of the Department of Psychology at Carleton University. There were four conditions in this experimental: control, slow music, moderate music and fast music. You were randomly assigned to one of these groups and, based on that group, exposed to fast music, moderately paced music, slow music or no music before your testing.

The Intention of this Research:

The study you just participated in is designed to examine the relationship between music and cognitive performance. Previous research has uncovered a link between listening to music and performance on some cognitive tasks. This study was designed to tease apart the underlying factors that contribute to this association and determine the underlying cause of this connection.

Implications of this Research:

Solidifying the link between music and performance could have implications for both education and workplace productivity. By extending our understanding of the link between music and cognition, music therapies for individuals with learning impairments can be adjusted to maximize their productivity.

If you have any questions or comments about this research, please feel free to contact the principal investigator Patrick Noonan (pnoonan2@connect.carleton.ca). You can also contact the faculty advisor, Dr. Gitte Lindgaard: (613) 520-2600 x 2255. For any other concerns, please contact Dr. Monique Sénéchal (Chair of the Carleton University Ethics Committee for Psychological Research, 613-520-2600 x 1155) or Dr. Janet Mantler (Chair, Carleton University Department of Psychology, 613-520-2600 x 4173).

If you are interested in learning more on the link between music and cognition see:

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.

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

395, 611.

Appendix C

Pre-Test Questionnaire

Subject Number:___

Please complete the following:

1. Gender:

☐ Male

☐ Female

2. Age: _______

3. Are you fluent in English?

☐ Yes

☐ No

4. Do you have any hearing impairments?

☐ Yes

☐ No

Appendix D

Post-Test Questionnaire

Please complete the following:

1. Please rate how enjoyable you found the musical piece you listened to from 1 to 10. A score of '1' means highly unpleasant, and a score of 10 means extremely pleasant: ____

2. Did you recognize the musical piece you were exposed to? YES/NO

if you answered yes to question 2, please state the name of the composer musical piece:

If you know the details of the piece, please write it here:

____________ __________________

3. How strong is your musical background (e.g. musician, avid music listener, etc.)? Please state any prior musical training, education or experience you might have:

____

4. On a scale of 1 to 10 please state how well you feel you performed on the task. (1 = completely incorrect; 10 = perfect): ______

5. In your leisure time, do you listen to music? YES/NO

If so what style of music do you usually listen to?

____

6. When you study, do you listen to music? YES/NO

If so please state what kind of music you listen to:

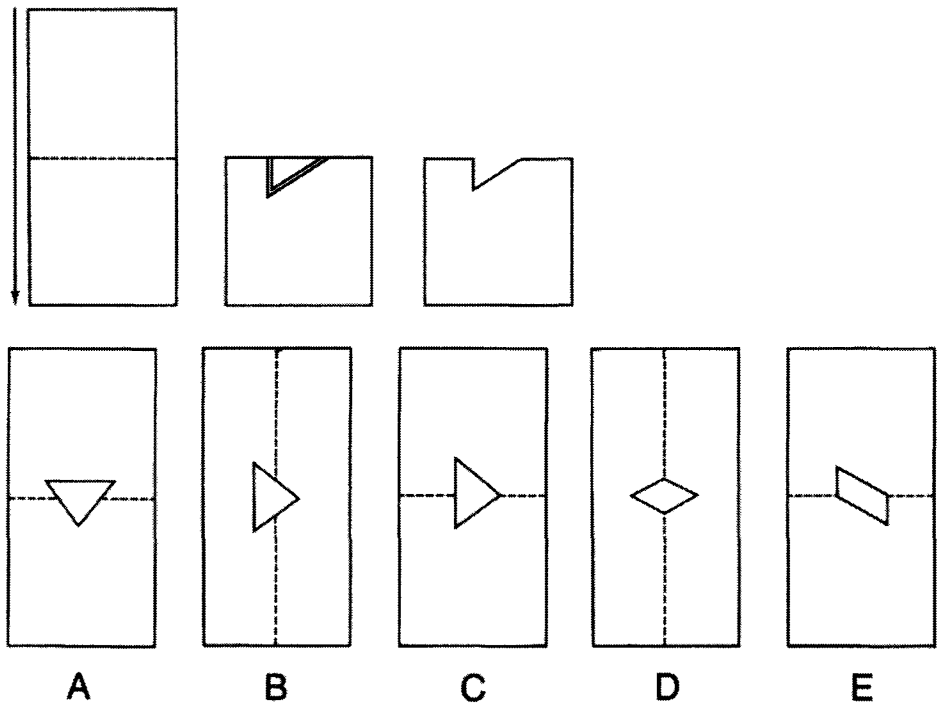
____

Approximately what percentage of your studying involves listening to music:

____

Appendix E

Example PF&C Item



When the item above is unfolded, which item below will it best resemble?

Appendix F

CDR System Task Instructions

cognitive drug research

Task Instructions for the CDR System

For all tasks, please ensure that the Participant responds as quickly as they can.

Each task is initiated by the administrator pressing the <Enter> ↵ key once he/she is sure the Participant understands what to do. For the Spatial and Numeric Working Memory tasks, the space bar is used to redisplay the target stimuli, if necessary. Prior to each task (excepting the word and picture presentations) the administrator should always make sure that the Participant's fingers are resting gently on the appropriate response buttons so that the speed of the response can be precisely measured.

The CDR System Task Battery

Word Presentation and Immediate Word Recall:

Administrator: Please read the following instructions to the participant.

> *15 words will appear in the middle of the screen, one at a time. Try to remember as many as you can. After the last word has been shown, some instructions will appear on the screen informing you that you have 60 seconds to write down as many of the words as you can remember, in any order. Near the end of the test session, you will again be asked to recall as many of the words as you can remember, but without seeing them again. So it is important to get the words fixed firmly in your mind. Administrator: Once you are sure the participant understands the task, press the 'Enter' key to initiate the task.*

Picture Presentation:

Administrator: Read the following instructions to the participant:

> *This task measures your memory. A series of pictures will appear on the screen, one at a time. Please look at each picture carefully as it appears and try to remember as many as you can.*

Administrator: Once you are sure the participant understands the task, press the <Enter> key to initiate the task.

Simple Reaction Time:

Administrator: Read the following instructions to the Participant:

> *This task measures your reaction time. You only need to use the YES button, so rest your finger gently on the YES button to get the fastest reaction time possible. The word YES will appear in the middle of the screen at varying intervals. Every time you see the word YES, press the YES button as quickly as you can.*

Administrator: Once you are sure the Participant understands the task, press the <Enter> key to initiate the task.

Digit Vigilance:

Administrator: Read the following instructions to the Participant:

> *This task measures how well you can hold your concentration on a series of rapidly changing digits. You only need to use the YES button, so rest your finger gently on the YES button to get the fastest reaction time possible. A single digit will appear on the right-hand side of the screen and remain there.*

Administrator: Press the <Enter> key to initiate this digit.

> *A continuous series of digits will appear in the middle of the screen. Every time the digit in the middle is the same as the digit on the right, press the YES button as quickly as you can, even if the digit in the middle has disappeared.*

Administrator: Once you are sure the Participant understands the task, press the <Enter> key to initiate the task.

Choice Reaction Time:

Administrator: Read the following instructions to the Participant:

> *This task measures your reaction time. You will need to use both the YES and the NO buttons, so rest your fingers gently on the YES and NO buttons so you can get the fastest reaction time possible. Either the word YES or the word NO will appear in the middle of the screen at varying intervals. Every time you see the word YES, press the YES button as quickly as you can, and every time you see the word NO, press the NO button as quickly as you can.*

Administrator: Once you are sure the Participant understands the task, press the <Enter> key to initiate the task.

Spatial Working Memory:

Administrator: Read the following instructions to the Participant:

This task measures how well you can remember where something was on the screen. You will see a house with 9 windows, 4 of the windows will be lit and 5 will be dark. You need to remember the position of the lit windows.

Administrator: Press the <Enter> key for the house to be shown on the screen. The house will remain on the screen for 10 seconds. The screen will then go blank. Now show the laminated diagram of the house to the Participant with the following instruction:

Can you point to the windows that were lit?

Administrator: If the Participant cannot point to the windows that were lit, press the 'space bar' to redisplay the house. The house can be redisplayed up to 2 times if required. Once you are sure that the Participant has remembered the position of the lit windows, continue with the task instructions:

The house will now appear again and again, but with only one window lit. For each house, if the window that is lit was also lit in the original house, press the YES button as quickly as you can, otherwise press the NO button as quickly as you can.

Administrator: Once you are sure the Participant understands the task, press the <Enter> key to initiate the task.

Numeric Working Memory:

Administrator: Read the following instructions to the Participant:

This task measures how well you can hold a short series of digits in your memory and how quickly you can recognize them. It is similar to remembering a telephone number for a short while. 5 digits will appear on the screen one at a time for you to remember. Say each digit aloud to help you remember it.

Administrator: Press the <Enter> key for the digits to be shown on the screen. After the digits have been shown, ask the Participant to repeat them back to ensure they remember them. If the Participant cannot remember the digits, press the 'space bar' to redisplay the digits. The digits can be redisplayed up to 2 times if required. Once you are sure that the Participant has remembered the digits, continue with the task instructions:

Now for each digit that appears on the screen, you should press the 'YES' button as quickly as you can if it is one of the digits you are remembering, or the 'NO' button if it is any other digit.

Administrator: Once you are sure the Participant understands the task and remembers the 5 digits, press the <Enter> key to initiate the next stage of the task.

Delayed Word Recall:

Administrator: Read the following instructions to the participant:

Now we are going back to the series of words you saw at the beginning of this testing session. You have 60 seconds to write down as many of the words that you can still remember. You can write down the same words that you wrote in the immediate word recall task, as well as any others you think were on the list.

Administrator: Once you are sure that the participant understands the instructions, press the <Enter> key to initiate the test

Delayed Word Recognition:

Administrator: Read the following instructions to the participant:

You will again see the series of words you saw at the beginning of the testing session one at a time on the screen. For each word, if you recognize it as being one of the words you saw at the beginning of the testing session, you should press the 'YES' button as quickly as you can, but if you do not recognize the word, you should press the 'NO' button as quickly as you can.

Administrator: Once you are sure the participant understands the task, press the <Enter> key to initiate the task.

Picture Recognition:

Administrator: Read the following instructions to the participant:

You will again see the pictures you saw at the beginning of the testing session mixed with similar pictures which will appear one at a time on the screen. For each picture, if you recognize it as 1 of those you saw at the beginning of the testing session, you should press the 'YES' button as quickly as you can, but if it is not one that you recognize you should press the 'NO' button as quickly as you can.

Administrator: Once you are sure the participant understands the task, press the <Enter> key to initiate the task.

Appendix G

Consent to Use Data

I, ______________________________(*full name*), understand now that the purpose of the experiment was to learn more about the effects of music on arousal and cognitive performance rather than to assist in the evaluation of cognitive measures. I also understand that it could have biased my performance if I had been informed about this in advance, which would have defeated the purpose of the experiment.

Now that I am aware of the real purpose of the experiment, I herewith give the researchers permission to use the data I have provided in this session.

Signed: __________________________________ Date: _______________

Witness: __________________________________ Date: _______________

Appendix H

Experimental Instructions

The purpose of this study is to help us understand the relationship between physiological measures and performance on various cognitive tasks. You will be asked to fill out a series of questionnaires and complete some cognitive tasks. I will be measuring your heart rate, galvanic skin response and brain activity. As these measurements are highly sensitive, I ask that you avoid large movements during the experiment. All your responses will be kept anonymous. Please complete each of the tasks to the best of your ability. Do you have any questions before we begin?