THE EFFECTS OF SOUND TYPES AND VOLUMES ON SIMULATED DRIVING PERFORMANCE, SIMPLE VIGILANCE AND HEART RATE

BRIAN HARRY DALTON

The Effects of Sound Types and Volumes on Simulated Driving Performance, Simple Vigilance and Heart Rate

By

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ABSTRACT

The purpose of the current thesis was twofold: 1) to review the literature while linking the effects of background noise, music and driving performance and 2) to determine the effects of sound type and volume and gender on driving-related activities. Driving involves great requirements for attention and concentration while performing concurrent tasks (i.e. listening to music, conversing). It has been previously demonstrated that loud industrial noise detrimentally affects human performance. Meanwhile, there exist inconsistent results on music and performance. Background hard rock music has been shown to have both facilitating as well as distracting characteristics. In the present study, it was demonstrated that loud sound volume (94 dB (A)) adversely affects simple vigilance, as well as simulated driving (SimD) performance. Hard rock music has a greater detrimental effect on male reaction times (RT) compared to females. Also, hard rock music was demonstrated to facilitate non-conscious perception performance, while increasing accommodation heart rate (HR). In conclusion, both genders should avoid loud noise or music when driving while males should be especially aware of the detrimental effects of hard rock music on their driving performance.

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THESIS STRUCTURE

The current thesis was prepared utilizing a non-traditional, manuscript format. It has been written as two manuscripts, which are formatted for publication.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVITIONS

ANOVA - Analysis of Variance

bpm – Beats per Minute

CNS – Central Nervous System

dB (A) – Decibels

deg – Degrees

DPS - Direct Parameter Specification

HR - Heart Rate

ms - Milliseconds

MT – Movement Time

NIOSH - National Institute for Occupational Safety and Health

RT - Reaction Time

s - Seconds

SD – Standard Deviation

SimD - Simulated Driving

SOA - Stimulus Onset Asynchrony

1. INTRODUCTION

Background of Study

Driving an automobile is a daily activity that involves a multitude of tasks as well as distractions. Driving tasks include concentration, attention, vehicular control, and reaction and movement time. However, the numerous distractors (i.e. conversing on a mobile phone, listening to music, adjusting the radio, etc.) fight for the driver's attention while controlling an automobile. It seems that currently, driving while listening to music is extremely trendy. It has been stated that approximately 91% of musical exposure occurs while commuting in an automobile (Sloboda, 1999; Sloboda, O'Neil & Vivaldi, 2001), while rock music is the most popular (Oblad, 2000). Thus, it is wise to review the literature to develop an understanding of whether music, in particular hard rock music, affects driving performance.

Within previous research, music has been shown to be both facilitating and distracting towards human performance. Music may facilitate activities that require high levels of attention and concentration as a result of an arousing effect (Corhan & Gounard, 1976; Davies, Lang & Shackleton, 1973; Ferguson, Carbonneau & Chambliss, 1994; Fontaine & Schwalm, 1979; Matthews, Quinn & Mitchell, 1998). However, music may distract human performance during certain tasks (Crawford & Strapp, 1994; Etaugh & Michals, 1975; Fogelson, 1973; Kallinen, 2002). Music has even been shown to be as distracting as noise (Furnham & Strbac, 2002). Music affects human performance, but does it have an impact on driving performance?

Driving and background music were initially studied in the 1960s (Brown, 1965; Konz & McDougal, 1968). A pioneer study conducted by Brown (1965) compared the effects of background music, speech and silence during varying traffic conditions. It was reported that listening to music may lower emotional arousal under frustrating situations, such as heavy traffic congestion. Further, Brown (1965) postulated that background music may slightly benefit driver performance. However, the results of the early studies were unable to distinguish the findings on background music as having a positive or negative effect on vehicular control (Brown, 1965, Konz & McDougal, 1968).

Recent literature contains inconsistencies regarding the effect of background music on driving performance. Even though music has been shown to benefit driving-related tasks (Matthews et al., 1998), it may still be a major distraction to driving capabilities (Beh & Hirst, 1999; North & Hargreaves, 1999; Slawinski & MacNeil, 2002; Spinney, 1997). Furthermore, music of an arousing nature may deter driving performance as a result of the competition for limited processing space within the central nervous system (North & Hargreaves, 1999). Thus, it is important to study the effects of music on driving performance due to its overwhelming popularity and safety implications.

Purpose of Study

Driving involves a wide array of relevant tasks. However, there are numerous irrelevant activities, which may interfere with performance and vehicular control (Strayer & Drews, 2004). The purpose of the current thesis is to determine whether there is a difference between varying types and volumes of sound on driving-related tasks.

According to past research, the findings have been inconsistent. Music has the capability of being beneficial (Beh & Hirst, 1999; Matthews et al., 1998; Recarte & Nunes, 2000), as well as detrimental (Spinney, 1997) to driving performance. From the research, it seems that moderate volumes of background music exposure improves driving performance. For instance, Spinney (1997) stated that quieter volumes of music (55 dB (A)) offered the best driving conditions when compared to loud music (85 dB (A)) and silence. Further, others have shown that moderate levels of music improved awareness and performance (Turner, Fernandez & Nelson, 1996), while creating the safest driving conditions (Mathews et al., 1998).

Also, music is known to be stimulating (Bernardi, Porta & Sleight, 2006; Brodsky, 2002). Thus, one may postulate that loud hard rock music may lead to greater arousal, and even improve vehicular control by enhancing awareness and response time (Matthews et al., 1998). Nevertheless, Matthews & colleagues (1998) only studied loud volumes between 70-90 dB (A). This volume range may be somewhat lower than what is actually considered loud by today's younger population of drivers. Moderate volumes of music may indeed facilitate driving capabilities, while loud volumes may deter driver performance, thus these conditions require further investigation. The present thesis will study the effects of loud (94 dB (A)) and quiet (53 dB (A)) volumes and varying types of sound, to help clarify the inconsistencies.

Significance of Study

Driving is now an important as well as critical part of today's society. With an ever-growing population, and vehicles congesting our transit systems, there are more distractions than ever before (i.e. mobile cellular phones, radios, music, etc.). Further, its seems to be the trend for younger drivers to listen to loud volumes of hard rock music. Thus, the purpose of the current thesis seems to be a logical response to the current trend and growing driving population. By reviewing the literature and linking the effects of different types and volumes of sound to driving it may be possible to bring an awareness to the importance of considering what to listen to while driving in terms of safety and performance.

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2. LITERATURE REVIEW

MUSIC & NOISE: DOES BACKGROUND STIMULI AFFECT TASKS RELATED TO DRIVING PERFORMANCE?

Author: Brian Dalton
School of Human Kinetics and Recreation
Memorial University
St. John's NL A1C 5S7

Running Title: Effect of Music and Noise on Driving

Abstract

Driving is an integral part of today's society. It is now trendy for younger populations to listen to loud volumes of hard rock music while driving. Thus, the present article is a review of the literature to develop an understanding of the effects of differing types of sound on tasks related to driving performance. Noise has always existed and has been a nuisance throughout human history. It has been demonstrated that background noise may affect an individual's cognitive ability as well as simple vigilant performance. However, music may not be considered noise to the listener, but it may have the same distracting effects. The previous research conducted on driving and music has been equivocal in the presentation of results. Thus, future research is necessary to develop a true understanding of types of music on driving performance.

Introduction

In today's society, driving is a popular form of transportation. While driving many people like to listen to a local radio station or their favorite music collection. A driving situation is a perfect example in which a driver is required to have great concentration and situational awareness, while making attentitive decisions. It has been demonstrated that musical stimuli may facilitate one's performance during driving (Matthews, Quinn & Mitchell, 1998); however, despite these benefits, it may also be a distraction to a driver's attention and performance (Beh & Hirst, 1999; North & Hargreave, 1999). It has been shown that music is as distracting as noise when it comes to vigilant performance (Furnham & Strbac, 2002). Thus, in a society that is infested with the growing problem of environmental noise pollution, it is only logical to investigate the effects of yet another source of extraneous stimuli.

Noise

There are numerous distractions and stressors in the environment that are harmful to the human population. Environmental noise is one such factor that is detrimental to one's health. Historically, noise has been considered a nuisance in society and there are a vast amount of publications depicting the negative side effects of this extraneous, unwanted sound (Gibson, 1999; Kryter, 1994; Rabinowitz, 2005; Smith 1989; Welch & Welch, 1970). Despite the minor irritation of extraneous external stimuli, there are numerous acute and long-term detrimental effects in respect to noise intensities. Noise is a central factor in many problems stemming from numerous sources. Some effects are based on the type of sound exposure; whereas intensity or volume levels determine other effects.

Noise fills everywhere and everything and can be found throughout our modern world. Noise impacts human performance from vigilance to the ability to enjoy a well-rested sleep. Even though, noise is defined as an unwanted sound or sound that is unpleasant and may be annoying to the listener (Garcia, 2001b). Like other major disturbances in society, noise is capable of affecting one's health, lifestyle, and performance.

Noisy History

Noise nuisances are not a new creation of modern society. Noise always has been a part of the world. It existed in natural forms, from people yelling to the natural occurrences of storms, volcanic eruptions and earthquakes. Yet, it simply did not incorporate the magnitude of the sources or exposure that exists today. Environmental noise is now considered one of the greatest nuisances and pollutants in developed countries. It is even the number one complaint reported by Americans (Garcia, 2001b).

In the Roman era, noise had been documented as a disturbance in the classical writings of Latin/Spanish poets of Marcial and Pliny the elder. Marcial commented on the noisy characteristics of Ancient Rome. One of his writings protested that he was constantly disturbed from a midday slumber by the cries of nearby school children and the tone of their teacher. However, if it was not the childish cries, the tinkering of mechanics was a great disturbance. The pleas of beggars and the strokes of bankers counting their wealth in coins added to the noisy surroundings. From another perspective, Pliny the elder referenced noise control tactics during this time period. The poet had a constant problem with noise generated by his slaves or other outside sources. Thus, he had his bedroom constructed with double walls to ensure an undisturbed sleep during the night. Furthermore, Ancient Rome demonstrated the early rise of primitive governmental noise control. During the nighttime hours, traffic of carriages was forbidden, to protect the sleep patterns of the Roman citizens (Garcia, 2001b). Yet, noise production was actually quite tame in this era in comparison to future generations.

Noise production has increased with the increasing development in technology. A significant point in time was the evolution of the industrial era. The industrial revolution marked a downfall in the quiet serenity of the world, as it once was known. With the production of factories and the creation of larger urban centers, noise production began a steady rise in the populated environment. The industrial revolution seemed to spark a decline in the quality of the urban environment, in respect to acoustical conditions. Since this time, there has been a dramatic increase in noise pollution and the situation continues to worsen (Bronzaft, 2002; Garcia, 2001b). With growing populations and an increase in centralization, noise levels are now at extremely high levels.

Noise Everywhere

Today, noise is simply ubiquitous. From the busy streets of the city to the rural outlets, noise problems are continuously on the rise (Bronzaft, 2002; Milne, 1979). Generally, loud levels of noise have been associated with the large urban centers such as Toronto and New York. These populated cities are the centers of attention for their countries in which millions of people have flocked due to the major financial and entertainment possibilities they possess. However, the noise levels of the city are now impeding rural civilization (Bronzaft, 2002). Presently, technology has progressed to allow individuals to partake in everyday household chores with noisy modern equipment. For instance, one can mow the front lawn with the efficiency of a lawn mower or clear a snow filled driveway with a snow blower. It seems as technology advances so does the noise these technologies produce.

A major advancement in technology that poses a serious threat to an increase in environmental noise pollution is the rise in regular air traffic (Bronzaft, Ahern, McGinn, O'Connor & Savino, 1998). New airports have arisen in recent years in the United States that are far removed from the urban area. Despite the distance from urbanization, the loud roar of the engines still have an effect on the human population due to the multiple flight routes (Bronzaft, 2002). Aircraft noise has been suggested to have negative effects on individuals, as well as children (Bronzaft et al., 1998; Smith, 2005); thus the development and expansion of air traffic will have a detrimental effect on the human population in respect to environmental pollution. As the world's population and technologies increase so does noise and its effects.

India is a prime example of the rising costs of environmental noise pollution. Maiti and Agrawal (2005) studied phenomenon of growing urbanization in metropolitan cities of India and how this urbanization related to environmental degradation. Using data on relevant issues, the authors studied important environmental problems that related to a rapid over population growth. It was stated that the India's urban growth has increased tenfold in the past century. Due to this uncontrollable rise in population, India is rapidly facing deterioration to its environment. The main factors attributable to the downfall are: accelerated industrialization, energy production, urbanization, commercialization, and increase in motorized vehicles (Maiti & Agrawai, 2005).

These factors lead to a high level of noise in the urban areas. Maiti and Agrawai (2005) discovered that noise pollution was above the prescribed standard in all metropolitan cities. Thus, it is obvious that the environmental parameter of noise is depriving the Indian citizens of quality sound levels for healthy living. Yet, the civilians of these urbanized sectors may become more miserable as the years progress for India's population continues to rise, which may cause further health hazards. It is suggested that attention must be made aware of the problematic noise and noise control implementation strategies may need to be put in place to manage the increasing problems.

Noise Control & Opposition

Noise is such an increasing problem that there are numerous campaigns that have been developed to combat the so-called pollution, which is dangerous to the population's health. In the past decades many publications have been written as a strategy to control environmental noise (Cmiel, Karr, Gasser, Oliphant & Neveau, 2004; Garcia, 2001a; Rosenhouse, 2001; Schmidt, 2005). Environmental noise is a serious problem, but despite the negative effects, campaigns against noise seem to be unpopular and encounter large opposition (Gibson, 1999). According to Gibson (1999), the opposition against the campaigns on noise are based on ignorance and misunderstanding. Noise issues are unpopular because if one lobbies against noise they are fighting against leisure pursuits for the simple reason that many past times are related to noisy events, such as: concerts, fairs, parades, social gatherings, and sporting events. Thus, it is beneficial to spread the message of noise pollution. So far many steps have been taken to improve environmental noise; however, there is still a lot to be completed. In Great Britain, from 1991 to 1994, 16 people had fallen to death during domestic conflicts over noise volume disputes (Gibson, 1999). The horrifying fact leads to the need for noise control regulations and further investigation into noise disturbances.

Noise & Health

Noise and Auditory Health

The most pronounced health effect related to exposure to environmental noise is the deterioration in auditory health (ACOEM, 2003). Excessive exposure to long term noise or intermittent exposure to higher intensity levels of sound may cause hearing impairment (Kryter, 1994; Thiessen, 1976). Hearing impairment is the result of damage to the inner ear or cochlea. According to Kryter (1994), this damage may occur to the cochlear structures within a few hours or days of noise exposure. It is dependent upon the intensity or volume at which the noise is produced. Less severe hearing loss is reversible. Sometimes this type of noise-induced hearing loss is due to structural fatigue (Kryter, 1994). Nevertheless, irreversible noise-induced hearing damage occurs when the cochlea is exposed to sound volumes greater than 80-90 decibels (dB) (Nakai, 1999). However, when the intensity or duration of exposure increases, mechanical and metabolic damage appears (Kryter, 1994; Nakai, 1999). Damage from short bouts of sounds exceeding 130 dB mainly occurs as mechanical cochlear damage (Nakai, 1999).

According to Nakai (1999), early acoustical over-stimulation of the inner ear, is characterized by sensory hair flexion, vesicular swelling, and fusion. In this early phase, there is an increased blood flow of the cochlear with a concomitant rise in intracochlear carbon dioxide, which results from an increase in metabolism. A gradual decrease in blood flow follows this response. Immediately following this over-stimulation, a noise-induced temporary threshold shift is observed due to vasoconstriction and adhesion of the sensory hairs. After mechanical damage, the nerve fibres and terminals of the organ of the Corti often remain in tact; thus, displaying a great resistance to traumatic sound levels (Nakai, 1999). From another viewpoint, noise exposure may induce metabolic and electromechanical responses resulting in pathological swelling and other conditions involving the hair cells, neural connections, and vascular system of the cochlea (Kryter, 1994). Noise not only affects the auditory functioning of full-grown humans, but also that of the fetus (Brattico, Kajula, Tervaniemi, Ambrosi & Monitillo, 2005; Etzel & Balk, 1997).

Prolonged exposure to noise may have an adverse effect on normal development of the auditory system in the fetus. The fetus is in a fragile state during development in the womb. A study conducted by Lalande, Hetu and Lambert (1986) studied children, 4-10 years of age, with high-frequency hearing loss. They concluded that children in this age range who possess the characteristics of hearing loss had a greater possibility to be born to women who were exposed to an occupational environment that consisted of a noise range of 85 to 95 dB during the pregnancy. Another study involving premature guinea pigs discovered an enhanced sensitivity of the developing cochlea to noise-induced damage (Douek, Dodson, Bannister, Ashcroft,

& Humphries, 1976). Thus, environmental noise has an evident impact on hearing impedance. Noise also has effects one's quality of sleep.

Noise, Sleep Disturbance & Performance

People who live in highly populated areas tend to report that their sleep is disturbed. Usually, these people live in the vicinity of highways, airports, and other major noise sources (Vallet, 2001). Noise is also a significant problem during patient sleeping hours during the night (Cmiel et al., 2004). Sleeper's exposure to noise may affect them physiologically and psychologically (Vallet, 2001). Even an individual's performance the following day after exposure to noise during the night is affected (Wilkinson, 1984).

According to Wilkinson (1984), when subjects were required to perform a simple vigilance test, it was revealed that subjects completed the test faster after a relatively quiet night. Furthermore, simple reaction times were impaired following a night's exposure to noise. These test results reveal that during a night of sleep interrupted or impeded by noise, the quality of sleep is poor and performance the following day may be hindered. Not only is music detrimental to sleep and auditory health, it also has an effect on stress and anxiety.

Noise and Vigilance Performance

Noise research involving vigilant performance is not a new phenomenon. In the mid 1950s, Broadbent (1954) revealed that continuous noise exposure above 90 dB and longer than 15 minutes attenuates vigilance performance. McCann (1969) studied the effects of continuous and intermittent ambient noise. The researcher discovered that there was no difference between the two types of noise in regards to total errors performed on the task; however, intermittent noise produced more omission errors as opposed to continuous noise. Another early study looked at the effects of steady state noise on vigilance (Hartley and Williams, 1977). Subjects were exposed to white noise and variable noise at 72 dB (A). Subjects decreased their vigilant performance and discriminability during exposure to variable noise, even though the differences were unreliable.

In another study, conducted by Smith (1988) on 64 female subjects from the college population, it was demonstrated that noise reduces the performance during a task involving the detection of repeated numbers. Additionally, noise did hinder the performance during estimation. Noise increased the frequency of extremely inaccurate estimates (Smith, 1988).

More recently, Button and colleagues (2004) studied the effects of noise and muscle contraction affecting vigilance. It was found that loud industrial noise exposure significantly increased the duration of reaction and movement times when performing simple vigilant tasks. Respectively, high industrial noise decreased a complex vigilance tasks to a greater degree. It was noted that loud sound exposures are expected to have a greater effect on tasks involving high levels of concentration due to the fact that higher amplitudes of auditory stimuli require greater central resources for processing. Another reason involves the increase in anxiety levels when one is exposed to loud intensity sound. This increasing anxiety may potentially over arouse the central nervous system, thereby decreasing one's responsiveness to vigilant specific tasks.

Noise & Cognition

Studies demonstrate the effects of noise on subjects' attention (Hockey, 1970; Kujala et al., 2004), reading deficits and skill (Evans & Maxwell, 1997; Maxwell & Evans, 2000). Other articles have focused on office noise and employee concentration (Banbury & Berry, 2005) and ambient noise and cognitive processing (Lercher, Evans & Meis, 2003). Furthermore, other researchers have studied the long-term effects of transportation noise and children's cognition (Boman, 2004; Hygge, Boman & Enmarker, 2003; Hygge, Evans & Bullinger, 2002; Smith, 2005; Stansfeld et al., 2005).

In recent years there has been a greater focus on aircraft and road traffic noise and child cognition in the literature. According to Stansfeld and contemporaries (2005), aircraft noise does indeed interfere with a child's ability to learn. Their conclusions revealed that chronic aircraft noise exposure impaired reading comprehension and recognition memory. Consequently, neither aircraft nor traffic noise affected self-reported health, overall mental health, or sustained attention. Similarly, Hygge and colleagues (2003) revealed that road traffic noise impaired recollection of text and semantic memory. The noise source also impaired attention. However, recognition was not affected by the noise sources. Thus, according to the studies (Hygge et al., 2003; Stansfeld et al., 2005) schools in close proximity of high volumes of road or air traffic are poor learning environments for children.

In another air traffic study, Hygge and associates (2002) conducted research on two groups of children. One group consisted of children attending school in an area of a new airport development (noise) and the other consisted of children attending school in the vicinity of a recently closed airport (quiet). The researchers discovered that after the opening of the new airport, the children's long-term memory and reading were impaired. Nevertheless, in the quiet group, these characteristics improved. Additionally, short-term memory also improved for those who attended school near the recent closure. Thus, it is quite possible external air traffic noise may play a role in impairing cognition in school aged children.

Likewise, Evans and Maxwell (1997) discovered that first and second grade school children have difficulties in learning to read when exposed to chronic aircraft noise. It has been demonstrated that these children have significant deficits in reading as indexed by a standardized reading test (Evans & Maxwell, 1997). In a more recent study, researchers also learned that pre-reading skills are affected by prolonged exposure to noise (Maxwell & Evans, 2000).

Recently, it has been studied that office noise may be distracting (Banbury & Berry, 2005). The researchers found that irrelevant distractions were the main culprit during the working day in an office setting. Despite the constant noise; however, the employees did not habituate to the background sounds. As a response to these background interruptions, 99 percent of the office employees displayed displeasure in their ability to concentrate and perform at the designated tasks (Banbury & Berry, 2005).

Music

Music is a popular source of leisure in today's society. It is also intertwined within many common activities that exist today: driving, exercising and even sleeping. However, it has been demonstrated that music actually affects individuals psychologically, physiologically, as well as socially. Music research has studied the relationship between music and retail environments (Herrington & Capella, 1996; Yalch & Spangenberg, 2000), music and parenting of young children (Ilari, 2005), and even the functions of music in everyday life (Sloboda , Oneil & Ivaldi, 2001). Other studies have shown that heavy metal music may be associated with careless behaviour in high school students (Arnett, 1991; Arnett, 1992). According to Arnett (1992), teenagers who are attracted to heavy metal or hard rock music are more likely to be involved in reckless or destructive behaviour. There are numerous underlying factors determining the effects of music on an individual's functioning.

Even an early study conducted on music discovered an affect on the cardiovascular system measurements: diastolic blood pressure, systolic blood pressure, heart rate, and electrocardiogram (Hyde, 1924). However, the researcher commented that the response was due to personality and experience of the subject. The reasoning underlying why an individual responds accordingly during exposure to music is debatable (Larsen & Galletly, 2006).

Music is Facilitating

During numerous studies, music played at moderate amplitudes has been shown to facilitate performance in activities that involved high levels of concentration and attention (Corhan & Gounard, 1976; Davies, Lang & Shackleton, 1973; Ferguson, Carbonneau & Chambliss, 1994; Fontaine & Schwalm, 1979; Matthews, Quinn & Mitchell, 1998). The reasoning why music facilitates such performance is that the stimulus played at a moderate intensity is considered to be stimulating, in that it increases motivation, arousal and ratings of perceived exertion and energy (Atkinson, Wilson & Eubank, 2004; Davies et al., 1973; Matthews et al., 1998).

Music is Distracting

It has been shown that music is capable of distracting or deterring performance of certain tasks (Crawford & Strapp, 1994; Etaugh & Michals, 1975; Fogelson, 1973; Kallinen, 2002). According to Etaugh and Michals (1975) music or sounds that are unfamiliar to the subject are more distracting than familiar sounds. Thus, in certain instances music is considered noise if it is unwanted or interferes with everyday activities of others when played at loud volumes. However, to the intended listener music may not be considered a noisy distraction. Nevertheless, it may not be the preference of the sound type that is the problematic distraction during music exposure. According to research conducted by Furnham and Strbac (2002) music is as distracting as noise. The researchers discovered that performance during a reading comprehension task was significantly worse with music in comparison to silence. There was also a significant difference between silence and noise, in which the noise condition showed worse performance. However, there were no significant differences in performance when comparing noise and music conditions. Thus, music and noise may be considered just as distracting during a cognitive task.

Other research has focused on the tempo of music and subject response to the stimuli (Kallinen, 2002; Mayfield & Moss, 1989; McElrea & Standing, 1992; Nittono, Tsuda, Akai, & Nakajima, 2000; North, Hargreaves & Heath, 1998; Roballey et al., 1985; Smith & Morris, 1976). It has been shown that fast tempo or high tempo music causes subjects to increase the speed of the activity in which they are participating

(Brodsky, 2002; McElrea & Standing, 1992). For example, McElrea and Standing (1998) studied the effects of fast and slow music upon subjects' duration to drink a can of soda. They discovered that the faster pace music decreased drinking time significantly compared to slower music. Brodksy (2002), discovered similar results in his study conducted on simulated driving and music tempo. The researcher suggested that fast music increased driving speeds and thus decreased driving times significantly. The reasoning behind the increased speed is that the higher tempos are arousing in nature. Furthermore, the results highlight a clear rhythmic contagion from the tempo music. There may even be an entrainment effect associated with the rhythmical beats of music. For instance, it has been shown that music resembles the rhythmicity of certain biological oscillations, such as heart rate (Larsen & Galletly, 2006).

Musical Rhythms & Cardiovascular Treatment

Music research is yet to fully understand the physiological consequences of acute exposures to musical stimuli. Previous research has attempted to study the phenomenon with little progression. An early experiment conducted by Ayres in 1910, as reported by Urbock (1961), demonstrated that cycling speed increases when subjects are exposed to marching band music as opposed to silence. Other cycling studies have attempted to reveal the caveats behind musical motivation and physiological alterations (Atkinson et al., 2004; Pujol & Lagenfeld, 1999; Szabo, Small & Leigh, 1999). One study demonstrated that music may increase an individual's estimation of his or her rate of perceived exertion, but it does not correspond to a physiological increase in heart rate (Atkinson et al., 2004). Furthermore, Szabo, Small and Leigh (1999) found similar results to Atkinson and colleagues (2004). The researchers discovered that performance increased with exposure to fast music during a progressive cycling test to failure. However, there were no significant heart rate differences in the comparison trials. The authors explained the occurrence to the musical exposures as being a distraction from fatigue and thus, the performance was dependent on the strength of the distracter to manipulate the participant's attention away from fatiguing indicators. Pujol and Langenfeld (1999) found that there were no significant physiological or performance differences when subjects participated in the Wingate Anaerobic Test with or without music. Thus, the above studies signify that music may not affect physiological parameters in respect to the cardiovascular system.

Biological rhythms resemble the beat of musical rhythms. However, there has been little research concentrated on the complexity between physiological and musical rhythms (Betterman, Amponsah, Cysarz, & van Leeuwen, 1999). Only physiological response and entrainment phenomena have been studied thoroughly with respect towards auditory stimuli (Cysarz et al., 2003; Hébert, Béland, Dionne-Fournelle, Crête & Lupien, 2005; Mockel et al., 1994). Hypothetically, exposure to different types and tempos of music may affect the rhythms of the cardiovascular and respiratory systems (Bettermann et al., 1999). For instance, musical therapy has been utilized as a recommended treatment or preventative measure against increased resting heart rate and systolic blood pressure (Chafin, Roy, Gerin & Christenfeld, 2004; Knight & Rickard, 2001). According to Knight & Rickard (2001), music may be considered an effective anxiolytic treatment. Quiet, relaxing music is able to relieve anxiety. As result, heart rate and blood pressure are also decreased or improved. Staum and

Brotons (2000) also revealed that soft intensities of music were preferred to medium and high volumes of music during relaxation. Soft music was considered to induce a relaxation response according to self-reported data. However, heart rate was not significantly affected. Lee, Henderson and Shum (2004) researched the effect of soothing music on anxiety levels of subjects while they were waiting for an operational day-procedure. The researchers revealed that during self-selected music played at comfortable levels, physiological parameters dropped and a reduction in anxiety levels were self-reported. Thus, it is suggested that music is capable of being a major external input factor in the control of the physiological responses of blood pressure and heart rate and creating a relaxing environment (Lee et al., 2004).

Relaxation Response

Listening to music has the potential to lower blood pressure, enhance relaxation and aid in recovery from stress (Chafin et al., 2004; Knight & Rickard, 2001; Staum & Brotons, 2000). For example, when university students were presented with a cognitive stressor of preparing for an oral presentation, it was found that music prevented stress-induced increases related to the stressor (Knight & Rickard, 2001). Furthermore, not only may music decrease stress levels, noise may also attenuate stress. Laether, Beale and Sullivan (2003) studied the effects of workplace noise on psychosocial stress within an office workspace. The researchers discovered that low levels of ordinary office noise seem to buffer the impact of psychosocial job stress.

In examination of a potential mechanism for this musical-induced relaxation, there seems to be two physiological responses responsible for the phenomenon: the autonomic nervous system response and peripheral neuro-vascular processes (Stefano, Zhu, Cadet, Salamon & Mantione, 2004). This calming effect seems to be related to the motivational and reward pathways of the brain (Stefano et al., 2004). Thus, relaxation results from an initial response at the cerebral cortex. Musical inputs are related to the emotional control sections of the brain. It is believed that the relaxation response involved with musical stimuli may be the result of the insular and cingulate amygdala and hypothalimic processes (Stefano et al., 2004). The importance of the insular cortex is that during cardiac regulation it is highly connected with the limbic system. This suggests that the insula is involved in cardiac rate and rhythm rate under the influence of emotional stressors, such as music. The cardiovascular and emotional response neural systems probably include numerous subcortical descending projections from the forebrain and hypothalamus (Seeley, 2006; Stefano et al., 2004).

There is an interrelationship amongst the musical stimuli and cardiorespiratory response. The cochlear nerve fibers enter the brain stem. This pathway is routed through the thalamus to the auditory cortex. It has been shown that through this path, the emotion centers within the limbic system are activated (Salamon, Kim, Beulieu & Stefano, 2003). The sensations evoked by musical inputs enter the neuronal pathway at the limbic system. Hence, listening to relaxing or easy listening music causes a top-down control of vasomotor activity (Stefano et al., 2004).

Once the signal reaches the periphery, nitric oxide and endogenous morphine (opiates) processes are a fundamental factor in the calming effect. Opiate processes originate in the CNS via the limbic system (Bianchi, Alessandrini, Guarna & Tagliamonte, 1993; Bianchi, Guarna & Tagliamonte, 1994; Stefano et al., 2004). Therefore, it is surmised that the opiate signaling system may be the primary and essential mechanism in which moderate levels of relaxing musical stimuli act as a relaxation device. The relaxation response pathway is developed via the central and peripheral nervous system (Stefano et al., 2004). Thus, these neurological responses initiate extrinsic regulation of the heart and respiration. This parasympathetic response will in turn decrease heart rate, blood pressure and respiratory rate (Seeley, 2006). In summary, by listening to soothing auditory signals, stimulation of higher centers of the brain has some reasonable control over the cardiorespiratory system through the previous stated pathways, which elicits a relaxation effect (Lee et al., 2004).

The previous hypothesis is suggested by Stefano and colleagues (2004) findings. The researchers found that when subjects were exposed to a musical stimulus, there was a significant increase in mononuclear cells and morphine 6-glucuronide in comparison to silence. The music exposure altered plasma signal molecule changes, which are consistent with physiological changes during music, such as attenuation of blood pressure (Stefano et al., 2004). Thus, music has a relaxation effect on subjects.

Sympathetic Response

From one perspective, musical inputs have a relaxation or calming effect in terms of the physiological aspects of the cardiovascular system. Yet, many studies have revealed that there may be no significant changes in physiological parameters when exposed to noise or music conditions (Mockel et al., 1994; Pellerin & Candas, 2003; Pellerin & Candas, 2004). However, as discussed earlier, music may induce an arousal effect (Bernardi, Porta & Sleight, 2006; Brodsky, 2002). Auditory input may contribute to stress responses in individuals (Hébert et al., 2005). Thus, it has the potential ability to increase cardiovascular parameters. The speculative arousal stimulation from musical stimuli may be based on the amplitude, tempo and rhythm of the input (Beh & Hirst, 1999; Brodsky, 2002; Bernardi et al., 2006; Bettermann et al., 1999).

The control of breathing and circulation are based on autonomic control. When exposed to an acute bout of music, played at a high volume level or at a fast tempo, there may be acceleration in sympathetic response. Basically, as stated earlier there is actually greater processing and arousal in the cerebral cortex. Louder sounds increase anxiety within an individual as well (Button et al., 2004). Previous studies have discovered that noise may increase irritability and stress, such as heart rate and blood pressure (Evans, Bullinger & Hygge, 1998; Malamed & Bruhis, 1996). Additionally, research has discovered that environmental noise, either chronic or acute may increase stress, as well as cardiovascular measures (Bradley & Lang, 2000; Evans, Hygge & Bullinger, 1995; Gomez & Danuser, 2004; Vallet, 2001). It has shown that during the waking hours, exposure to noise is accompanied with an increase in the cardiac rhythm. However, after prolonged exposure the resting heart rate or rhythm returns to normal conditions. This response is usually activated within 45 to 60 minutes (Vallet, 2001).

There seems to be an interrelationship between the emotional and musical processing centers. Thus, the greater stimulation from the intense music input causes the auditory stimulus to stimulate nerve afferents that stimulate the cardiovascular and respiratory control centers (Larsen & Galletly, 2006). In regards to heart rate and blood pressure, the signal passes through the cardioregulatory center in which the frequency of sympathetic nerve signals are increased to the adrenal medulla. The action potential enforces the secretion of epinephrine and norepinephrine into general circulation. This catecholamine response increases heart rate and stroke volume, which may lead to an increase in systolic blood pressure (Bernardi et al., 2006; Seeley, 2006). On the other hand, the sympathetic signal travels from the respiratory control center, which increases the frequency or rate of respiration (Seeley, 2006).

From another perspective, increases in cardiorespiratory response may be due to entrainment. Entrainment also activates sympathetic response. It is known that rhythms of the respiratory system and heart closely resemble that of musical beats (Bettermann et al., 1999). Auditory inputs have been shown to produce entrainment in respiratory timing and thus, music may be able to modify breathing frequency (Larsen & Galletly, 2006; Thaut, 1999). Therefore, as the tempo increases within an acute musical stimulus, an autonomic response will be sent from the respiratory centers after an initial response from the musical/ emotional areas of the higher brain centers. The sympathetic response will again stimulate a release of catecholamines: epinephrine and norepinephrine (Seeley, 2006). The sequence of events may lead to an increase in heart rate, stroke volume, blood pressure and respiratory rate.

The logical explanation between entrainment and arousal during exposure to loud and fast tempo music is that there is a concomitant response due to the sympathetic nervous system. Direct arousal in respect to sympathetic nervous system response and respiratory entrainment may be coexistent and interrelated (Bernardi et al., 2006). For instance, it is assumed that the breathing rate itself may increase sympathetic activity (Seeley, 2006). Therefore, both factors may contribute to the phenomenon of increased cardiovascular and respiratory activity.

Silence: When the Music Stops

However, after a bout of high volume music or fast tempo music, the increases in cardiovascular and respiratory response drop below baseline values during silence. As stated earlier, music is a stimulating precursor for sympathetic activity and arousal. Thus, without an arousing input during a music stoppage, a relaxation phase occurs (Larsen & Galletly, 2006). The system is working at higher frequencies than normal. The physiological system has to adapt to the new situation; thus, a parasympathetic response decreases the cardiorespiratory factors.

An alternative view of the calming phenomenon is that due to the belief that the biological oscillators were forced into overdrive during exposure to high levels of musical amplitude, sympathetic outflow and respiratory frequency were elevated (Bernardi et al., 2006). The auditory stimulus was the driving force behind the physiological increments in heart rate, blood pressure and respiratory rate. The cardiorespiratory factors increased due to the fact that physiological responses were a product of the intrinsic state and the musical stimuli. A consequential result may be a decrease in the intrinsic frequency of the biological oscillators (Larsen & Galletly, 2006). This observation is present when the music is stopped.

Driving Safety

With increasing number of vehicles on today's highways, roads and streets, road safety should be of the utmost concern. According to Sleet and Branche (2004), approximately one million people are killed and tens of millions are injured yearly on the world's roadways. In the United States alone, there were 42, 815 deaths and close to 3 million nonfatal injuries related to road traffic collisions in 2002 (National Safety Council, 2002). Road traffic-related accidents impose a great burden on public health (Sleet & Branche, 2004). Thus, it is important for research to focus on preventative measures to decrease the number of accidents on the roadway systems.

There has been a vast amount of research conducted on the distractions of driving. Research studies have included driving performance and stress and fatigue (Matthews, 2002), ambient temperature (Daanen, van de Vliert & Huang, 2003), abrupt interruptions (Monk & Boehm-Davis, 2004), conversation (McPhee, Scialfa, Dennis, Ho & Caird, 2004), and speech shadowing (Spence & Read, 2003). Also, it is understood that distractions cause drivers to be less attentive or perform greater errors (Goodman, Tuerina, Bents & Wierwille, 1999; West, French, Kemp & Elander, 1993). For an in depth analysis on drivers' ability to pay attention behind the wheel please view Trick, Enns, Mills, and Vavrik's (2004) review article. One of the more popular research topics in recent years deals with driver attention and distraction while using mobile telephones.

Driving and Cellular Phone Use

Recently, the effects of cellular phone use on driving related tasks have been saturated in the literature (Atchely & Dressel, 2004; Consiglio, Driscoll, Witte & Berg, 2003; Haigney & Westerman, 2001; Hancock, Lesch & Simmons, 2003; Hunton & Rose, 2005; Kawano, Iwaki, Azuma, Moriwaki & Hamada, 2005; Liu, 2003; Matthews, Legg & Carlton, 2003; Strayer & Drews, 2004; Strayer & Johnston, 2001). Cell phone utilization during crucial driving maneuvers erodes performance, decreases overall safety margin, and distracts drivers from critical primary tasks (Hancock et al., 2003). Mobile phone use during driving is considered dual-task processing (Stayer & Drews, 2004; Strayer & Johnston, 2001). The activity of conversing on a telephone while driving competes for one's attention with critical life saving controlling activities related to vehicle control (Consiglio et al., 2003; Hunton & Rose, 2005). Talking on a mobile phone impairs reaction time to a braking stimulus (Consiglio et al, 2003), increases crash risk (Hunton & Rose, 2005), and distracts drivers from performing critical maneuvers (Hancock et al., 2003). It is well documented that cell phone use impairs driving performance (Alm & Nilson, 1995; Brown, Tickner & Simmonds, 1969; Redelmeier & Tibshirani, 1997)

The actual act of conversation interferes with reaction time. According to Consiglio and others (2003) conversation performed either in person or by telephone caused slower reaction times. Additionally, conversation limits one's functional field of view while driving (Atchley & Dressel, 2004). In another study, Strayer and Drews (2004) investigated the effects of hands-free cell phone conversations on simulated driving in both young and old drivers. Strayer and Drews (2004) stated that when the dual-task of driving and conversing was compared to the single-task (driving only), reactions were 18% slower, following distance was 12% greater, and recovery of speed lost to breaking was 17% longer. Furthermore, rear-end crashes multiplied twofold when participants chatted on the mobile phone, demonstrating that driving performance decrements were observed without the possible manual manipulation of a cellular telephone (Strayer & Drews, 2004). Therefore, the simple act of conversing is a distraction when performing driving related tasks.

When conversing on a mobile telephone, drivers have a tendency to partake in buffering activities to avoid fatal accidents. One common occurrence is for a driver to increase the distance between his or her vehicle and the automobile in front. However, this compensatory behavior is not the best precaution (Strayer, Drews & Johston, 2003). Reaction times are still delayed during cellular phone use. Furthermore, delayed reaction times during driving increase the severity of the impact upon collision and it is enhanced at highway speeds (Brown, Lee & McGehee, 2001; Lee, Vaven, Haake & Brown, 2001). Cellular phone use is definitely detrimental to driving performance, whether it is the use of a traditional phone or a hands-free system.

Driving & Music

The main method of transportation in today's society is driving an automobile. Even more so is one's tendency to turn on the car radio or stereo system as he or she enters the vehicle (Bull, 2004). Listening to music while one drives is an increasingly popular practice than ever before. 91% of music exposure occurs during transportation transits (Sloboda, 1999; Sloboda, O'Neil & Vivaldi, 2001). Oblad (2000) reported that the music most frequently played in personal automobiles is different varieties of rock. Music has the capability to influence driver stress, relaxation or even the speed at which one drives (Brodsky, 2002; Staum & Brotons, 2000; Wiesenthal, Hennessy & Totten, 2000). Further, it has been suggested that listening to heavy metal or hard rock music is correlated with negative behaviors, such as reckless driving and traffic accidents amongst younger drivers (Arnett, 1991; Gregersen & Berg, 1994). Music has the ability affect driving performance both negatively and positively. Exposure to music has also been shown to facilitate one's performance (Turner, Fernandez &

Nelson, 1996). It is unclear whether music is beneficial to driving and controlling an automobile. Thus, it is of an increasing concern to study the effects of music on driving and the related tasks.

Early Studies

Driving research in respect to background radio sound is not a new phenomenon. Early research began in the 1960s (Brown, 1965; Konz & McDougal, 1968). One of the early pioneer studies conducted by Brown (1965) studied the effects of background music, speech and silence during light and heavy traffic. Eight subjects were tested on a 2.2-mile standard test circuit. Subjects were tested on the use of car controls and duration to complete the designated course. It was reported that music significantly reduced the frequency in which the accelerator and brake pedals were used in light traffic. Meanwhile, during heavy traffic, the music condition increased the amount of time taken to complete the circuit. Brown (1965) reported the findings as music reducing stress on the driver and lowering emotional arousal under frustrating circumstances of driving in heavy traffic. The music provided an alternative stimulus in which attention is averted. However, it was noted that listening to music had insignificant adverse effects on driving performance as pertaining to the experiment. It was even stated that listening to music may even have a slight beneficial affect during driving in that it reduces frustration caused by certain stressors (i.e. heavy traffic).

Another early study conducted by Konz and McDougal (1968) concocted an experiment involving 24 automobile drivers. The subjects were required to drive on a four-lane divided highway for 11.5 miles. The circuit was not closed. The participants were exposed to three separate conditions: silence, slow music and Tijuana brass music. Drivers participated in greater control activities (i.e. steering wheel movements, brake usage, and accelerator usage) during more 'peppy' music or during the Tijuana brass music. However, it was reported that it is difficult to distinguish whether these control activity changes are positive or negative (Konz & McDougal, 1968). Furthermore, both types of music were shown to increase the speed of the activity. An arousal effect was a factor in the speed increases. During the background music, the driver was more aware and alert, which led to faster lap times. The researcher concluded that greater alertness, would lead to greater improvement in driving (Konz & McDougal, 1968). The previous studies are the basis of driving research in relation to background music.

Driver Stress & Music

Automobile driving, at times, is extremely irritating and stressful (Gulian, Matthews, Glendon & Davies, 1989; Hennessy & Wiesenthal, 1997; Matthews, 2002; Wiesenthal et al., 2000). It may even be considered to evoke aggressive behavior (Hennessy & Wiessenthal, 1999; Wiesenthal, Hennessy & Totten, 2003). However, a preventative measure to reduce stressful situations during driving an automobile is to listen to one's favorite music collection. As stated earlier, musical therapy has been shown to reduce stress (Hammer, 1996; Takeshi & Nakamura, 1991) and enhance relaxation (Staum & Brotons, 2000). According to Wiesenthal and colleagues (2000) music is an important mechanism in coping with driver stress. Yet, the impact of music is unnoticed during low traffic congestion scenarios. The researchers studied commuters in two types of scenarios: when listening to one's favorite music and when traveling in silence. During both conditions driver stress significantly increased during high congestion traffic compared to low. Nevertheless, during the silence situation, driver stress increased significantly in high congestion as opposed to music exposure. During high congestion, music exposure seemed to have a soothing effect on driver stress (Wiesenthal et al., 2000). The authors go on to state that music is alleviating during undesirable circumstances by distracting drivers from the frustrating events.

During another study, the same researchers determined that high congestion traffic had an increasing effect on mild driver aggression (Wiesenthal et al., 2003). Therefore, music was studied to determine if it had a similar response on driver aggression as it did on driver stress. Similar results were reported. During high congestion traffic, listening to one's favorite music lowered mild aggression. It has been considered that music is capable of obscuring peripheral environmental stimuli during cognitive and motor tasks (Furnham & Bradley, 1997; Poulton, 1979). During music exposure, drivers are less aware of potential environmental stressors or frustrating occurrences that would normally increase aggression while driving. Hence, musical listening is distracting in respect to irritating and frustrating driving-related events (Wiesenthal et al., 2003). Furthermore, familiar music also has a relaxation effect on an individual. However, due to the distracting nature of music during motor vehicle control, the driver's performance is at risk in an effort to decrease aggression and stress.

Music Tempo

Today, still little is known about music intensity or volume and driving performance. However, music amplitude is not the only parameter that may affect driving skills (Brodsky, 2002). Music tempo also has an affect on driving performance. Higher tempos are symbolic of today's popular hard rock music. Yet, there is little research on tempo of music and driving tasks. A recent study discovered that faster music in respect to beats per minute increases both simulated driving speed and one's perceived driving time. During the study (Brodsky, 2002), subjects not only drove faster with a faster music tempo, but additionally also perceived themselves to be driving faster. Meanwhile, participants underestimated their faster recorded driving speeds by approximately 45 kilometers per hour less. Furthermore, drivers partake in more at risk behaviors when listening to higher tempo music. Drivers also had greater incidences of collisions, disregarded red lights, and lateral weaving, which indicate that tempo music causes rhythmic contagion or even entrainment (Brodsky, 2002). It has been viewed that music amplitude is responsible for the arousal effect while listening to music, but it is safe to state that tempo also plays a role in the stimulation (Brodsky, 2002). Faster-paced background music affects drivers' performance, but there have been conflicting results on whether or not music facilitates or distracts a driver's ability to perform vehicular controlling tasks.

Background Music & Driving: Facilitation or Distraction?

Music has been shown to facilitate performance during driving related activities (Beh & Hirst, 1999; Matthews, et al, 1998; Recarte & Nunes, 2000; Spinney, 1997; Turner et al., 1996). Comfortable or moderate intensities of background musical stimuli improve one's performance when partaking in driving-related tasks. As reported by Spinney (1997), quiet music played at 55 dB (A) provides for optimal driving conditions when compared to silence and loud music of 85 dB (A). Listening to the quieter music condition will improve reaction time and avoidance of hazards (Spinney, 1997). Drivers improve their performance and awareness when exposed to music that is related to their own comfort level (Turner et al., 1996). Turner and colleagues (1996) demonstrated that reaction and total response times to unexpected external stimuli are a U-shaped function of music amplitude. Moderate music (70 dB (A)) improved response time to a randomly activated red light in comparison to quiet music (60 dB (A)) and loud music (80 dB (A)). However, movement time was not affected. Moderate intensities of background music stimulate driver's awareness (Matthews et al., 1998).

The arousing nature of hard rock music may lead to the postulation that loud rock music has the ability to enhance reaction times or speed one's awareness or detection of unexpected hazards during certain scenarios (Matthews et al., 1998). Matthews and associates (1998) discovered that response times to cued stimuli were significantly improved when the subjects were exposed to rock music. The researchers concluded that loud rock music has a tendency to enhance energy and maintain interest in a specific task during stressful and non-stressful situations. The results somewhat differed from Wiesenthal and colleagues (2000), who claimed that music only enhances concentration towards driving during high congested traffic. Nevertheless, Matthews and colleagues (1998) did show that moderate intensity rock music facilitates driving performance in both irritating and nonirritating conditions, but not during loud rock music (intensity only ranged between 70-90 dB (A)). Hence, there is some evidence that music facilitates alertness and performance while controlling an automobile.

Further, Beh and Hirst (1999) found that during high-demanding situations loud music facilitates performance of vigilance when signals are centrally located. Under certain circumstances, louder volume music is even superior to lower volumes for facilitating attentional focus to vigilant performance. High intensity music may prove beneficial to performance under high arousal situations.

The literature has been somewhat inconsistent in reporting the results of music and its effects on driving related-tasks. Even though music has been shown to facilitate driving performance and behavior, it is still considered a major distraction and detrimental to one's cautious driving abilities according to some studies (Beh & Hirst, 1999; North & Hargreaves, 1999; Slawinski & MacNeil, 2002; Spinney, 1997). Beh and Hirst (1999) concluded that music did not facilitate performance during simple tracking tasks, which required continuous motor involvement and visuomotor coordination. Loud music did not interfere with tracking performance. Yet, loud music significantly affected response time to peripheral stimuli, which counter-balances the facilitation effect of the researchers findings related to centrally located stimuli. Moderate intensity music facilitated performance requiring a wide attentional span, whereas loud background music impaired performance under similar conditions (Beh & Hirst, 1999; North & Hargreaves, 1999).

Furthermore, high arousal music competes for limiting processing space within the cortex (North & Hargreaves, 1999). Greater cognitive space is required during high arousal stimulation, to process the external information. North & Hargreaves showed that high arousing music, increased lap times and impaired performance during simulated driving. Hence, higher arousing levels of music will in turn impair cognitive or driving related performance (North & Hargreaves, 1999). Different types of music or sounds may have different effects on driving performance.

Conclusions

As seen in the literature, noise has been a part of our society throughout history. Noise is considered a nuisance. Background noise has detrimental effects on personal health (i.e. auditory health) (ACOEM, 2003). The annoying background stimuli also deter one's performance in relation to cognition and vigilance (Button et al., 2004; Hockey, 1970; Stansfeld et al., 2005). However, music has been demonstrated to distract human performance (Crawford & Strapp, 1994; Etaugh & Michals, 1975; Fogelson, 1973; Kallinen, 2002). Music also has the same effect during driving-related tasks.

There have been equivocal outcomes in relation to driving performance and background music. One perspective states that music facilitates driving performance (Beh & Hirst, 1999; Matthews et al., 1998; Recarte & Nunes, 2000). On the other hand, others have demonstrated that loud music is detrimental to driving performance (Spinney, 1997). The results are inconsistent. Therefore, future research is necessary to develop a full understanding of background stimuli on tasks related to driving scenarios.

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3. CO-AUTHORSHIP STATEMENT

My role in developing, and preparing this thesis is underlined in the following statements:

1) **Design and identification of the research proposal:** Previous work conducted by Dr. David Behm and colleagues spawned the present research manuscript. Dr. Behm, Dr.Armin Kibele and I discussed and developed the current methodology for the research project. Dr. Behm provided a general overview of the previous research conducted at the lab and we identified the dependent variables.
2) **Practical aspects of research:** Raw data was collected by the primary author.
3) **Data Anlaysis:** Under Dr. Behm's supervision, I conducted all procedures involving data analysis.
4) **Manuscript Preparation:** I prepared the current manuscript under the supervision of Dr. Behm.

4. ARTICLE

THE EFFECTS OF VARYING SOUND TYPES AND INTENSITIES ON SIMULATED DRIVING PERFORMANE, SIMPLE VIGILANCE AND HEART RATE MEASUREMENTS

Author: Brian Dalton
School of Human Kinetics and Recreation
Memorial University
St. John's NL A1C 5S7

Running Title: Simple Vigilance, Simulated Driving & Music

Abstract

The purpose of the study was to determine whether specific types of sounds or sound volumes affect tasks that involve simulated driving performance, movement and reaction time, and heart rate measurements. Participants completed six separate trials of approximately 45 minutes each. The subjects were exposed to a combination of sound types (hard rock music, classical music & industrial noise) and intensities (53 db (A) versus 95 db (A)). During each trial, participants executed a randomized order of tasks, involving: movement and reaction times, simulated driving control, attention, and non-conscious perception of masking stimuli. Prior to the study, all participants were required to attend an orientation session where they completed the experimental design without background auditory stimuli. The results suggest that reaction and movement times were impaired due to high volumes of sound. During hard rock music, male reaction time (RT) was significantly slower than female RT. However, RT was enhanced significantly when subjects were exposed to hard rock music during a non-conscious task of longer duration. Simulated driving (SimD) time was significantly impaired during exposure to loud volumes of sound for all subjects. Additionally, the numbers of SimD crashes were increased during quiet hard rock music in comparison to quiet industrial noise. Accommodation heart rate (HR) was significantly higher during hard rock music. Whereas, experimental HR was lower during quiet sound volumes for both genders. In summary, loud volumes affect simple vigilance (i.e. applying the brake while driving in response to a red light) with the findings also suggesting that hard rock music may affect performance in tasks involving concentration and attention especially with males.

Key Words: driving, vigilance, music, heart rate

Introduction

Background of Study

Today, environmental noise is a major problem. Background noise is not only a nuisance, but it also affects human health (Kryter, 1994; Thiessen, 1976). The most obvious effect of high intensity noise exposure is noise-induced hearing loss (ACOEM, 2003). Yet, noise also affects concentration (Banbury & Berry, 2005; Hockey, 1970; Kajala et al., 2004) and human performance (Smith, 1988; Wilkinson, 1984). A recent study conducted by Button, Behm, Holmes, & MacKinnon (2004), studied the effects of industrial noise and muscle contractions on simple and complex vigilance. It was stated that high intensity industrial noise impaired reaction and movement times when responding to simple vigilant tasks and decreased performance during a complex vigilant task. However, do loud volumes of music have the same detrimental effect on human performance?

Music is a popular form of entertainment in society. However, it may facilitate or distract human performance. From one perspective, music may facilitate activities that require high levels of attention and concentration (Corhan & Gounard, 1976; Davies, Lang & Shackleton, 1973; Ferguson, Carbonneau & Chambliss, 1994; Fontaine & Schwalm, 1979; Matthews, Quinn & Mitchell, 1998) due to its stimulating nature. On the other hand, music may also be distracting to human performance during specific tasks (Crawford & Strapp, 1994; Etaugh & Michals, 1975; Fogelson, 1973; Kallinen, 2002). Music may even be as distracting as noise (Furnham & Strbac, 2002). Music and its distracting or stimulating nature has become intertwined with many popular activities in today's society.

The most popular form of transportation in our current society is driving an automobile and many drivers seem to listen to their car radios or stereos on a regular basis. It has been stated that approximately 91% of musical exposure occurs during automobile transits (Sloboda, 1999; Sloboda, O'Neil & Vivaldi, 2001), with rock music being the most popular (Oblad, 2000). However, the research has opposing opinions on whether music negatively impacts driving-related tasks.

Early driving research related to background music and vehicle control began in the mid to late 1960s (Brown, 1965; Konz & McDougal, 1968). One of the pioneer studies developed by Brown (1965) studied the effects of background music, speech and silence during light and heavy traffic. Brown (1965) reported that music may reduce stress during driving, lowering emotional arousal under frustrating circumstances, such as heavy congested traffic. It was summarized that listening to music may even have a slight beneficial effect on control activity of a vehicle (Brown, 1965). However, the early studies found it difficult to distinguish whether background music demonstrated a positive or negative effect on driving performance (Brown, 1965, Konz & McDougal, 1968).

More recent studies have highlighted both positive and negative outcomes in respect to driving performance and background music. In numerous instances, music has been found to facilitate performance during driving related tasks (Beh & Hirst, 1999; Matthews et al., 1998; Recarte & Nunes, 2000; Spinney, 1997; Turner, Fernandez & Nelson, 1996). According to the literature, it seems that moderate or comfortable volumes of background music exposure improves one's performance when performing driving-related tasks. For example, Spinney (1997) reported that quieter volumes of music played at 55 dB (A) provided an optimal driving condition in comparison to silence and loud music played at 85 dB (A). Moreover, it has been stated that drivers improve their awareness and performance when exposed to music that is in a range of their own subjective comfort level (Turner et al., 1996). It was demonstrated that moderate levels of music intensities report the safest driving conditions in that it stimulates driver awareness (Matthews et al., 1998).

Due to the stimulating nature of music, it may be purported that loud hard rock music may be stimulating and thus improve driving performance through enhanced reaction times and awareness (Matthews et al., 1998). However, the study conducted by Matthews & colleagues (1998) only looked at loud volumes ranging between 70-90 dB (A), which may be lower than what is considered loud by today's younger driver. Thus, a moderate volume of music may in fact enhance driving performance, whereas loud volumes may distract drivers.

The literature has been somewhat inconsistent in reporting the findings on the effects background music has on driving related-tasks. Even though music has been shown to benefit driving performance and behavior, it still may be a major distraction and detrimental to driving abilities (Beh & Hirst, 1999; North & Hargreaves, 1999; Slawinski & MacNeil, 2002; Spinney, 1997). Additionally, high arousal music may deter driving performance due to competition for limited processing space within the cortex (North & Hargreaves, 1999). North & Hargreaves (1999) found that high arousing music, increased lap times and decreased performance during simulated driving. Thus, higher arousing levels of music may impair cognitive or driving related performance (North & Hargreaves, 1999).

However, does gender play a factor in the effect of music on performance? It has been demonstrated that males have superior visuomotor and visuospatial attention skills compared to females (Robinson & Kertzman, 1990; Schueneman, Pickleman & Freeark, 1985). Schueneman and colleagues (1985) reported that during a visuomotor task females partook in the activity with greater cautiousness to reduce the number of errors related to the given task. Furthermore, by nature males are on average more aggressive than females (Eagly & Steffen, 1986). Therefore, it is important to study the effects of music on driving performance in relation to gender and type and volume of sound.

Significance of Study

Driving is now an integral part of today's transportation matrix. With the large masses driving on the highways, there exist more distractions than ever before (i.e. mobile cellular phones, radios, music, etc.). Also, it seems that it has become trendy in the younger populations for drivers to listen to hard rock music at extremely high volumes and heavy bass. Thus, it seems logical for the current study to focus on varying sound types and intensities and the associated effects on driving-related tasks.

Purpose of Study

Driving is a complex task involving a combination of relevant actions. However, there are numerous irrelevant activities (i.e. conversation, answering cell phone, adjusting the radio), which may interfere with the performance of driving (Strayer & Drews, 2004). The purpose of the current study is to determine whether different types of music or intensities of music affect performance during driving-related activities.

Further, there may be differences between genders concerning the aforementioned parameters.

No studies demonstrate the differences between today's popular hard rock music and classical music. The present study will investigate the differences, if any between different types of music and sound on driving-related tasks.

It is hypothesized that low volume sound will facilitate driving-related tasks, whereas loud volume sound will impair performance. In relation to type of sound, it is hypothesized that hard rock will affect tasks more detrimentally compared to classical music. The following methodology was constructed to test the above hypothesis.

Methodology

Participants

Six male (173 $\pm$ 6 cm, 72.57 $\pm$ 8.61 kg, 22 $\pm$ 1.21years) and six female (171 $\pm$ 3.5 cm, 66.9 $\pm$ 15.1 kg, 27 $\pm$ 10.34 years) participants from the university community volunteered for the experiment. None of the participants indicated a history of hearing or visual impairments. Additionally, all subjects held a valid driving license for at least four years. All participants indicated they either did not play or rarely played video games. Additionally, all subjects were initially unfamiliar with the steering wheel and video game used for the study. Participants read and signed a consent form prior to commencement of the study. The Memorial University of Newfoundland Human Investigations Committee granted approval.

Experimental Design

Participants completed six different trials of approximately 45 minutes each. Participants were subjected to a combination of auditory stimuli and sound intensities.

Conditions included loud (95 dB (A)) and quiet (53 dB (A)) levels of hard rock music, classical music, and industrial noise. Conditions were randomized for all participants. Tasks performed during the testing block included: simulated driving performance, reaction and movement time tasks, and a non-conscious perception task. The dependent variables were dispersed randomly within the testing block. Prior to the experiment, participants were granted an orientation session in which they completed the experimental tasks without the conditions of music or noise.

Dependent Variables

Dependent variables included reaction and movement time tasks, vigilance and driving performance, and heart rate (HR).

Vigilance Tasks

Reaction time (RT) and movement time (MT) were measured with an apparatus developed by the Memorial University Technical Services (Electronics, Newfoundland, Canada). The testing apparatus consisted of an analogue timer (L15-365/099, Triton Electronics, Great Britain), a stop clock (58007, Lafayette Instrument Company, Lafayette, IN), a stop clock latch (58027, Lafayette Instrument Company, Lafayette, IN) which attached the analog timer and stop clock, a custom designed box (62 cm (length) x 15.5 cm (width) x 9 cm (height)) with the distance of 50 cm from centre of start button to the centre of the stop button, and a trigger plate for the start of the task (Button et al., 2004). The task required movement of the driving leg (right) following the illumination of an incandescent light bulb (Fig. 1). The subject began with the right driving foot on the start button. Once the light was illuminated, the participant would release the start button and move the right foot and leg to push the stop button. The time between the lighting of the bulb and the release of the start button was recorded as the RT. MT was measured as the duration between the illumination of the light stimulus and the pressing of the stop button. Three trials of RT and MT were randomly performed during a three-minute time period. All trials registered a MT & RT. The mean of the three trials were used in the statistical analysis of RT and MT.

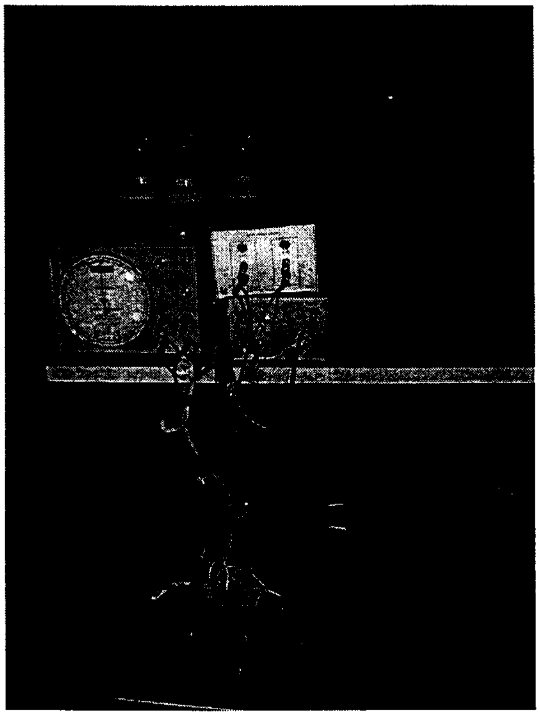

Figure 1. Simple Vigilance Task.

Simulated Driving (SimD) Performance

SimD performance was tested using a video game console (Playstation 2, Sony) with the software game, 'Gran Turismo 4: The Real Driving Simulator' (Sony Computer). The software permits the user to complete individual timed laps. Lap times were recorded to the nearest hundredth of a second at the conclusion of a lap. Subjects controlled the game with the GT Driving Force Pro Force Feedback Racing Wheel (239298, Logitech) (See Fig. 2). The same course and vehicle was used for each participant. Duration of the task was approximately five minutes. Driving performance was determined from a combination of the driving times, crashes, and shoulder hits. All participants were instructed that driving times, crashes, and shoulder hits were taken into consideration. All participants were granted a 60-minute orientation session with the video game and its controls prior to the testing. A plateau of SimD time demonstrated a baseline for all participants.

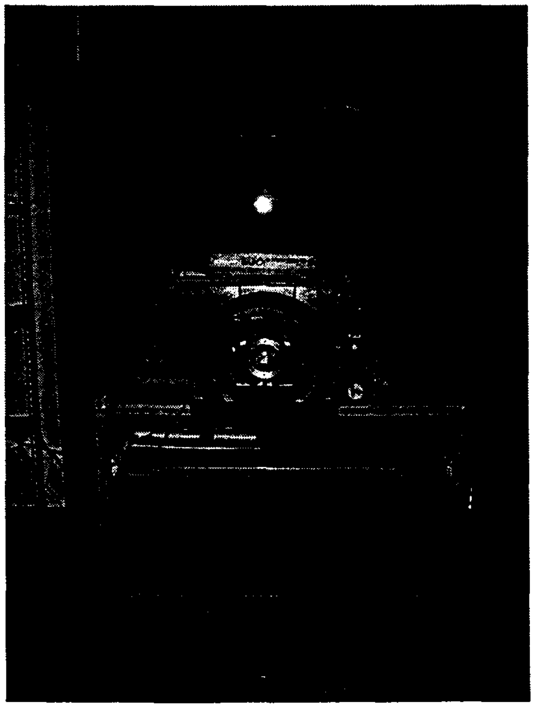

Figure 2. Simulated Driving Setup.

Heart Rate

Resting HR and accommodation HR were measured prior to the start of a testing block. HR was also measured during the experiment. All tasks were performed in the presence of music (hard rock or classical) or industrial noise.

HR was monitored with a heart rate monitor (Polar S810i Heart Rate Monitor, Polar Electro Oy, Finland, Model # 1903020). HR was recorded into three categories: resting, accommodation, and experimental. Resting HR was recorded approximately 5 minutes after the subject was seated in the testing chair. Accommodation HR was recorded approximately 2 minutes after the intended sound and volume commenced playback through the headphones placed on the subject. Experimental HR was recorded immediately following the termination of each testing variable. All heart rate measures are described in beats per minute (bpm).

Non-conscious Perception

In research with healthy people, one experimental paradigm with which Direct Parameter Specification (DPS) has been successfully investigated is the Metacontrast Dissociation. It was first employed by Neumann & Klotz (1994), based on earlier work by Neumann (1982) and Wolff (1989).

Participants perform a two-alternative choice RT task with geometric shapes as the stimuli. Participants are presented with a stimulus display that consists of a target and a distractor. They are asked to execute one of two motor responses (e.g., pressing a left or right mouse button), depending on whether the target appeared on the left or right. Unknown to participants, these stimuli are preceded by a pair of masked primes, which are smaller replicas of the target (target-like prime) and/or of the distractor (distractor-like prime; Figure 3). There are three conditions. In the neutral condition, the target as well as the distractor are preceded by distractor-like primes. In the congruent condition, the target is preceded by a target-like prime, and the distractor is preceded by a distractor-like prime. In the incongruent condition, this mapping is reversed. Thus, to the degree that the masked primes can cue a response, the correct response will be cued in the congruent condition, and the incorrect response will be cued in the incongruent condition, while no response is cued in the neutral condition.

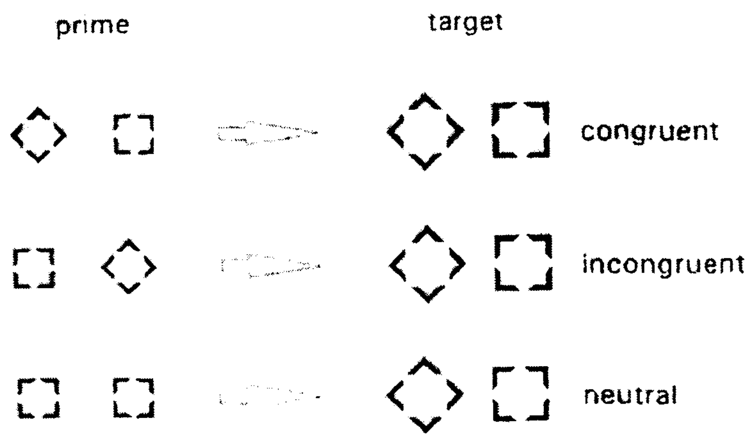

Figure 3. Examples of Stimuli (Klotz & Neumann, 1999).

Apparatus. The stimuli were presented on a 17" monitor (refresh rate 67 Hz), controlled by a microcomputer. Viewing distance was approximately 50 cm. Participants responded by pressing a mouse button (Fig. 4).

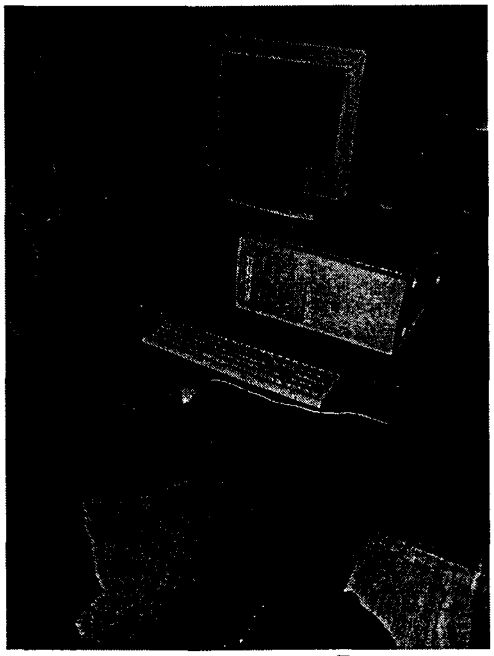

Figure 4. Metacontrast Testing.

Stimuli. Stimuli were displayed in black (5 cd/m^2) on a white background (130 cd/m^2). A trial encompassed a dynamic fixation assistance, a prime pair and a target-distractor pair (Figure 5). The target-distractor pair also served as a mask for the prime pair. The dynamic fixation assistance was employed to direct attention towards the center of the screen. Four dots moved from the corners to the center of the screen in 750 ms. At the starting position, the distance between the dots was 19 deg. In the center they merged into one dot and disappeared. The target-distractor pair was composed of a square and a diamond, each with star-like inner contours, aligned horizontally at a retinal eccentricity of 3 deg either above or below the center of the screen. The outer distance between the square and the diamond was 4.3 deg. The prime pair consisted of two smaller replicas of either two diamonds, two squares, a left diamond and a right square, or a left square and a right diamond. The outer contours of the primes coincided with the corresponding part of the inner contours of the target-distractor pair. Exposure durations were 30 ms (prime pair) and 90 ms (target-distractor pair). The stimulus onset asynchrony (SOA) was 75 ms.

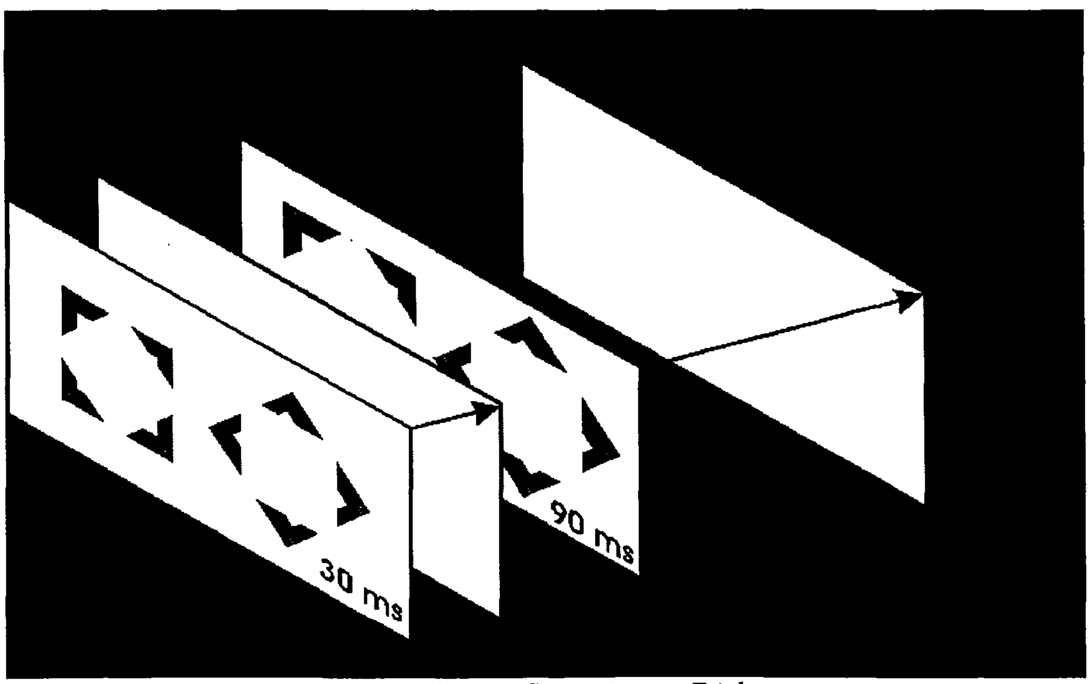

Figure 5. Event Succession per Trial

Procedure. The experiment took place in a dimly lit room and took about 15-20 minutes. In half of the trials the target-distractor pair was a left square and a right diamond, in the other half the arrangement was reversed. For half of the participants, the square was assigned as their target stimulus, for the other half the diamond was the target stimulus. There were three prime/target conditions. In the congruent condition the diamond in the target-distractor pair was preceded at its position by a diamond prime, and the square member of the target-distractor pair was preceded by a square prime. In the incongruent condition the assignment was reversed. In the neutral condition there were two identical primes that were smaller replicas of the distractors (squares or diamonds, depending on stimulus assignments). The inter trial interval was approximately 5 - 7 sec. The experiment encompassed 180 trials in a random order, different for each participant and consisting of 60 each congruent, incongruent, and neutral prime/target pairings. In each of these conditions, there were equal numbers of trials with stimulus presentation above or below the fixation point, and with the target in the left or right position. These experimental trials were preceded by 10 - 15 practice trials. Participants were instructed to press the left mouse button with the index finger of their left hand if their assigned target appeared on the left, and the right mouse button with the index finger of their right hand if it appeared on the right. They were asked to respond as fast as possible, but try to avoid errors. If no response was registered within one second, RT was omitted. Response latency was measured from the onset of the target.

Independent Variables

Each intervention (hard rock, classical, and industrial noise at loud and quiet volumes) was incorporated on separate occasions. Each session was performed within 24-48 hours of the previous session. All sessions per subject were tested at similar times during the day to account for circadian rhythms.

Auditory Stimulus

Participants were subjected to digitally recorded (www.sounddogs.com) loud industrial noise volume (similar to construction and industrial work) of 95 dB (A) (Sinclair & Haflidson, 1995), quiet industrial noise volume (similar to a quiet office environment) of 53 dB (A) (Passchier-Vermeer & Passchier, 2000), loud hard rock music at 95 dB (A), quiet hard rock music at 53 dB (A), loud classical music at 95 dB (A), or quiet classical music at 53 dB (A). The hard rock music was a recording of various compilations (See Table 1 for song list). Meanwhile, the classical music was a compilation of songs featuring the panpipes (Magic of the Panpipes, Gheorghe Zamfir, Universal Music, Willowdale, Ontario). During both conditions, the music was randomly selected and played.

Black Sabbath – Iron Man (Warner Brothers, 1971)
Disturbed – The Game (Giant, 2000)
Hair of the Dog – Rise (Spitfire, 2000)
Megadeth – Disintegrators (EMI Music Canada, 1997)
Metallica – Frantic (Elektra Entertainment, 2003)
Metallica - Holier Than Thou (Elektra Entertainment, 1991)
Metallica - Sad But True (Elektra Entertainment, 1991)
Metallica - The Shortest Straw (Elektra Entertainment, 1988)
Mötley Crüe - Dr. Feelgood (Hip-O Records, 1989)
Motley Crüe – Kickstart my Heart (Hip-O Records, 1989)
Orgy – Blue Monday (Reprise, 1998)
Rammstein – Links 2 3 4 (Universal Music Group, 2001)
Rammstein – Zwitter (Universal Music Group, 2001)
Rob Zombie - Dead Girl Superstar (Universal Music Group, 2001)
Rob Zombie – Dragula (Universal Music Group, 1998)
Rob Zombie – Scum of the Earth (Universal Music Group, 2001)
Soil – The One (Sony Music Canada Inc., 2001)
White Zombie - Children of the Grave (Sony Music, 1994)

Table 1. Hard rock music list.

Subjects were exposed to each auditory stimulus through stereo headphones (HR-80, Toshiba, Japan) that were connected to am/fm stereo receiver (VRX-2700, Vector Research, USA). The National Institute for Occupational Safety and Health (NIOSH) advises that the average person can be safely exposed to auditory stimuli at 95 dB (A) for approximately one hour. The exposure during this experiment was approximately 45 minutes. To ensure auditory stimuli levels remained within NIOSH recommendations, auditory stimuli levels were averaged through a pre-test. A sound level meter (Sound Level Meter 33-2055, Radioshack, Canada) was placed between the headphones for a five-minute period prior to commencement of the experimental session in order to monitor the average decibel level.

Statistical Analysis

All data were analyzed with a three-way analysis of variance (ANOVA) (3x2x2) (type of sound, sound volume, and gender) with repeated measures (GB Stat V7.0 for Windows (Dynamic Microsystems, Inc.)) to determine whether there were significant main effects or interactions of the testing blocks. However, the non-conscious perception task was analyzed with a three-way ANOVA (3x3x2) (meta-contrast condition, type of sound, sound volume) with repeated measures (GB Stat V7.0 for Windows (Dynamic Microsystems, Inc.)). F ratios were considered significant at $p<0.05$. If significant main effects or interactions were present, a Bonferroni (Dunn's) procedure was conducted. Descriptive statistics include means +/- standard deviation (SD) for both the text and figures.

Results

Simple Vigilance Tasks

Reaction Time

Loud sound volumes significantly ($p<0.01$) impaired RT by 15% compared to quiet sound volumes (Fig. 6). Significant ($p<0.01$) interactions were noted. Loud hard rock music, loud classical music and loud industrial noise impaired RT by 16.9%, 10.1% and 18.7% compared to quiet hard rock music, quiet classical music and quiet industrial noise respectively (Table 2). Loud classical music significantly ($p<0.01$) decreaseded RT by 7.5% compared to loud industrial noise (Table 2). There were no significant differences between loud hard rock and loud classical music, nor loud hard rock music and loud industrial noise.

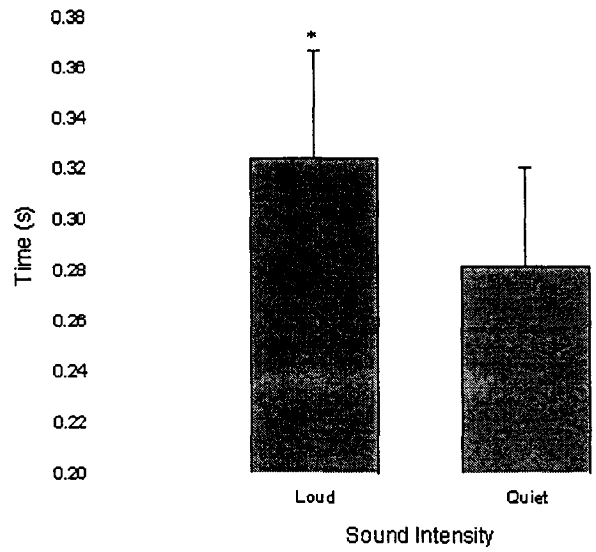

Figure 6. RT was significantly (p<0.01) impaired during loud sound exposure.

	Hard Rock	**Classical**	**Industrial Noise**
Loud Intensity	.324 ± .040 s	.313 ± .038 s	.337 ± .048 s
Quiet Intensity	.278 ± .044 s	.284 ± .038 s	.284 ± .037 s

Table 2. Summary of RT during varying sound volumes and types (Mean ± SD).

In respect to gender, there was no main effect. Males were more adversely affected by hard rock music compared to females. Hard rock significantly ($p<0.01$) impaired male RT by 9.5% compared to females (Fig. 7). Other types of sound did not show any significant differences with respect to gender (Table 3).

Figure 7. Hard rock music significantly (p<0.01) impaired male RT.

	Hard Rock	Classical	Industrial Noise
Male	.315 ± .050 s	.300 ± .039 s	.313 ± .056 s
Female	.288 ± .044 s	.297 ± .043 s	.307 ± .046 s

Table 3. Summary of gender RT during varying sound types (Mean ± SD).

Movement Time

Loud sounds significantly ($p<0.01$) impaired MT by 8.2% compared to quiet sound volumes (Fig. 8).

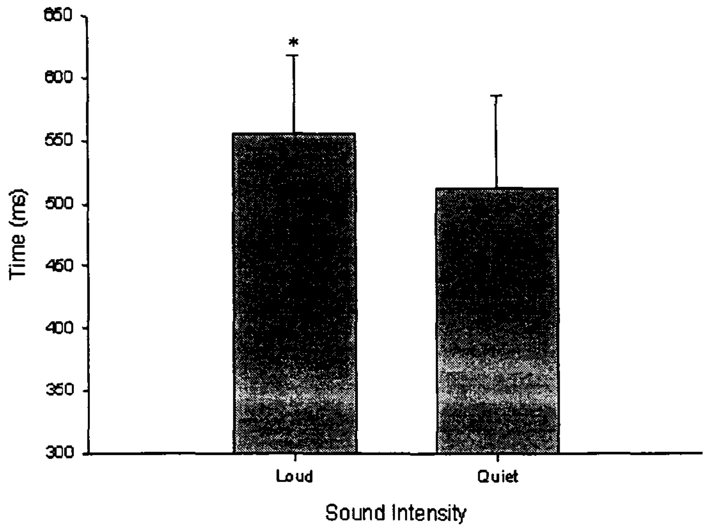

Figure 8. Loud sound significantly (p<0.01) impairs MT.

Simulated Driving (SimD) Performance

In respect to gender, male SimD times were significantly ($p<0.01$) faster by 14.3% compared to female SimD times (Fig. 9). Significant ($p<0.05$) interactions were noted. Loud classical music impaired SimD times by 2.1%, 1.7% and 1.5% compared to quiet volumes of classical music, industrial noise and hard rock respectively. Furthermore, quiet classical improved SimD times by 1.6% and 1.4% compared to loud volumes of hard rock and industrial noise respectively. It is also interesting to note that loud and quiet volumes of classical music showed the slowest and fastest SimD times respectively, despite any significant differences (Table 4). Loud volumes of sound significantly ($p<0.01$) impaired SimD times by 1.3% compared to quiet volumes of sound (Fig. 10).

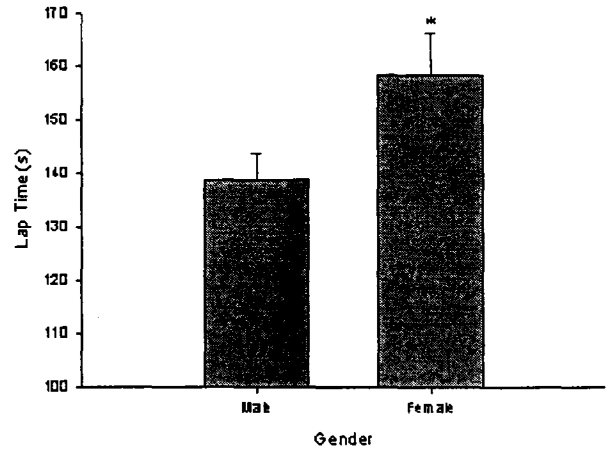

Figure 9. Male SimD times were significantly (p<0.01) faster than female SimD times.

	Hard Rock	Classical	Industrial Noise
Loud	149.35 ± 13.19 s	150.12 ± 12.16 s	148.99 ± 12.97 s
Quiet	147.92 ± 11.05 s	146.97 ± 12.09 s	147.63 ± 12.06s

Table 4. Summary of SimD times during varying sound volumes and types (Mean ± SD).

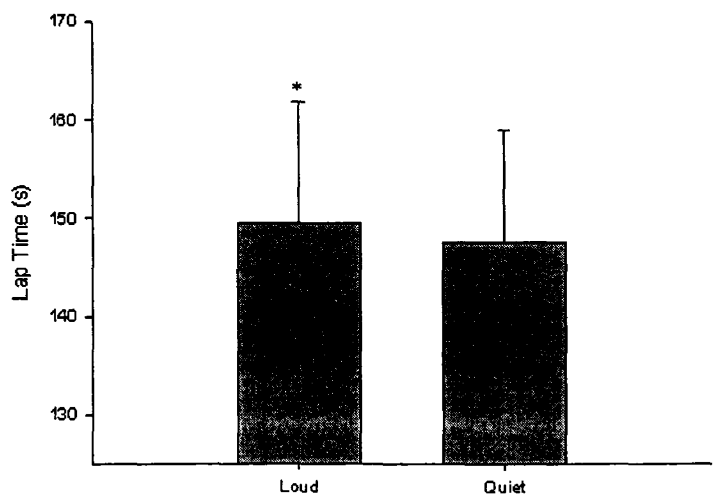

Figure 10. Loud sound significantly (p<0.01) impairs SimD times.

SimD crashes showed a strong trend (p=0.0566) for hard rock music exposure to produce more crashes per lap driven by 18.4% (1.48 ± 1.16 to 1.25 ± 1.01 crashes per lap) compared to industrial noise. In respect to gender, sound type had no influence on female SimD crashes. There were no significant differences amongst male SimD crashes (Table 5).

	Hard Rock	Classical	Industrial Noise
Male	1.5 ± 1.17	1.29 ± 0.96	1.04 ± 0.78
Female	1.46 ± 1.20	1.46 ± 1.18	1.46 ± 1.20

Table 5. Summary of SimD crashes per lap in relation to gender and sound type (Mean ± SD).

When data were collapsed over gender, quiet levels of industrial noise significantly ($p<0.01$) decreased SimD crashes by 40% and 44% compared to quiet volumes of hard rock and classical music respectively. The data is summarized in Table 6.

	Hard Rock	Classical	Industrial Noise
Loud	1.5 ± 1.30	1.25 ± 0.87	1.46 ± 0.89
Quiet	1.46 ± 1.05	1.5 ± 1.24	1.04 ± 1.12

Table 6. Summary of SimD crashes per lap in relation to sound volume and type (Mean ± SD).

There were no significant differences in respect to shoulder hits.

Heart Rate

Male resting HR was significantly ($p<0.01$) lower (63 ± 9.2 to 72 ± 14.1 bpm) compared to females.

Accommodation Heart Rate

With data collapsed over gender and volume, accommodation HR significantly ($p<0.05$) increased by 4.2% during exposure to hard rock compared to classical music (Fig. 11). Industrial noise showed no significant differences compared to hard rock or classical music.

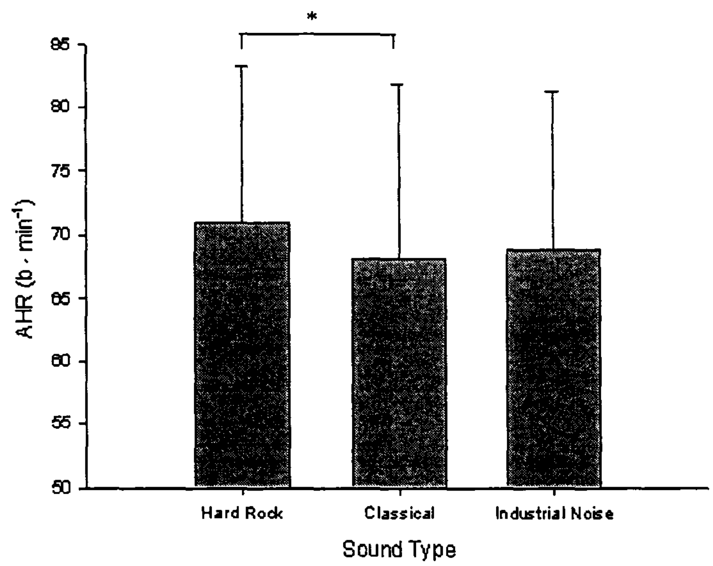

Figure 11. Hard rock significantly (p<0.05) increases accommodation HR.

With data collapsed over volume and type of sound, male subjects had significantly ($p<0.01$) lower accommodation HR by 12.4% (65 $\pm$ 9.2 to 73 $\pm$ 14.4 $b \cdot min^{-1}$) compared to females. There was no main effect for volume.

Experimental Heart Rate

With data collapsed over volume and type of sound, male HR during the experimental protocol was significantly ($p<0.01$) lower by 9.9% (74 $\pm$ 7.8 to 81 $\pm$ 14.3 $b \cdot min^{-1}$) compared to female HR. Collapsed over gender and type of sound, experimental HR significantly ($p<0.05$) increased during loud sound volumes by 4.5% compared to quiet intensity sounds (Fig. 12). Furthermore, female experimental HR was significantly ($p<0.05$) higher during loud hard rock exposure by 16 % compared to quiet hard rock music (Fig. 13). There was no main effect for type.

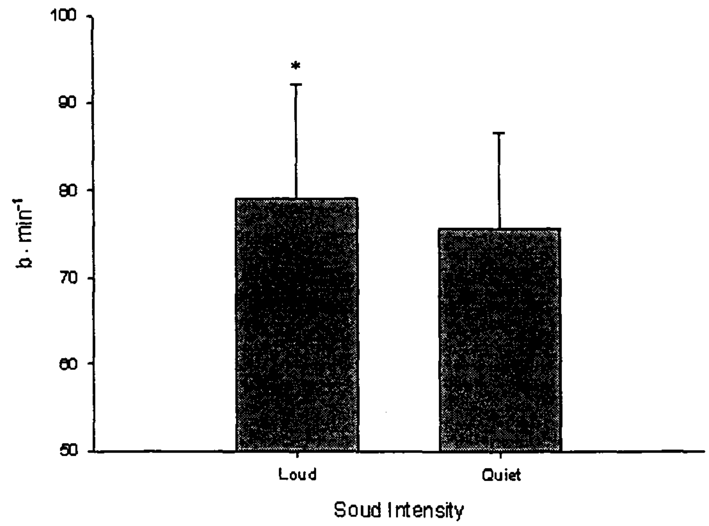

Figure 12. Loud sound significantly (p<0.05) increased experimental HR.

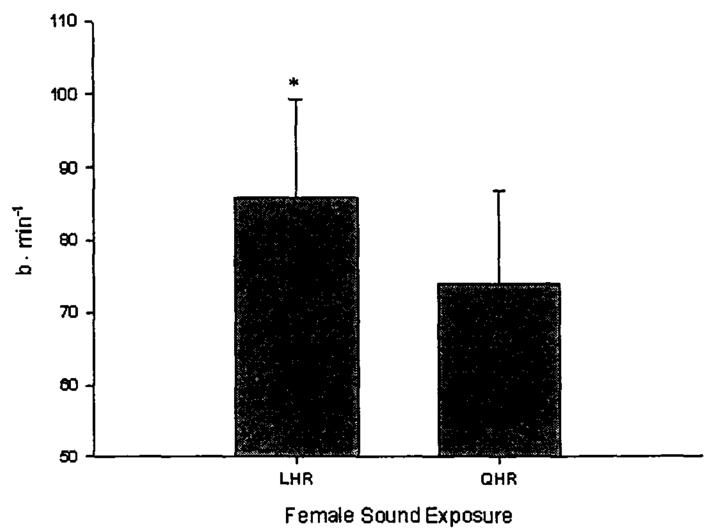

Figure 13. Loud hard rock significantly (p<0.05) increased female experimental HR.

Non-conscious Perception: Metacontrast Masking Test

With data collapsed over type and volume of sound, RT were significantly ($p < 0.01$) different for all three conditions of the metacontrast masking protocol. Congruent RT was the fastest (372 ± 47 ms) followed by mixed RT (396 ± 38 ms), while incongruent RT were the slowest (434 ± 41 ms). Further, with data collapsed over sound volume and metacontrast condition, hard rock music significantly ($p<0.01$) facilitated RT of all metacontrast conditions by 3.3 % and 3.8 % compared to classical music and industrial noise respectively (Fig. 14).

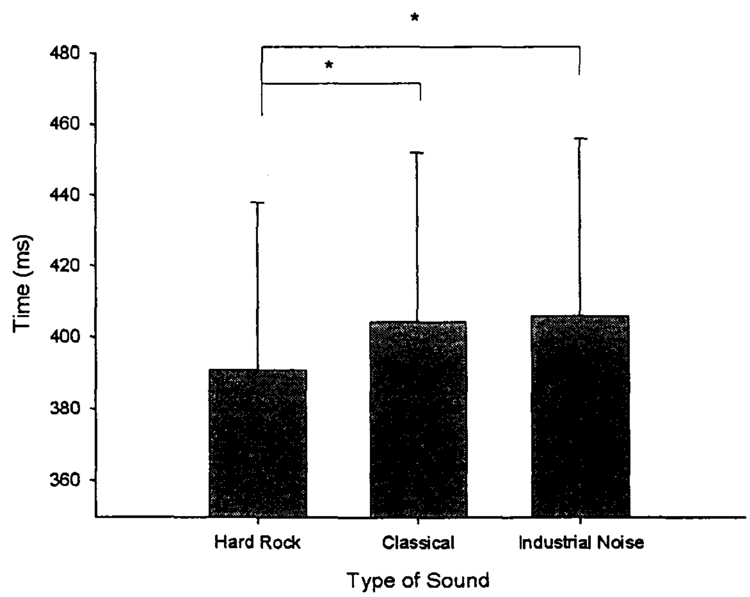

Figure 14. Hard Rock music facilitated RT (p<0.01).

Discussion

Similar to previous research (Button et al., 2004) the present study illustrated that high volume sounds significantly impaired RT and MT. In the current study, high volume sound impeded SimD time performance. Unique to the present study, male RT was adversely affected by hard rock music. Conversely, hard rock music generally (high and low volumes) improved RT during a metacontrast-masking task.

Sound & Simple Vigilance Performance

Data from the current study indicated that high volume sounds of any type (hard rock, classical, or industrial noise) impaired RT and MT tasks significantly. These findings confirm previous studies in the area of high volume noise and music on vigilant activity (Beh & Hirst, 1999; Button et al., 2004; Turner et al., 1996). These results have been noted previously in the literature where music is as distracting as noise during human performance (Furham & Strbac, 2002). But why would loud volumes be detrimental to performance?

It was purported recently by Button and colleagues (2004) that loud volumes may impact vigilance due to its greater processing demands on the central nervous system (CNS). Attention may be deterred from the task at hand; thus, causing an impaired RT and MT. Another reason is that such high volumes of sound may cause an anxiety effect within the subjects (Edsell, 1976). It is well documented that chronic exposure to noise increases stress levels (Evans, Bullinger & Hygge, 1998; Evans, Hygge & Bullinger, 1995). Music also increases the stress response during human performance. According to Hébert, Béland, Dionne-Fournelle, Crête and Lupien (2005), auditory input in the form of background music significantly increased stress response during video game play. Increased anxiety level response is also supported by the present study in which experimental HR was significantly increased during exposure to loud sounds. Increasing the state of anxiety and stress seems to over arouse the CNS, which in turn deters performance. Results from a previous study conducted by Delay and Mathey (1985) can describe this effect. The researchers discovered that subject's performance during a time estimation task increased consistently between noise intensity levels of 50 to 80 dB (A). Nevertheless, as the noise intensity approached 90 dB (A) the subject's ability to estimate time decreased (Delay & Mathey, 1985). Accordingly in the present study, simple vigilance was impaired perhaps as a result of higher levels of arousal impacting anxiety and processing within the CNS.

Possibly originating from similar mechanisms, loud classical music was significantly more detrimental for RT compared to loud industrial noise. Due to the nature of classical music, the auditory stimulus is complex in the design and may have greater arousal compared to simple random noise. Thus, the processing of loud classical music may have higher processing demands. There may be an increased attentional demand for this type of music in comparison to loud industrial noise. Again, there may be higher arousal levels to deter the subjects from the vigilant tasks at hand. According to North and Hargreaves (1999) higher arousing music led to worse performance during a SimD activity. It was proposed that the results reflect the possibility that the concurrent music and the task compete for limited cognitive space. Thus, in combination with higher arousal and volume levels, loud classical music increases greater processing within the CNS, which impairs performance during simple vigilance.

Also, an important note to mention is that RT was affected to a greater extent than MT. This result replicates the findings of Turner and associates (1996). They suggested that RT may be a more crucial factor in response time during visual vigilance performance.

Male participants were more adversely affected by hard rock music in comparison to females during simple vigilant performance. One common thread prominent in hard rock music utilized for this study and popular today is the abundance of bass. The preference for this type of music may be affected by many variables, including gender, individuality, or psychoticism (McCown, Keiser, Mulhearn & Williamson, 1997). As reported by McCown and colleagues (1997), males prefer music containing additional bass. In another, study conducted by McCown (1996) as cited by McCown and colleagues (1997), the researchers collected data on individuals with enhanced speakers in their vehicles to reproduce exaggerated bass sounds. The researcher reported that out of the 85 vehicles observed, 73 were driven by males. Hence, similar to the distracting effect of loud noise for both genders, the bass-induced arousal in males would interfere with the cognitive processing associated with simple vigilance (North & Hargreaves, 1999). However, non-conscious perception RT did not show similar results in the present study.

Non-conscious Masking Performance & Sound Type

Similar to previous research (Klotz & Neumann, 1999; Neumann & Klotz, 1998), the current study revealed metacontrast dissociation, which signifies non-conscious perception. However, RT did not show any significant differences to the level of sound volume during the metacontrast-masking test even though the simple vigilance task reported detrimental effects to loud volumes. One postulation could be that the stimuli for this non-conscious task are more centrally located as opposed to the simple vigilance task. The simple vigilance task encompasses peripheral field of vision as well. It has been reported in the literature that loud volumes distracts response time to peripheral stimuli, but not centrally located stimuli (Beh & Hirst, 1999). It was demonstrated by Beh & Hirst (1999) that participant's response times were facilitated by exposure to both quiet and loud music conditions. However, high volume music impaired response times to peripheral signals. Thus, the intensity of the music may not have an effect during the non-conscious perception task due to the centrally located stimuli.

Another possible postulation is that the processing of the visual stimuli are processed via varying pathways within the CNS, which is known as the two system theory (Goodale & Milner, 2004). According to Goodale & Humphrey (1998) there may be a separation in processing visual stimuli via the dorsal pathway or the ventral pathway. The non-conscious may be more centrally processed via the dorsal pathway; whereas the simple vigilance stimuli may have been processed via the ventral pathway (Goodale & Milner, 2004). Therefore, the different processing routes of the visual stimuli may be a factor in to why loud volume sounds have a greater affect on the simple vigilant task.

Another interesting finding in the current study was the observation that hard rock music improved RT when data were collapsed over volume of sound and metacontrast condition. In previous studies, hard rock music has been shown to facilitate simple performance (Matthews et al., 1998; Spinney, 1997; Turner et al., 1996). According to Turner and colleagues (1996), the arousing and stimulating nature of hard rock music may enhance speed of reaction to particular stimuli.

Sound & Simulated Driving (SimD)

In the present study, loud sound volumes significantly increased SimD times per lap. According to Spinney (1997), rock music played at moderate intensities (55 dB (A)) facilitated driving performance and may provide for optimal driving conditions; whereas, loud intensities (85 dB (A)) of rock music are detrimental to driving performance. Due to the distracting effect of loud sound volumes during SimD, the participants of the current study were unable to match the lap times of the lower sound volumes. As previously stated, the louder volumes seem to require greater cognitive processing within the CNS and capture the attention of the individual. Thus, SimD times may be slower during loud intensity sound. Also, in the present study loud volumes of sound impaired simple vigilance. Therefore, to compensate for impairments in RT and MT, participants' SimD times increased. There were no significant differences in the volume of sound on SimD crashes, but the type and intensity of sound in the current study affected SimD crashes.

Quiet volumes of hard rock and classical music increased the number of crashes in comparison to quiet industrial noise. Once again this result may be due to the fact that the music had a greater requirement for CNS processing. During the quiet intensities, the level of sound is at an approximate equivalent to a quiet office space (Passchier-Vermeer & Passchier, 2000). During quiet industrial noise exposure there was little requirement for central processing. However, during exposure to quiet volumes of hard rock and classical music the lyrics of the music were heard as a whisper. Therefore, CNS processing may have increased to more fully appreciate the music being played. Furthermore, Turner and colleagues (1996) reported that lower and higher music volumes (60 dB (A) and 80 dB (A)) were detrimental to driving performance, whereas a moderate level of intensity was determined optimal.

The current study reported that males on average had faster SimD times than females. According to previous research (Robinson & Kertzman, 1990; Schueneman, Pickleman & Freeark, 1985) males are superior to females in terms of visuomotor and visuospatial attention skills. Therefore, females may have shown greater caution during the SimD task. Also, with the aggressive nature of males (Eagly & Steffen, 1986), SimD times were faster for males. Gender was also a factor in heart rate parameters during the present study.

Heart Rate & Sound

During both recordings of experimental HR and accommodation HR, male subject HR was significantly lower than female HR. However, this may be simply due to the population tested. Prior to the testing, the resting HR was recorded and male HR was lower during this measure as well.

Further data analysis demonstrated that accommodation HR increased during exposure to hard rock music. Random noise has also been shown to increase HR (Evans et al., 1995). It is known that rhythms of the respiratory system and heart closely resemble that of musical beats (Bettermann et al., 1999). Auditory inputs have been shown to produce entrainment in respiratory timing and thus, music may be able to modify breathing frequency (Larsen & Galletly, 2006; Thaut, 1999). With entrainment activating an arousing response (Thaut, 1999), the music-induced increase in HR may depend upon the amplitude, tempo and rhythm of the input (Beh & Hirst, 1999; Brodsky, 2002; Bernardi et al., 2006; Bettermann et al., 1999). Hence, the high tempo hard rock music influenced the accommodation HR in this study.

The current study also reported that experimental HR increased during exposure to high volume sounds. Previous research has demonstrated that loud noise may increase irritability and stress, such as heart rate and blood pressure due to the increased sympathetic response (Evans et al., 1998; Melamed & Bruhis, 1996). Further, research has discovered that loud sounds, either chronic or acute may increase stress, as well as cardiovascular measures (Bradley & Lang, 2000; Evans et al., 1995;

Gomez & Danuser, 2004). Thus, similar to previous studies, the high volume sound increased HR during the experimental sessions.

Conclusions & Implications

The current study demonstrated that intensity and type of sound can have detrimental effects on driving-related tasks. High volume sounds decrease simple vigilance and SimD performance. Similar to loud noise levels, these decrements may be a result of greater arousal and stress levels, associated with greater processing within the CNS. Further, high volume sounds may also be seen as distracting, thus taking away from concentration and attention needed for driving performance. Listening to loud volumes of popular music is a trendy ritual during today's automobile transits. However, this act may affect concurrent tasks involved in automobile control due to detrimental effects on RT and MT.

More so, the popular choice of music to escort today's male drivers is hard rock. Yet males are most susceptible to its detrimental effects. Hard rock music impairs male RT more so than females. From one perspective, hard rock music may seem to be an excellent choice due to its facilitation response during centrally located stimuli. However, there are other decrements that may outweigh this benefit. The present study reported hard rock music increased SimD crashes, which may lead to speculation that attention is decreased during this type of auditory stimuli. Therefore, not only does the volume level of music one listens to, but also the type of music one listens to may magnify driving capabilities related to attention and concentration. However, one limitation to the current study was the varying tempos of the background conditions. Yet, it is still safe to state that listening amplitude and type of musical selection should be taken into consideration before venturing onto the busy roadways.

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5. SUMMARY & CONCLUSIONS

Throughout history, noise has been considered a nuisance and according to the literature it is detrimental to personal health (ACOEM, 2003). The annoying background stimuli deter human performance (Crawford & Strapp, 1994; Etaugh & Michals, 1975; Fogelson, 1973; Kallinen, 2002) in relation to cognition and vigilance (Button, Behm, Holmes & MacKinnon, 2004; Hockey, 1970; Stansfeld et al., 2005). Yet, music, in general, is pleasing to the intended listener; however, music may have detrimental and distracting effects on human performance as noise (Furnham & Strbac, 2002).

However, equivocal results exist in the literature on driving-related tasks and background music. These results are usually reported as a twofold: music may be facilitating (Beh & Hirst, 1999; Matthews et al., 1998; Recarte & Nunes, 2000) or distracting (Spinney, 1997) to driving performance. The inconsistent results provide a gap in the literature for future research in the area.

The current study focused on three basic conditions: the type and volume of sound, and gender. The present results demonstrated that certain volumes and types of sound can have detrimental effects on driving-related activities. Loud sound volumes decrease simple vigilance and simulated driving (SimD) performance. The stated decrements are the consequence of greater stress and arousal levels (Evans, Bullinger & Hygge, 1998), which are linked to greater processing activities within the central nervous system (CNS) (Button et al., 2004). Additionally, loud volume sounds are simply distracting, thus impairing attention and concentration that are required for effective driving performance. Today, listening to loud volumes of music is a popular activity during automobile commutes. However, this ritual may affect concomitant tasks, such as movement time (MT) and reaction time (RT), which are integral parts in controlling a vehicle.

The trendy music choice of today's male driver is hard rock (Oblad, 2000). However, males are most susceptible to the detrimental effects of hard rock music. In comparison to females the aforementioned music impairs male RT to a greater extent. To a certain extent, hard rock may serve as an excellent musical choice for its facilitating characteristics during centrally located stimuli. Yet, other decrements exist that may negate this enhancement. The present study stated that SimD crashes were increased as a result of listening to hard rock, which may decrease attentional awareness and capacity during exposure to this type of sound. Both type and volume of sound impact driving-related tasks. Thus, before getting behind the wheel of an automobile, the type and volume of the auditory stimulus should be taken into consideration to ensure the safety of the driver and other commuters on today's congested roadways.

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