Emotional Driving: Examining how Mood–Valence affects Driving Performance

by

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EMOTIONAL DRIVING: EXAMINING HOW MOOD–VALENCE AFFECTS DRIVING PERFORMANCE

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This thesis is an investigation of how positive and negative emotions affect driving speed, steering, and hazard response times while controlling arousal. Previous driving literatures have shown emotions to influence attention either by preparing drivers for action or impairing performance. Moreover, the environment exposes the driver to many factors that can change their emotional state. Given that previous experiments commonly confounded valence with arousal, further experiments are needed to determine the different effects of valence and arousal have on attention. Contrary to expectations, results revealed no significant effect of emotional valence on speed and steering. Furthermore, an unexpected interaction between valence and hazard position emerged in reducing brake response time. These findings suggest arousal to have a more important role in attention than previously thought in literature. Moreover, valence and arousal may have different roles in influencing different driving attentional mechanisms.
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Chapter 1 – Overview

This paper presents multiple experiments designed to look at how emotional valence affects driving performance; valence is defined by how positive (e.g., happy, content) or negative (e.g., sad, anxious) the stimuli makes you feel. Emotional valence is thought to influence cognitive processing such as attention. For example, positive emotions has been shown to broaden attention while negative emotion narrows attentional view (Derryberry & Tucker, 1992; Fredrickson & Branigan, 2005; Wadlinger & Isaacowitz, 2006; Fredrickson, 2001). When driving, individuals are exposed to many factors in the environment that can change their emotional state. This change in emotion while driving can influence their attentional view and therefore, affect mean driving speed, steering performance, as well as how fast the driver can detect different types of hazards on the road. The influence emotion has on attention while driving can ultimately determine life or death outcomes in a driving environment. Thus, it is important to have a better understanding on how things like emotions affect driver behaviour and performance.

In the following sections I will first clarify what emotion means by introducing different theories of emotion. Following that, I will be presenting literature focused on emotional valence as it is measured in the basic research on attention. Then, I will focus on driving, a day–to–day task that requires attention that has safety implications. I will then discuss the different ways emotion can be manipulated in driving tasks and present why music was chosen to manipulate valence in the following experiments. The methodology, results, and discussion of two separate music pilot experiments designed to test selected music stimuli and its effects on producing desired emotional states will then be presented. The first pilot experiment was designed to test
how emotional music could manipulate valence and control arousal alone. Results revealed emotional music alone was not a powerful enough manipulation of valence. This lead to the design of a second pilot experiment that adopted a mood induction task and music manipulation of valence, given that this method was successful at producing desired emotional states as shown by previous published literature. After presenting the music experiments, data from my driving experiment will then follow. The driving experiment was designed to look at how positive and negative emotions affects driving performance while controlling arousal, to expand our understanding on how positive and negative emotions affects driving. The results derived from the driving experiment showed no evidence of positive and negative emotions to influence mean driving speed and steering performance. Moreover, an unexpected interaction occurred between valence and hazard type that was the opposite of what was expected.
Chapter 2 – General Introduction

2.1 Emotion – Valence and Arousal

Emotion can be considered in several ways. In some studies emotions are considered as discrete and intense experiences. For example, there could be studies that look at the effects of discrete emotions such as fear, anger, and sadness. However, in a number of studies emotion is considered in terms of a variety of different underlying sub–components. For example, according to the circumplex model of affect (Russell, 1980), emotion consists of two dimensions, valence and arousal. Valence is defined by the polarity of the emotion. In other words, it is how positive or negative the emotions are. Some examples of positive emotions include happiness and joy, while sadness and anxiety are examples of negative emotions. Conversely, arousal by definition is the level of intensity of the stimulus. For example, how exciting or energizing the experience of emotions are. Specific examples that induce high levels of arousal include sudden and loud sounds of thunder while low levels of arousal can be induced by completing simple repetitive tasks. Depending on the different combination of valence and arousal intensities, specific emotional states are induced. When combining positive emotions with high arousal experiences of excitement are induced while depression is defined by a state negative emotion and low arousal. Similarly, negatively valenced states and high arousal is associated to states of stress and anxiety while positively valenced states low arousal relates to feelings of contentment (Russell, 1980). It is important to note that in the emotion literature the terms emotion and mood are sometimes used interchangeably though the two are different. Emotions typically refer to short term and intense experiences while the term mood and affect refer to longer emotional states (Lench, Flores, & Bench et al., 2010; Yiend, 2010).
2.2 The effects of Emotion in Laboratory Tasks

Positive and negative emotions have been shown to affect attention differently. Attention is the ability to focus or redirect consciousness (Sieb, 1990). Research has shown that emotional stimuli are prioritized because they often result in threatening or rewarding events (Harrison & Woodhouse, 2016). This is evident in a study conducted by Harrison and Woodhouse (2016), where they presented visual stimuli that differed in valence (based on the International Affective Picture System (IAPS), Lang, Bradley, & Cuthbert (2005)) during a visual cuing task. During the task, participants were presented with a single pictorial image that was either positive, negative, or neutral valence at the left or right side of the screen. Images of kittens were an example of positive images while pictures of garbage represented negative images respectively. Neutral images was depicted by pictures of mushrooms. Following the presentation of the image, an immediate auditory target in either the same side of the image (valid–cue) or opposite side of the location (invalid–cue) was presented. Participants were expected to respond if the auditory stimulus was presented in the left or right side using specific keys on the keyboard. The results revealed a significant main effect of emotional valence (positive, negative, neutral) where responses to positive images were faster than responding to negative images. They also found an overall cue validity effect where participants responded to auditory stimuli presented on the same side of the screen as the image faster than trials where the auditory stimuli were presented on the opposite screen of the image. This phenomenon is known as the “crossmodel emotional cue validity effect” and is also evident in spatial cuing paradigms (Posner, 1980) where the attentional processing of visual stimuli is facilitated at the same location an emotional stimuli was presented. This is important to note because the facilitation of a specific location using visual stimuli can overall affect the observations made in studies that look at emotion and visual
search tasks. It is possible that individuals have increasing focus on specific locations in their visual field because they were cued by the emotional stimuli.

Emotional stimuli such as positive and negative images have also been shown to influence the allocation of attention during flanker tasks despite controlling for emotion cue effects of location. The flanker task involves the participant to report on properties of a central item when there are other items around it (known as flankers) with different properties, and is regarded as a measure to focus attention on a relevant item. For example, in the study conducted by Fenske and Eastwood (2003), they presented participants with visual schematic facial stimuli that had different affective expressions (e.g., smiley face for positive and sad face for negative affect). In their experiment, they used a flanker paradigm to test for the broadening or restriction of attentional focus. It has been theorized that positive emotions broadens the scopes of attention while negative emotions restricts attentional focus (Derryberry & Tucker, 1992; Fredrickson & Branigan, 2005; Wadlinger & Isaacowitz, 2006; Fredrickson, 2001). To control for emotion cue validity effects, stimuli were presented at locations that participants knew in advance. During the experiment, participants were exposed to four different trials; a no–flanker baseline trial where a single affective facial stimulus was presented, a compatible trial where flanking items were identical to the target, an incompatible–neutral trial where the affective target was flanked with neutral faces, and an incompatible–affect trial where the target was flanked with the opposite affect (e.g., positive affect targets were be flanked by two negative affect targets). Given the flanker compatibility effect, it was expected that response times for identical flank items were faster and that its effect would vary depending on the target’s emotional expression. Specifically, because negative affect restricts attention, negative faces should have less interference when presented in incompatible flanks compared to positive faces. The results reveal a significant
difference between negative and positive affect faces where the effect of flank compatibility was smaller for negative than positive targets. In other words, the ability to pay attention towards negative stimuli is less affected by interference of other stimuli. This provides support that facial expressions that differ in negative and positive affect plays a role in how attention is focused; in this case negative affect restricts attentional focus while positive affect broadens attention (Fenske & Eastwood, 2003).

There is other evidence that show positive emotions to broaden attention while negative stimuli restrict attentional focus. For example, Derryberry and Tucker (1994) proposed that individuals experiencing positive emotions such as happiness have broadened scopes of attention. Evidence of this proposal stems from clinical research where patients with manic cognitions (high arousal positive emotion) became more creative and applied more global categories in their art.

Additional evidence of positive emotions broadening attention is evident in a study conducted by Fredrickson and Branigan (2005). In their study, they applied a global local visual processing paradigm to evaluate attentional focus.

![Figure 1](image.png)

*Figure 1. An example of the global–local visual processing paradigm*

In global/local tasks, participants are required to judge which two of three figures are more similar, when there is a difference between the overall (global) shape of a figure created
from component elements (the local attributes.) For example, in the figure above (Figure 1), participants were asked to say which of two figures at the bottom was a better match to the figure at the top. If people indicated that the figure on the left (the triangle made of component triangles) was more similar to the figure at the top (a triangle made of component squares) than the figure on the right (a square made of component squares), then that would indicate a global bias. Conversely, if participants indicated that the square made up of component squares was more similar to the triangle made up of component squares that would indicate a local (component) bias. Based on previous studies, personality traits associated with positive emotions (optimism) adopted a more global bias consistent with broadening attentional focus. In contrast, traits such as anxiety and depression related to negative emotions adapted a more local bias consistent with narrowed attentional focus.

Taking this into consideration, Fredrickson and Branigan (2005) wanted to observe how different emotional affective states influence attentional view. In their experiment, they manipulated emotion into positive, negative, or neutral valence using videotaped film clippings. In total, they had five different videos (two positive, two negative, one neutral). Positive videos were of penguins waddling and swimming to elicit amusement and a nature video (e.g., fields, streams, and mountains) to elicit calmness. Negative videos – witness showed an individual being insulted and bullied to elicit anger and disgust and a cliffhanger climbing accident was showed to elicit fear and anxiety. Neutral videos were of sticks falling and piling up. Participants were randomly assigned one of the five clips followed by an immediate completion of the global–local task. As a result, they found a significant main effect of emotion film clips where the positive film clippings reported significantly greater global biases compared to the negative film clippings. From this evidence they concluded that positive emotions to broaden attention.
The notion that positive emotions broaden the scope of attention is supported by the “broaden and build” model of positive emotions (Fredrickson, 2001). According to the “broaden and build” model, positive emotions broaden the scopes of attention, cognition, and action. This leads to the promotion of expanding attention or interest in the environment (Wadlinger & Isaacowitz, 2006).

In 2006, Wadlinger and Isaacowitz evaluated the “broaden and build” model in context of visual attention using an eye–tracking system. In accordance to the “broaden and build” model (Fredrickson, 2001), they hypothesized that participants induced by positive emotions would show greater attentional range as indicated by significantly increased percentage of fixation on peripheral images when compared to control as well as increased fixation towards positive and neutral images and not of negative images. Participants in the positive emotion condition were offered a small bag of candy in the beginning of the experiment in order to induce positive states whereas the control group was offered the bag of candy at the end of the experiment. Participants were then asked to observe a screen (no response tasks were given) that presented real–world images at both central and peripheral fields of the screen. Images were randomly generated and were of positive (6 – 9 score on a Likert scale), negative (1 – 4), and neutral valence (4 – 6) based on the International Affective Picture System (IAPS, Lang et al., 2005). During the experiment, participants were tasked to only observe the screen (no response tasks were given). The eye movements during slide presentations were then tracked and assessed. The results indicated that positively induced participants (that is, the ones given candy before the experimental procedure) reported a significantly greater positive mood than did the control group. This indicates that the positive manipulation was adequate for inducing a short term mood change. Furthermore, the researchers found that during the observation task, the positive emotion
group displayed significantly longer fixation on peripheral stimuli than did the control group (who only received candy after glance durations were measured) and that this increased fixation only occurred for positive and neutrally rated images (in accordance to the IAPS). This observation confirmed their expectations that positively induced participants were expected to show greater eye movements based on higher fixation on peripheral information but only when the images were of positive or neutral valence. The findings are consistent with observations made from Fredrickson and Branigan (2005), where positive emotions were also found to broaden the scope of attention. Together, these experiments support the notion that positive emotions expand attention in positively induced individuals as suggested by the “broaden and build” model (Fredrickson, 2001). However, one important factor the researchers did not address in their first experiment was the potential effects of arousal on attention.

It is possible that valence and arousal have interactive effects on performance. However, many studies confound valence and arousal. Typically, positive emotion is associated with high arousal while negative emotion is associated with low levels of arousal. For example, one limitation of Wadlinger and Isaacowitz (2006)’s experiment is the possibility that participants in the positive group were increasingly more excited (i.e., positive emotion higher arousal) than the control group because they received candy before the experiment while the control group did not. However, they did not control for this possibility but instead decided to do control arousal through their images during their second experiment. Positive and negative visual stimuli selected for the second experiment were now associated with low – moderate ratings of arousal according to the IAPS (Lang et al., 2005). Once again, participants were assigned to a positive mood condition (e.g., candy) or control condition (e.g., no candy) and were asked to look at slides that consisted of positive and negative images. Following the second round of analyses,
the researchers found similar patterns as observed in their first experiment where the positive group displayed significantly longer fixations images presented in their periphery but only towards positive and neutral images. Altogether, based on these results the researchers concluded that the “broaden and build” model is a function of positive affect and not that of arousal.

Overall, past experiments that tested the “broaden and build” model showed positive emotions to influence attentional view (Wadlinger & Isaacowitz, 2006; Fredrickson & Branigan, 2005). However, there were limitations to these studies. Research has shown that positive and negative emotions affecting attention differently; however, the conclusions from Wadlinger and Isaacowitz (2006) were based on a positive and neutral emotion comparison. Wadlinger and Isaacowitz (2006), neglected to include a negative mood condition to observe how negative emotions affected attention. Although the goal of their experiment was to test a model that is based on positive emotions, having a negative emotion condition would have been beneficial for group comparisons. In addition, Fredrickson and Branigan (2005) found increased global biases following positive emotion film clippings, but failed to find support of local bias in their manipulated negative conditions. Altogether, these two experiments only found support for the effects of positive affect compared to neutral affect. The lack of a negative emotion condition does not accurately reflect how overall emotional valence affects attention and performance.

Another limitation of the Wadlinger and Issacowitz (2006) study is that their conclusion about positive emotions broadening the scopes of attention is based on eye–tracking methods or eye–movement behaviour. Though the researchers found increased eye–fixations in the periphery for their positive condition, these eye–behaviours do not necessarily reflect attention towards this information. For example, research has shown that the position of the attentional focus can be relocated faster than the eyes can be moved to different locations (Shulman, 1984; Posner, 1980).
In driving, drivers fail to attend to things that they are looking at, and this gives rise to the “looked but failed to see” collision. In other words, drivers collide with things that they are looking at (White & Caird, 2010). One way to assess whether or not the participant was attending visual information was to have them respond to specific target images. However, given that the participants in this experiment were instructed to only view the visual presentation passively, the conclusion that positive emotions broaden attention is unclear whether the attentional focus was really broadened.

Finally, the conclusions about the function of the “broaden and build” model (Fredrickson, 2001) are of valence and not that of arousal are based on methods that were incomplete. For example, they did not look at the interactive effects of valence and arousal nor did they have a measure to assess arousal ratings. On the other hand, Wadlinger and Isaacowitz (2006) attempted to address the potential confounds of arousal by selecting low – moderate ratings of arousal in their images. However, selecting low – moderate ratings of arousal for the images was not controlling arousal because there is still the possibility of low and moderate levels of arousal affecting attention (by drawing focus towards images that were of low / moderate arousal). In addition, they still confounded positive mood inductions with candy where the unexpected offer of candy could have resulted in an increase of excitement and arousal. Thus, there is the possibility that the positively valenced group were high in arousal. If it were the case that arousal levels were significantly different amongst participants, the conclusion that Wadlinger and Isaacowitz (2006) came to about the “broaden and build” model being a function of emotional valence and not of arousal may be unclear and inaccurate.

In fact, more recent literature shows interactive effects of valence and arousal on attention and performance (Jefferies, Smilek, Eich, & Enns, 2008). Jefferies et al. (2008)
measured how attention was affected by positive and negative emotions that differed in high and low arousal using an attentional blink task (AB). During the attentional blink task, sequences of letters and digits were presented. Each item (letter or number) was presented for 82 ms and participants were instructed to identify all letters they saw by pressing on the corresponding keys. To assess attention, they expected two letters that were separated by 2 or 4 items have reduced second–target accuracy compared to a separation of 8 letters because participants typically fail to attend second targets that occurred rapidly after the first. This pattern is referred to as the attentional blink (Shapiro, Arnell, & Raymond, 1997). Using emotions such as sadness (low arousal, negative affect), calmness (low arousal, positive affect), happiness (high arousal, positive affect), and anxiety (high arousal, negative affect) the researchers observed how these different emotional states affected performance on the AB task. Their results revealed a significant main effect of arousal such that the accuracy rate of identifying a second target immediately followed by the first target was significantly increased for individuals with low arousal emotions (e.g., sad) when compared to high arousal emotions (e.g., anxiety). Researchers also found a significant interaction of arousal and valence, where the effects of arousal were greater in the two negative affect conditions (sad vs. anxiety) while the effects of arousal on the two positive affect conditions were lacking (happiness vs. calmness). Overall, this experiment showed evidence that arousal and valence have different effects on attention. Differences in arousal was shown to have a greater influence on attentional blink (e.g., low arousal conditions have reduced attentional blink than high arousal conditions). In addition, this experiment shows that arousal and valence interact to create unique influences on attention. For example, the effects of arousal were greater when conditions were negatively valenced while the effects of arousal on attentional blink were miniscule when conditions were positively valenced. These
interactive effects are important to keep in mind given that it provides evidence of arousal and valence influencing attention differently.

2.3 Emotion and Driving

Up until this point I have been discussing laboratory tasks, but in my thesis I am interested in driving, a topic with many practical implications as it relates to safety. Driving is a common task that many individuals engage in on a daily basis. The task of driving also requires significant amounts of attention, rapid reactions, and motor skills (Ting, Hwang, Doong, & Jeng, 2008). The strong association between emotion and attention while driving can alter driving behaviour that may result in either positive or negative consequences on the road. Given that drivers encounter many stimuli that can influence emotions within the environment (e.g., music, road users, conversation etc.), and these may influence attention, it is imperative that we have a better understanding on how these different emotional states influence driving. Laboratory research on attention suggests that emotion can affect performance in a variety of attentional tasks, including visual cuing, filtering/focusing tasks (Stroop tasks), and naming items in rapid sequences (the attentional blink paradigm) as discussed in the earlier section. In driving literature, there are several studies that looked at how emotions affect driving behaviour and performance. However, unlike many of the laboratory studies discussed so far, a number of the driving studies do not consider valence and arousal, the sub–components of emotion, but rather focus on discrete emotions such as anger, fear, and sadness. For example, there are studies that look at individual differences in propensity to certain core emotions, such as anger (road rage) (James, 1997; Yu, Chin Evans, & Perfetti, 2004), and fear (anxious drivers) (Barnard & Chapman, 2016), or studies that endeavor to create feelings by having people ruminate on tasks that made them happy or sad.
Studies have shown that specific individuals are more inclined to adopt certain driving behaviours. For example, some people are more inclined to “road rage” (James, 1997), a term used to describe angry drivers on the road as a result of feelings of anger and frustration (emotions defined by negative affect high arousal). Some individuals have a propensity to become angry while driving. Experiences of “road rage” have also been shown to have a reciprocal relationship with aggressive driving. Aggressive driving is defined by increased speeding, weaving in and out of lanes, and violating traffic conditions while on the road (Yu, Chin Evans, & Perfetti, 2004). Yu and colleagues (2004) found that individuals who reported experiencing higher “road rage” were more likely to adopt aggressive driving behaviours. In return, the aggressive style of driving resulted in increasing experiences of “road rage”. These aggressive behaviours in driving have become an increasing concern because of the rise of violent vehicular collisions on a yearly basis (Mizell, 1997).

In contrast, other drivers are more inclined to experience fear and anxiety while driving. Anxiety is a result of feeling threatened with little probability of the threat from actually occurring while fear is a product from the driver knowing that environmental sources are an immediate threat to the self (Barnard & Chapman, 2016). For example, individuals experience fear when they know that they are more likely to be involved in a situation that results in injury or death. In driving environments, it would be the physical danger of collision. Both emotional states of anxiety and fear are defined by negative affect high arousal. While driving, these emotional states can dictate how the driver behaves on the road. For example, previous studies have proposed that anxiety consumes cognitive resources because of the rumination anxious people tend to engage in when completing a task (Eysenck, Derakshan, Santos, & Calvo, 2007). Given that driving requires sustained attention and relatively stable emotional states, anxiety may
result in more dangerous driving behaviours. In a study conducted by Dula, Adams, Miesner, and Leonard (2010), they tested to see if individuals with high trait anxiety were more likely to report dangerous driving behaviours. Their results revealed a significant main effect of anxiety where individuals with higher anxiety (as indicated by the Beck Anxiety Inventory (BAI), Beck et al., 1988) reported significantly more dangerous driving behaviours than did the low and moderate anxiety groups. Specifically, some examples that individuals with high anxiety reported more than the low and moderate anxiety groups include driving while intoxicated, running through stop signs, and at fault crashes. It is also interesting to note that people with high anxiety also reported experiencing anger more than the other two groups. Thus, it is possible that anxious drivers also more likely to experience “road rage” like behaviour on the road.

Emotional experiences of fear have also been shown to influence driving performance and behaviour. For example, Taylor, Deane, & Podd (2007) investigated driving skills in woman who reported having a fear of driving. Given that the predominance of participants that reported having fearful driving were women, the sample group consisted of only female participants. Driving ability was assessed using advanced driving assessment methods where drivers were being observed for 40 minutes while driving on the road. Overall, the fearful group was shown to make significantly more errors while driving than did the control group. Specifically, fearful drivers were more likely to fail using correct lanes, slowing and stopping at appropriate traffic situations, and failing to communicate through signaling.

The studies reviewed to this point focus on individuals who are inclined to specific emotions (anger, fear) perform when driving. It is interesting to note that although anger and fear are both defined by negative affect high arousal emotions, these two emotional states affect driving performance differently. However, the problem with this type of research is that it is not
clear whether the effects arise due to the emotions per se or other individual difference variables. For example, road rage is more common in individuals with Attention Deficit Hyperactivity Disorder (Richards, Deffenbacher, Rosén, & Barkley, 2006). This is evident in previous experiments that examined the relationship between ADHD and driving behaviour. One study found increased self–report of experiencing angry emotions and crash–related outcomes in ADHD participants than non–ADHD groups (Richards et al., 2006). ADHD participants also reported being more angry, risky, and unsafe drivers than did the non–ADHD group. However, it is unclear whether it is the anger/road rage or the ADHD that is causing the problem because ADHD may be associated with higher collision risk (Richards et al., 2006). Similarly, anxious and frightened drivers may differ from other drivers in other ways. For example, anxious driver may be less experienced than other drivers because they may avoid driving. Driving performance improves when individuals practice. Thus, it may not be the anxiety/fear per se that causes the problems but rather the fact that these drivers are less experienced than others that have had their license for the same amount of time. Moreover, anxious drivers are less confident in their driving ability as evident in a study conducted by Chai, Qu, Sun, Zhang, and Ge (2016). In this experiment, they found that people who reported higher anger and trait anxiety scores also tend to report more negative biases when reporting on their own driving ability. It is also important to point out that most driving behaviour studies are assessed using self–report questionnaires. Questionnaires alone are not reflective of real life driving behaviours. Unfortunately, these studies are flawed both by quasi–experimental (individual differences) manipulations and the reliance on subjective self–report measures of performance. Thus, there is a need for experimental studies where emotions are manipulated and the effects are measured in terms of objective measures of actual driving performance.
2.4 Experimental Manipulations of Emotional States in Driving Studies

Because of the shortcomings of the individual differences related research, there are other studies that examine the effects of emotion on driving through the use of experimental manipulations. For example, Jeon and Yim (2011) showed that individuals induced with anger and individuals induced with fear emotions differed in driving performance within a simulated driving environment. Anger and fear were manipulated using a mood–induction task where participants were asked to write down events in their life that were associated with anger and fearful emotional events. Once complete, driving performance was then assessed using a driving simulator. As a result, the researchers found angry drivers made significantly more driving errors than fearful drivers. Specifically, angry drivers made more errors in lane keeping (i.e., deviations from lane) as well as more violations of traffic rules (e.g., speed limit). This is important to keep in mind when examining positive and negative emotions, as differing emotions of negative affect (in this case anger and fear) had different influences in driving.

Similarly, previous driving experiments use other ways to manipulate emotion using auditory and visual stimuli. For example, Chan and Singhal (2015) had people driving in a driving simulator while listening to emotional words to assess driving performance. Emotional words differed in positive, negative, and neutral valence and were all associated with high ratings of arousal. Examples of positive words included laughter, love, and freedom while negative words included abuse, rape, and prison. Neutral words consisted of kettle, foot, and tree. Participants in this experiment performed a dual–task condition where they had to drive and respond by clicking on a button when they heard specific target words (e.g., animal words) as an indication of response time and attention towards target words. Driver speed and lane position (assessed using root mean square error of the driver’s lane position from the centre of their lane)
were used to reflect driving performance. Overall, Chan and Singhal (2015) found significant main effects of word condition on driving speed, lane position, and target response time. For driving speed, individuals listening to emotional negative words drove significantly slower than the neutral (control) and positive word group. Furthermore, negative words were also shown to reduce lateral control (i.e., producing increased steering variability) compared to positive words. When it comes to target response time, the positive word condition had higher mean response times when they heard these target animal words compared to the neutral word condition though differences were not shown between the positive and negative word conditions. Though this study provided insight on how overall emotional valence affected driving performance there were a few limitations. The first limitation is the absence of investigating hazard response time as an assessment of driving performance. Hazard response time is important because it is the variable most associated with driver safety, or more properly risk (collisions). The second limitation of this experiment was the possibility of biases that come with associating words with individual emotional responses. For example, the word “pain” was categorized as a negative word, but it is possible that the subjective emotional response to “pain” may vary in individuals depending on their past experiences with pain. Finally, this experiment confounded valence and arousal. It is unclear whether the effect of driving speed and impaired lateral control was an effect of valence alone or an effect of the interaction between emotional valence and arousal. For example, the negative word torture may elicit higher arousal than the positive word beach. Nevertheless, in addition to auditory stimuli, other methods of emotional manipulation include the use of visual stimuli.

In driving experiments, visual stimuli are typically presented as billboards on the side of the road or on a screen–display within the driving simulator. For example, in the study conducted
by Chan, Madan, and Singhal (2016) they wanted to investigate how taboo–related words differed from positive, negative, and neutral words in terms of driving performance. These words were presented as text on billboards within the driving environments. Taboo–related words were defined as words that were relatively offensive to people in general based on the Janschewitz (2008) normative word database. Taboo words were categorized as highly arousing words while positive and negative words were of moderate arousal. Neutral words were represented as non–arousing. Similar to their previous experiment, they observed driving performance based on driving speed and lateral position.

Overall, they found a significant main effect of word condition on driving speed where the positive word group had significantly greater driving speeds than the taboo, negative, and neutral word conditions. Additionally, word condition also had a main effect on lateral positioning where taboo words had significantly lower variability in their lane keeping than did the positive and neutral word groups. Although there was no significant difference in lateral position between taboo and negative words, a marginal effect was found ($p=0.08$). Although this experiment offered insight on how visual representations of words affect driving performance, it is not really reflective on how emotional valence influences driving. The main limitation of this study was how they categorized their emotional word sets. For instance, taboo related words were of high arousal while positive and negative words were of moderate arousal. Once again, Chan and colleagues confounded valence and arousal. It is unclear if the differences in lateral position were a result of taboo words or a result of high arousal factors in the word.

It is also odd that in the results, the negative word condition displayed higher mean lateral control than did the positive word condition. Although these differences were not significant, it is contradictory to what they previously observed in the 2015 study of emotional auditory words
where negative words had poorer lateral control than did the positive words. These contradictory results may be a result of confounding valence and arousal. In fact, more accurate conclusions about emotional valence on driving performance can be derived from a study by Trick, Brandigampola, and Enns et al. (2012) where they controlled confounding effects of valence and arousal by manipulating these two factors separately in their driving experiment.

In the study conducted by Trick et al. (2012), they observed the effects of valence and arousal on driving performance using images as stimuli. In this experiment, driving performance of 26 participants was assessed using a driving simulator. Images differed in positive and negative emotions at differing high and low arousal ratings based on the IAPS (Lang et al., 2005). In other words, there were four emotion manipulations, positive affect low arousal, positive affect high arousal, negative affect low arousal, and negative high arousal. This design was effective in controlling for confounds in valence and arousal as these factors were manipulated separately. Randomly throughout the drives, participants were expected to indicate whether images presented on a small display in the vehicle were positive or negative by pressing on a button on the steering wheel (after which time the image disappeared). For most images, there was no associated braking event after the button press, but in 1/3 of the trials where there was an image, there was sudden lead vehicle braking which required the driver to make an immediate braking response. The lead vehicle brake occurred either 250 or 500 ms after the button press was completed (in half of the trials where there was lead–vehicle braking there was no preceding image, so lead vehicle braking was not always predicted by images). Driving performance was reflected by steering performance and braking response times to the hazard.

The results were quite complex, insofar as they involved three factors: valence, arousal, and the timing of the post–image braking event (250, 500 ms after the button press was
When it comes to steering performance, Trick et al. (2012) found a significant main effect of valence on steering variability where positive images had significantly lower steering variability than negative images. However, in addition to the main effect of valence the researchers also found interactions between valence and arousal on steering performance where positive and negative images differed in steering variability but only in low arousal conditions. This is consistent with evidence found in Chan and Singhal (2015) study where they found negative words to have poorer lateral control.

In addition, valence and arousal had interacting effects on mean hazard response times. Specifically, when braking event occurred in a short interval (250 ms) after the button press, high arousal positive images significantly reduced brake response times but not for negative images. In contrast, when hazardous events occurred 500 ms after the visual presentation, an interaction between valence and arousal was seen in brake response times where positive images were affected by arousal less than negative images. In both cases, high arousal was associated with increased brake response times. Altogether, these results provide a clearer understanding on how different dimensions of emotion such as valence and arousal affect driving performance. However, the main limitation of this experiment is the use of only central hazards to test for hazard detecting performance. Drivers encounter dangers in both their central and peripheral field of view, and the lack of peripheral events in their simulation is unrepresentative of the real world driving experience. Furthermore, it makes it difficult to investigate one of the implications of the “broaden and build” theory of valence (Fredrickson, 2001), which relates to the spatial extent of the attentional focus. That raises the question of whether valence and arousal affects hazard types differently; one of the research questions that is addressed in the present experiment.
Generally, there are limitations in studies that use auditory words and visual stimuli such as pictures or written words to manipulate emotion, in that these stimuli may be more inclined to have very short-term (fleeting) effects, and indeed, the Trick et al. (2012) study suggests the nature of the effect may even change within 250 ms (250 as compared to 500 ms after the image disappears) when a variety of types of image are presented in each drive. In order to look at longer effects of emotion (i.e., mood), other methods of manipulations are required. In addition, visual stimuli require drivers to take their eyes off the road for a period of time and that in itself may interfere with driving. For example, peripheral vision of the driver is generally associated with lane positioning and lateral control where increasing peripheral view results in better lateral control (van Erp & Padmos, 2003). If visual stimuli are presented in the peripheral view of the driver it may actually influence their overall steering performance. In this case, it was evident in the billboard visual stimuli design used in the study conducted by Chan and Singhal (2016). The presentation of visual stimuli is also typically accompanied with a behavioural response such as a button press to ensure that drivers are actually looking at the stimulus as evident in both the Chan and Singhal (2015) and Trick et al. (2012) experiments. The mere act of button pressing on the steering wheel can influence the driving such as rotating the wheel. Though the button response occurred before a hazard event, there was still a recovery period where participants had to redirect the eye back to the centre of the road and getting their hands back in normal position for steering. The interval between button response and hazard events was also of short duration (250 or 500 ms). When driving, it is also relatively uncommon for individuals to encounter emotional billboards or even taboo words on display on the road. Presenting emotional images on a display within a car is also not reflective of real–world driving. In fact, it is dangerous for drivers to look at images displayed on a screen as it distracts them from looking at the road.
In contrast to studies that investigate the effects of fleeting emotions (briefly presented emotional words or images), this present experiment was designed to look at how long term positive and negative emotions (i.e., mood) affects driving performance as it relates to mean driving speed, steering and hazard response time. Taking the limitations of visual stimuli into consideration, other methods of manipulating emotion need to be implemented; stimuli that does not require drivers to look away from the road and is able to sustain emotional inductions for long periods of time. As a result, the present study used music as a way of manipulating emotions while driving.

There are many advantages in using music stimuli compared to auditory words and visual stimuli. Music does not require drivers to divert their eyes away from the road to process emotional information nor does it require a behavioural response to ensure that it was “looked at” or “listened to” (i.e. there is no need for the participant to make an overt response to the stimulus). Typically, in real driving situations, drivers don’t have to make a response to every word they hear or every picture they see. Listening to music is also the most common activity done when driving (Ünal, De Waard, Epstude, & Steg, 2013) thus, making it more likely to be a factor in actions of daily driving. Most importantly, music is able to produce the long–term effects of positive and negative emotion manipulation while driving.

2.5 Experiments that use Music to Manipulate Emotion

Literature on music and emotion examined how various properties of music affects driving performance in terms of mode (major vs. minor key), tempo (speed), and intensity (volume). In a study by Pêcher et al. (2009), they used music to manipulate emotion into positive and negative states. Emotional music was used to induce positive and negative mood. Positive
and negative music was characterized by differences in music key and music tempo (speed). Happy music was associated with major keys and fast tempo while sad music was associated with minor keys and slow tempo. Using these manipulations, participants were then exposed to a driving task using a driving simulator and listened to one of the three music conditions as a within factor (happy, sad, and no music). Driving performance was assessed by the participants’ ability to control their driving speed and steering. They argued that individuals who drive in a positive mood (i.e., happiness) have an expanded attentional focus and increased reckless driving due to higher reports of self-confidence. In contrast, individuals who experience negative mood (i.e., sadness) engage in a more passive style of driving defined by slower driving because attentional resources are redirected to the self. Overall, their experiment showed that during happy music, drivers tend to drive in a more reckless manner compared to sad music. Specifically, happy music had significantly higher differences in their mean driving speed (e.g., more variation in speed) as well as more deviations from their lane position compared to the sad and no music groups.

Although the researchers in this study found support for their hypotheses, there are a couple of limitations that they did not consider in their experimental design. Similar to previous experiments on emotion in driving, this experiment failed to implement hazard detection as an assessment of driving performance, an important factor in safety. When it comes to emotional music stimuli, the researchers confounded music key with music tempo to create happy and sad songs. Music mode (e.g., major and minor key) has been shown to successfully induce positive and negative emotions (Gomez & Danuser, 2007). On the other hand, music tempo is associated with different levels of arousal where slower tempos decrease arousal while fast tempo increases arousal (Gomez & Danuser, 2007; Husain et al., 2014). Ultimately, it is unclear if the
observations seen here were an effect of emotional valence or of arousal given that music key and music tempo was confounded. Furthermore, music enjoyment could also have influenced overall perceived valence. For instance, although individuals listened to all three music conditions at some point during the drive, if they did not enjoy listening to the music stimuli at all, this would affect their overall emotional state. Similarly, the level of familiarity could have also influenced how much attention was directed towards the stimuli. Research has shown that individuals exposed to novel stimuli paid more attention to this information as opposed to familiar information (Johnston et al., 1990). The researchers would be able to observe these complicating effects by monitoring familiarity and music enjoyment through self-report scales at post-tests.

While driving, this diversion of attentional resources towards novel music stimuli can affect overall driving performance (e.g., less attention paid on the road), there is also a complicating variable with the lyrics of the song and emotional valence. All music stimuli in this experiment had lyrics and lyrics may have complicated emotional response and behaviour (Eerola, 2012). In addition to music mode, previous experiments have shown that arousal is affected by music tempo and intensity.

Music tempo has been shown to be associated with both subjective and objective measures of arousal as evident in a study by Gomez and Danuser (2007). Here, they examined how different properties of music influences emotional valence and arousal. They found an association between fast tempo music and higher levels of self-report arousal as well as increasing heart rate. Arousal has been shown to also be affected by differing music intensities (e.g., loud vs. moderate volumes) where loud volumes of music increased mean heart rate (Ünal et al., 2013). In a study conducted by Ünal et al. (2013), they investigated how music volume
affects arousal and driving performance in monotonous (boring) environments. During the drives, participants listened to either music that was manipulated into loud (85 dB) or moderate (70 dB) volumes or no music at all. They hypothesized that when listening to loud music, arousal levels would increase as reflected by increased heart rate. As a result, when it comes to physiological measures of arousal there was a main effect of music volume, where individuals in the loud music group had higher mean heart rate than people listening to moderate volumes of music. For driving performance, researchers found that the two conditions of music (listen to music, no–music) had no significant differences in mean response times to central hazards. This indicates that although listening to music is a secondary task while driving, it does not impair driving performance when compared to not listening to music.

Overall, previous experiments have shown that music can successfully manipulate emotional valence as well as emotional arousal while driving, though it has never been successfully accomplished in a single experiment. For example, in the study by Pêcher et al. (2009) they were able to produce positive and negative conditions by categorizing music keys into major and minor mode. Similarly, the association between music valence and music key was found in the study by Gomez and Danuser (2007). Furthermore, Gomez and Danuser (2007) found an association with fast music tempo and increased subjective self–report arousal and objective physiological monitoring such as heart rate. The effects of music intensity was also shown to affect arousal such that loud volumes increased heart rate as shown by Ünal et al. (2013).

Though there are previous experiments that music to induce different emotions in driving, it is unclear whether the effects of emotion are based on valence or of arousal because most studies that use music confound music key with music tempo. As evident in Pêcher et al.
happy music was confounded with major key and fast tempo while sad music was
confounded with minor key and slow tempo. Given that research on emotional valence and
driving has only been conducted in recent experiments (Chan & Singhal, 2015; Chan et al., 2016;
Trick et al., 2012), further research is needed to examine how valence affects driving
performance. Thus, the present experiment was designed to manipulate valence and control
arousal to observe how it affects driving performance in mean driving speed, steering
performance, as well as hazard detection for both central and peripheral hazards.

2.6 Present Experiments

In these studies, our goal was to manipulate emotional valence while controlling arousal
arousal, in order to determine how valence and arousal affects attention and driving performance
differently. We did this by manipulating music mode (major, minor) to create different emotions,
while controlling arousal by holding music tempo, and intensity relatively constant. Specifically,
positive and negative music conditions can be induced through major and minor keys
respectively (Pêcher et al., 2009; Gomez & Danuser, 2007) while arousal can be controlled by
having a controlled music tempo presented at a relatively comfortable listening volume
(Brodsky, 2002; Ünal et al., 2013). Given that most driving commutes of driving can last up to
an hour long, it is important to observe how long term emotional states (i.e., mood) can influence
driving behaviour and performance. In this study we controlled arousal instead of manipulating
it, although it would be better because manipulating valence and arousal in the same music
would enable us to look at interactions. However, it was not feasible to do this when using music
to manipulate emotion. That is because certain combinations of valence and arousal are rare in
music. For example, it is difficult to find positive low arousal music or negative high arousal
music. Both slow–paced happy music and fast–paced sad music may actually sound humorous or
bizarre to listeners. For example, imagine listening to the Waltz of the Flowers from "The Nutcracker" (Tchaikovsky) in a slow tempo of 40 – 70 bpm. It is much easier to find music that is happy (positive high arousal) and sad (negative low arousal) and hence the common confound of valence and arousal in music studies. Keeping this in mind, music with natural moderate tempos was adopted for both the major and minor key (positive and negative valenced) stimuli.

Altogether, the present experiments used music to look at how long term positive and negative emotions affects a broader range of driving behaviours such as driving speed, steering variability, as well as hazard detection.

An initial music pilot experiment was conducted to ensure that the selected music stimuli was able to produce the desired emotional states (e.g., positive and negative mood) as well as control arousal. Participants were assigned to one of two music conditions, major key to induce positive affect and minor key to induce negative affect. Although the music was intended to manipulate valence and control arousal, the initial music pilot experiment failed to produce strong effects of valence with musical key alone and this is further supported by previous meta–analyses (Lench, 2010). The first music pilot study also found differences in arousal which was unpredicted. Hence, a second pilot study was administered that involved a mood induction task and music manipulations to create a stronger effect of valence. The combination of a mood induction task and music stimuli have been shown to be an effective method of manipulating valence (Jefferies et al., 2008).

In both music pilot experiments, we did not allow people to choose their own music because research showed driver preferred music (i.e., music brought from home) to significantly increase driving deficiency in young novice drivers. Such driving behaviours included violation
to traffic instructions, aggressive driving, and delayed response times (Brodsky & Slor, 2013). Participants choosing their own music may also experience stronger emotions and higher arousal and pleasure (Eerola, 2012). Therefore, by preventing participants from bringing their own music there would be no driving violations associated with driver preferred music.

In terms of the driving experiment, it was designed to examine how long term positive and negative emotions affects driving performance while controlling arousal. When looking at the effects of emotional valence on driving performance, we looked at effects on driving speed, steering performance, and hazard response (braking response to hazards) as measured in a driving simulator. Interestingly, there is some suggestion that different attentional mechanisms govern steering and hazard response (braking response times to hazards). According to Wickens’ (2002) theory, there are two different attentional mechanisms involved in driving: ambient and focal attention. Ambient attention is involved in controlling the body’s position in space, and is related to steering (lateral control of the vehicle position), as measured by Standard Deviation of Lateral Position (SDLP), with better steering performance associated with a smaller amount of variability in the position of the centre of the vehicle as compared to the centre of the lane. This type of attention does not require fine detail (or the fovea) and is not as closely related to eye movements.

In contrast, focal attention involves object recognition and visual search, abilities important for recognizing and responding to hazards. Focal attention requires intimate eye movements to place information in the fovea of the eye (the part most sensitive to fine details) in order to distinguish one object from the other, as is necessary for recognizing obstacles or driving hazards. Hazard response performance is often measured by braking response times. In
other words, this means how long it takes for the driver to respond to an event on the road using the brakes of the vehicle.

The evidence for the difference between the ambient and focal systems rests on studies that show that variables can have different effects on steering and hazard response (braking). Higgins et al. (1998) showed that reducing drivers’ visual acuity to 20/200 by having them wear special goggles had no effect on their steering performance, but it had a substantial effect on their hazard response times. In fact, most experienced drivers seem to use peripheral vision to drive, and do not move their eyes back and forth between the margins of the road in order to steer (Summala, Nieminen, & Punto, 1996; Summala, Lamble, & Laakso, 1998). However, although acuity does not seem to be important in steering, the breadth of the visual field does seem to have an effect. Previous research that tasked participants to drive using different field of vision cameras showed that cameras with a wider span of vision (e.g., increased peripheral vision) lead to better lateral control and lower steering variability whereas decreasing the focus decreases had the opposite effects (van Erp & Padmos, 2003).

Based on observations found from laboratory and driving tasks, because arousal is being controlled for through music tempo, we expected mean driving speed to not differ between music induced valence groups.

As for steering performance, given that positive emotions broaden attention and expand periphery vision according to the “broaden and build” model of positive emotions (Fredrickson, 2001), it was expected that drivers induced with positive emotions would have better steering performance compared to the negative and no–music control group. (van Erp & Padmos, 2003; Fredrickson & Branigan, 2005; Wadlinger & Isaacowitz, 2006). Given that this present
experiment included both central and peripheral hazards and that positively valenced states broadens attention, it was expected that positive emotion would reduce response times for peripheral hazards but not central hazards. Conversely, given that negative emotions narrows attentional focus it was possible that they may be faster at detecting central hazards than the positive and control groups. However, at this time, there is very little literature that supports this, which is hardly surprising because the full range of emotional valence has never been explored (positive to negative) and furthermore, the central/peripheral distinction in hazard detection has never been investigated in studies of emotion and driving. Even the original studies that looked at emotional valence on attention such as Wadlinger and Isaacwotz (2006) only looked at positive and neutral valence. Fredrickson and Branigain (2005) failed to see evidence of narrowed attention in the negatively valenced group as a lack local–bias response from the negative emotion group based on the global–local task. The only other study that did look at negative emotions was done by Trick et al. (2012) however, that study only looked at central hazards and this effect was an interaction between valence and arousal. Negative affect low arousal reduced response times while negative affect high arousal increased response times. These observations were also dependent on the amount of time between the image in question and the hazard event (250 as compared to 500 ms). Given that this experiment was designed to control arousal by keeping it constant at a moderate tempo, it is unclear how negative emotions with a moderate level of arousal may affect central hazard response times.

Nevertheless, the following text is divided into three separate sections. An initial music pilot experiment that showed musical key alone was not strong powerful enough to manipulate valence. A second music pilot study designed to test the power of the mood induction task and
music to manipulate valence and control arousal, followed by a driving experiment designed to observe how long term positive and negative emotions affects driving using a driving simulator.
The first pilot experiment was designed to test music that was relatively unfamiliar and instrumental, and could control arousal between the positive and negative music groups. Therefore, instrumental music from video game soundtracks was selected to make most the participants unfamiliar with its music. Previous literature on music has shown that the key or the mode of a musical piece can induce positive and negative moods within participants such that major keys typically create positive moods while minor keys generally induce negative moods (Gagnon & Peretz, 2003; Husain et al., 2014; Pêcher et al., 2009). Thus, for the purpose of this experiment, music was divided into two different groups based on its mode; major keys were used for positive music and minor keys were used for negative music. Music tempo and music volume were also kept constant in order to hold arousal constant. Keeping music tempo at a moderate tempo (range of 85 – 110 beats per minute) and music volume at comfortable volumes arousal can be controlled, an appropriate strategy given that faster paced music increases arousal, while slow tempo decreases arousal (Gomez & Danuser, 2007) and louder volumes increase arousal (Ünal et al., 2013).

To ensure that my music manipulation was successful in influencing perceived valence while at the same time controlling arousal, emotional valence ratings were administered before and after music presentation (pre–test and post–test) to serve as a manipulation check. The Positive and Negative Affect Schedule (PANAS) inventory (Watson, Clark, & Tellegen, 1988) was administered at pre and post–tests to assess positive and negative affect as it has been shown to be an affective measure of perceived valence. The PANAS (Watson et al., 1988) is comprised of 20 adjectives, 10 for each positive and negative affect scales.
Based on the PANAS inventory (Watson et al., 1988), participants in the major key music group were expected to report an overall increase of positive emotions and decrease of negative affect at post–measures while the minor key music group showed opposite trends, decrease of positive affect scores and increase of negative affect scores respectively. Because music tempo and intensity was being controlled (held relatively constant), it was anticipated that arousal levels would show no significant differences between music groups. A self–report Likert scale to measure how familiar the participant was with the music was also included to control for potential complicating effects and to ensure that music stimuli was relatively unfamiliar. The lowest value of the scale indicated “Not at all familiar” while the highest value indicated “Extremely familiar”.

3.1 Method

Design

A mixed design was used to compare the perceived valence scores of the two manipulated valence music groups (major, minor) at pre–test (pre–test positive affect, pre–test negative affect) and post–test (post–test positive affect, post–test negative affect), as well as self–report arousal ratings. Scores of positive affect and scores of negative affect were added separately by summing the scores on items that represented positive or negative affect respectively using the PANAS (Watson et al., 1988). In addition, further analysis was conducted to observe the potential complicating factor that music familiarity had on perceived valence scores. If music familiarity was shown to affect perceived valence scores, an analysis of covariance (ANCOVA) was used for analysis.
Participants

In this small pilot study, a between groups design was administered. 12 students (5 male, 7 female) of the University of Guelph ranging from 18 to 28 years, with a mean age of 18.75 (SD=2.09) participated in this experiment in exchange for course credit. Participants were recruited through the University of Guelph’s Psychology Department Research Pool System (SONA) and informed consent was obtained from all participants in accordance with the Research Ethics Board of the University of Guelph.

Apparatus and Stimuli

To prevent potential complicating effects triggered by the context of the music such as emotional cues associated with certain phrases, words, or beliefs, non–lyrical and instrumental music was selected for this experiment (Eerola, 2012). Music was selected from video game soundtracks, in particularly the Final Fantasy Piano Collections Albums (SQUARE ENIX CO., LTD, 1994 – 2004) in an attempt to make the majority of the participants unfamiliar with the music (see Appendix A). All prospective music was played using one instrument, the piano, and was classified into positive and negative conditions using their mode. Major keys represented positive affect while minor keys represented negative mood. To maintain and control arousal, all music stimuli were adjusted using the Audacity software to a moderate tempo range (85 – 110 beats per minute). Given that music intensity (i.e., volume) affects arousal (Ünal et al., 2013) with loud volumes associated with high arousal, all music were played at a comfortable level of volume (as indicated by the participant) through an acoustic noise–cancelling headphone (Bose Quiet Comfort 15) connected to a laptop using Windows Media Player. Code letters were used to replace music titles in case of potential influences the title of the music piece may have on
perceived valence. This method was recommended by previous literature to eliminate potential response bias (Eerola, 2012).

Self-report questionnaires were administered to participants prior to the experiment including items about demographics, musical history, mood, arousal etc. Demographics included questions about age and gender while music history included items that asked how frequently the participant listened to music on a daily basis and their overall formal training with music. Perceived valence was assessed through two separate scores, a positive affect score and a negative affect score using the PANAS inventory (Watson et al., 1988). There were 10 adjectives that represented positive affect (e.g., interested, excited, strong, enthusiastic, proud, alert, inspired, determined, attentive, and active) and 10 adjectives that reflected negative affect (e.g., distressed, upset, guilty, scared, hostile, irritable, ashamed, nervous, jittery, and afraid). Participants scores ranged from 10 – 50, with higher scores representing higher levels of the positive or negative affect (e.g., a score of 40 on negative affect indicated a high level of negative affect). These two scores of positive and negative affect were compared between music group (major vs. minor) at both pre-test and post-test. Post arousal was assessed using a 1 – 7 Likert scale. The full detail of the pre-test questionnaire package can be found in Appendix B. In addition, participants were also asked about their music familiarity using a scale of 1 – 7 to control for potential complicating effects. The items used in the post-test questionnaire can be found in Appendix C.

Procedure

Prior to the experiment participants were assigned to either a major key music condition or a minor key music condition using a random number generator. After obtaining informed
consent, participants were administered a self–report questionnaire that measured perceived valence and arousal, and other general questions about demographics and music talent. Once the initial self–report questionnaire package was complete, participants were then instructed to listen to approximately 30 minutes of music through the use of headphones.

Once participants finished listening to music and after completing the final self–report assessments, participants were debriefed. The total time to complete one session was approximately 60 minutes.

3.2 Results

An alpha level of .05 was used for evaluating significant results. Perceived valence consisted of two separate scores, positive affect and negative affect, and was assessed at two separate times (pre–test and post–test) between the two music groups (major vs. minor music) using separate one-way analysis of variances (ANOVA). To clarify, perceived valence was compared between music groups using one-way ANOVAs for pre–test positive affect and pre–test negative affect, and another one-way ANOVA for post–test positive affect, and post–test negative affect. One–way ANOVAs were used to assess pre–test and post–test arousal scores between music groups as well.

*Pre–test analyses of Positive Affect, Negative Affect, and Arousal scores*

This first set of analyses were conducted to find out whether the random assignment worked, so that there were no differences between the two music groups (major vs. minor) at pre–test positive affect, pre–test negative affect, and pre–test arousal. If there were significant differences, analysis of covariance was then conducted to covary out these effects.
One-way ANOVA was used to compare pre–test perceived positive affect and pre–test negative affect scores between the two music conditions (major and minor music). The analyses revealed no significant differences for pre–test positive affect scores between the major music and the minor music conditions, $F(1,10)=.22$, $p=.65$, as expected from randomly assigning participants into their music groups (see Figure 2). Surprisingly, it was odd to find significant pre–test negative affect scores differences between the two music groups, $F(1,10)=5.56$, $p=.04$, $\eta^2=.36$, where the major music group reported significantly lower perceived negative affect scores ($M=13.5$) than the minor music group ($M=18.5$) (see Figure 3). This indicated that the random assignment was not successful at controlling random error. One-way ANOVA was used to assess pre–test arousal scores, and results indicated no significant differences, $F(1,10)=.04$, $p=.84$ (see Figure 4).

**Covariates**

A bivariate correlational analysis was used to examine whether or not music familiarity affected post–test perceived positive affect, post–test perceived negative affect, and post–test arousal scores. Overall, analysis revealed no significant correlation between music familiarity and post-test perceived positive affect ($r(10)=-0.29$, $p=.45$), post-test perceived negative affect ($r(10)=0.30$, $p=.44$), and post-test perceived arousal ($r(10)=0.18$, $p=.64$).

**Post–test analyses of Positive Affect, Negative Affect, and Arousal scores**

Given that pre–test analysis revealed negative affect to significantly differ between music groups, ANCOVA was used for the following analyses using pre–test negative affect as a covariate. ANCOVA was used to compare perceived positive affect, negative affect, and arousal scores at post–tests between the music groups (major vs. minor).
The analyses revealed a marginal difference for post–test positive affect scores between the major music ($M=29.83$) and the minor music ($M=21.67$) conditions, $F(1,9)=4.58$, $p=.06$, indicating that the music failed to produce the expected valence inductions. In this case, the music failed to significantly increase positive affect scores for the major music group (see *Figure 5*). Similarly, no significant differences were found for post–test negative affect between the music groups, $F(1,9)=1.02$, $p=.34$, indicating that the music failed to induce the expected negatively valenced state (see *Figure 6*).

Furthermore, analysis revealed a significant difference of post–test arousal between the two music groups, $F(1,9)=6.60$, $p=.03$, $\eta^2=.42$. Given that this experiment was designed to keep arousal relatively constant, the significant differences found between music groups on post–test arousal failed to produce the desired effects (see *Figure 7*).

### 3.3 Discussion

Overall, this pilot experiment was designed to confirm that the selected music stimuli were able to produce the expected effects of perceived valence and arousal. The results indicated that although the music selected for inducing positive affect showed a trend in higher post–test perceived positive affect for the major music group compared to the minor music group, it failed to induce negative emotions as reflected by the post–test negative affect scores. This indicated that the music stimuli selected for this pilot experiment was not effective at manipulating valence. This may be due to the fact that manipulating valence using musical key alone was not a powerful method as indicated by previous meta–analyses (Lench, 2010). In past literature, music was used in combination with another task to successfully manipulate valence. For example, in the study conducted by Jefferies et al. (2008), they used the combination of both music and a
mood induction task to successfully manipulate valence. Taking this into consideration, this method was adopted for the upcoming second pilot experiment to create a more powerful method of manipulation of valence.

In addition to attempting to manipulate valence into positive and negative groups, this experiment was also designed to control arousal through music tempo. Research suggests that music tempo governs arousal such that arousal increases as music tempo increases. Thus, in order to control arousal between major and minor music, moderate tempos of music were selected. However, despite controlling for music tempo and the duration of the task being the same for both conditions, results showed a significant group difference for post–test arousal scores (arousal not controlled). The difference in post–test arousal scores may have been affected by the range of tempo used for the music stimuli (85 – 110 beats per minute). The range of music tempo may have influenced arousal due to the variation of moderate tempos between the different music pieces selected. Thus, it is important to note this for future studies to try to maintain tempo at a constant value as opposed to a range of moderate tempos, to avoid possible variations between musical pieces.

Nevertheless, the first pilot experiment indicated several important things. First, this pilot experiment showed musical key alone was not powerful enough to successfully manipulate valence and that a mood induction task is needed in order to increase effect size. Moreover, this suggests that it would be beneficial to include a mood induction. Furthermore, the goal of this experiment was to keep arousal constant between the positive and negative music, and the selected music did not seem to produce the desired effects. Thus, stimuli needed to be changed and tested. Taking all of these factors into consideration, a second pilot experiment was conducted using different sets of music to determine whether adding a mood induction task and
using music that has been used in other published studies on the effects of valence would make it possible for us to manipulate perceived valence while keeping arousal relatively constant as desired.
Chapter 4 – Music Experiment – Pilot Study #2

The second music pilot experiment was designed to address the limitations found in the first music pilot experiment by implementing a mood induction task and selecting entirely new music stimuli from those in published articles on music valence. Given that the previous pilot experiment showed musical key alone was not a strong enough manipulation of valence with supporting evidence from previous literature that showed music induced valence to have small effect sizes (Lench, 2010), it was hoped that mood induction in combination with music modality would engender a more powerful manipulation of valence. The mood induction task was administered prior to music presentations to initiate the intended valence manipulation. During the mood induction task, participants were instructed to recall certain events that were related to the music condition they were placed in (e.g., participants in the major key music group were instructed to think of happy events while the minor key music group were instructed to think of sad events). Music was then presented to keep the manipulated mood ongoing for a longer duration period especially given that the proposed driving experiment was a long driving task. This method of manipulating valence was based on previously published literature that was successful at manipulating perceived valence using both music and mood inductions (Jefferies et al., 2008). Thus, this present experiment was designed to confirm whether combining mood inductions and music were able to produce the effects of perceived positive and negative emotions while controlling arousal.

Similar to the first music experiment, music stimuli that have been shown by previous literature in successfully producing desired valence effects were divided into two different groups of major key (positive affect) and minor key (negative affect). As for arousal, given that this experiment was designed to hold arousal constant, music tempo and volume were relatively
constant between musical selections, an appropriate strategy given that faster paced music
increases arousal, while slow tempo decreases arousal (Gomez & Danuser, 2007) and louder
volumes increases arousal (Ünal et al., 2013). Unlike the first pilot experiment that used a range
of tempos to control arousal (e.g., 85 – 110 bpm), this experiment kept tempo constant at an
average single value of 90 bpm and presented the music at comfortable volumes as indicated by
the participant (e.g., moderate intensity).

To confirm that the music and mood induction task were successful in influencing
valence while at the same time controlling arousal, perceived emotional valence ratings were
recorded before and after music presentation (pre–test and post–test) to serve as a manipulation
check using the PANAS inventory (Watson et al., 1988).

Based on the PANAS inventory (Watson et al., 1988), participants in the major key
music group were expected to report an overall increase of positive emotions and decrease of
negative affect at post–measures while the minor key music group showed opposite trends,
decrease of positive affect scores and increase of negative affect scores respectively. Because
both music tempo and volume was controlled (held relatively constant), we anticipated that
arousal levels remained the same between music groups. Furthermore, two Likert scales were
administered to assess music familiarity and music enjoyment, where the lowest value indicated
“Not at all” and the highest value indicated “Extreme”. Given that how familiar the individual
was to the stimuli and how much they enjoyed listening to the music may have an effect on their
perceived valence, these measurements were included to control for potential complicating
effects through analyses.

4.1 Method
Design

The design of this experiment was similar to the previous pilot experiment. Perceived valence scores at pre–test (pre–test positive affect, pre–test negative affect) and post–test (post–test positive affect, post–test negative affect), as well as self–report arousal ratings were compared between the two manipulated valence music groups (major vs. minor music). The sum of the positive affect and negative affect scores were added separately by summing the scores on items that represented positive or negative affect respectively on the PANAS (Watson et al., 1988). In addition, further analyses were conducted to examine whether music familiarity and music enjoyment influenced post–test perceived valence. In the case that these factors did influence perceived valence, they were used as covariates in ANCOVA.

Participants

In this small pilot study, a between groups design was administered to 12 participants (5 male, 7 female) of the University of Guelph ranging from 18 to 28 years, with a mean age of 21.83 (SD=2.89). All 12 participants were recruited through the distribution of an approved advertisement that was forwarded to students through email. Physical copies were also posted all around campus of the University of Guelph. At the initial form of communication, all participants were informed that was no compensation for participation and those that were still interested were scheduled in for a session. Informed consent was obtained from all participants in accordance with the Research Ethics Board of the University of Guelph.

Apparatus and Stimuli
To prevent potential complicating effects triggered by the context of the music such as emotional cues associated with certain phrases, words, or beliefs, non–lyrical and instrumental music was selected for this experiment (Eerola, 2012). All music stimuli came from published literatures that were successful at producing significant valence effects (Jefferies et al., 2008; Jeong & Yim, 2011). Music stimuli were all classical genre and were classified into positive and negative conditions based on their key signature. Major keys were used to induce positive mood while minor keys were used to induce negative mood. Music tempo was kept constant at 90 bpm to control arousal using the Sonar 6, Producer Edition (Cakewalk, Inc., 2016) software. A total of 12 music pieces were used and the full list can be seen in Appendix D.

Music stimuli were all coded with letters in case of potential influences the title of the music piece may have on perceived valence. This method was recommended by previous literature to eliminate potential response bias (Eerola, 2012). Given that music intensity (i.e., volume) affects arousal (Ünal et al., 2013) with loud volumes associated with high arousal, all music was played at a comfortable level of volume (as indicated by the participant) through an acoustic noise–cancelling headphone (Bose Quiet Comfort 15) connected to a laptop using Windows Media Player.

The same pre–test self–report questionnaires from the previous pilot experiment were administered to participants that asked about demographics, musical history, mood, arousal etc. Refer again to Appendix B for full details of the pre–test questionnaire package. However, for post–test questionnaires, this present experiment also included an additional scale that assessed music enjoyment using a scale of 1 – 7 to control for potential complicating effects. The items used in the post–test questionnaire can be found in Appendix E.
Procedure

Prior to the experiment participants were assigned to either the major key music condition or the minor key music condition using a random number generator. After obtaining informed consent, participants were administered a self–report questionnaire that measured perceived valence and arousal, and other general questions about demographics and music talent. Once the initial self–report questionnaire package was complete, participants were then instructed to perform a mood induction task where they had to recall events in their life related to the condition that they were in. For example, participants assigned to the major key music condition were instructed to think about events in their life that made them happy, while participants in the minor key music group were asked to think about events in their life that made them sad. Instructions researchers used for the mood induction task can be found in Appendix F. Participants were encouraged to think of these events as they were listening to approximately 30 minutes of music stimuli using headphones.

Once participants finished listening to music and after completing the final self–report assessments, participants were debriefed. The total time to complete one session was approximately 60 minutes.

4.2 Results

An alpha level of .05 was used for evaluating significant results. Perceived valence consisted of two separate scores, positive affect and negative affect, and was assessed at two separate times (pre–test and post–test) between the two music groups (major vs. minor music) using one-way ANOVAs. To clarify, perceived valence was compared between music groups using one-way ANOVAs for pre–test positive affect and pre–test negative affect, and another
one-way ANOVA for post–test positive affect and post–test negative affect. One-way ANOVAs were used to assess pre–test and post–test arousal scores between music groups as well.

Pre–test analyses of Positive Affect, Negative Affect, and Arousal scores

This first set of analyses were conducted to find out whether the random assignment worked, so that there were no differences between the two music groups (major vs. minor) at pre–test positive affect, pre–test negative affect, and pre–test arousal. If there were significant differences, analysis of covariance was then conducted to covary out these effects.

One-way analysis of variance was used to compare pre–test perceived positive affect and pre–test negative affect scores between the two music conditions (major and minor music). Contrary to predictions, analyses revealed a significant difference for pre–test positive affect scores between the major music and the minor music conditions, $F(1,10)=5.15$, $p=.05$, $\eta^2=.34$, where the major music group ($M=23.33$) reported significantly lower perceived positive affect scores than the minor music group ($M=32$) (see Figure 8). This was unexpected given that randomly assigning participants into their music groups was supposed to eliminate random error. However, no significant difference was found in the pre–test negative affect scores between the two music groups, $F(1,10)=3.01$, $p=.11$ (see Figure 9). Together these results indicated that random assignment of participants in their groups was not successful at controlling random error within a small sample size ($n=12$).

One-way analysis of variance was used to compare pre–test arousal scores between the two music groups. Given that these were pre–test arousal scores, it was expected that arousal scores would not differ significantly between groups. As expected, results showed no significant
differences of pre–test arousal between the major and minor music condition, $F(1,10)=2.55$, $p=.14$ (see Figure 10).

**Covariates**

A bivariate correlational analysis was used to examine whether or not music familiarity and music enjoyment affected post–test perceived positive affect, post–test perceived negative affect, and post–test arousal scores.

Overall, analysis revealed no significant correlation between music familiarity with post-test perceived positive affect ($r(10)=-0.20, p=.53$), post-test perceived negative affect ($r(10)=0.13, p=.69$), and post-test perceived arousal ($r(10)=-0.42, p=.18$). However, it was surprising to find a significant positive correlation between music enjoyment and post–test perceived positive affect scores ($r(10)=0.80, p < .01$) though no significant correlations were found for post-perceived negative affect ($r(10)=-0.33, p=.29$) and post-test perceived arousal ($r(10)=0.28, p=.38$). Taking this into consideration, the following analysis used ANCOVA to compare post–test perceived valence between the two music conditions while using music enjoyment as a covariate.

**Post–test analyses of Positive Affect, Negative Affect, and Arousal scores**

Given that pre–test analysis revealed positive affect to significantly differ between music groups and music enjoyment being a complicating factor in perceived valence, ANCOVA was used for the following analyses. When analyzing post–test positive affect scores, ANCOVA was used to co–vary out the effects of pre–test positive affect and music enjoyment. As for comparing post–test negative affect and post–test arousal, only the effects of music enjoyment were co–varied out to maintain higher statistical power (more degrees of freedom).
Unexpectedly, ANCOVA revealed no significant differences for post–test positive affect scores between the major music ($M=17.5$) and the minor music group ($M=30$), $F(1,8)=1.99$, $p=.20$. The lack of perceived positive affect differences between groups showed that the mood induction task and the major music stimuli failed to produce the effects of positive mood (see Figure 11). In contrast, predictions were confirmed when a significant difference was found for post–test negative affect scores, $F(1,9)=6.93$, $p=.03$, $\eta^2=.44$, where the major music group reported significantly lower perceived negative affect scores ($M=14.17$) than the minor music group ($M=18.17$) (see Figure 12). These results indicated that the mood induction task and the minor music stimuli were successful at producing the effects of negative emotion. Altogether, these findings indicated that the experimental design partially successfully manipulated valence into their expected outcomes (e.g., minor music inducing negative mood).

In addition, ANCOVA was also used to analyze post–test arousal scores between the two music groups using music enjoyment as a covariate. As predicted, results revealed no significant differences in post–test arousal, $F(1,9)=1.78$, $p=.22$ (see Figure 13). Because there was no significant difference between the two music groups (major vs. minor) the results confirmed that arousal remained relatively constant.

### 4.3 Discussion

Overall, the pilot experiment was designed to confirm whether the combination of the mood induction task and music was able to effectively manipulate perceived valence while keeping perceived arousal relatively constant. Based on initial analyses, the results showed a significant difference of pre–test positive affect scores between the major and minor key music groups. The results revealed individuals in the minor music group felt generally more positive
emotions than the participants in the major music group before mood manipulation. Although this pattern was seen in the pre–test positive affect scores, the result was not the found for pre–test negative affect scores. The group differences in perceived positive affect scores before mood manipulations may have influenced the post–test positive affect scores where participants in the minor music group reported higher mean post–test positive affect scores when compared to the major music group. In other words, individuals who felt generally more positive emotions continue to remain positive despite mood and music inductions. It may be due to the fact that it was more difficult to induce negative moods in individuals who initially report high positive emotions. Individuals who felt positive emotions were less affected by negative mood inductions than those who reported lower on positive affect. Although participants were randomly assigned to different groups, the source of random error (higher perceived positive emotions before music manipulation in the minor music group) may have occurred due to the small sample size ($n=12$). Thus, it is important to keep in mind that a larger sample size was needed for the proposed experiment to avoid random error and group differences.

When looking at post–test positive affect and post–test negative affect scores, it raises concerns in the subjective scale used to assess perceived valence. The PANAS (Watson et al., 1988) implemented in this experiment may not be the most effective way to measure valence as the positive and negative affect scores also included measures of arousal when scoring overall perceived valence. Hence, the scores of perceived valence are not of valence alone per say. It was an overall score of valence and arousal together, making individual self–report scores of perceived valence unclear. This may have contributed to the minor music group reporting higher scores for both post–test perceived positive and post–test perceived negative affect. Other
measures such as a continuous bar (e.g., 1 – 100) may be more accurate in assessing self-report perceived valence and arousal.

Interestingly, the results showed music enjoyment to be a complicating factor when looking at perceived valence because of its strong correlation. In other words, music enjoyment was associated with perceived affect scores depending on whether the participant enjoyed listening to the music. This indicated that even though the mood manipulation for the major music group was intended to induce positive mood, individuals who did not enjoy the music stimuli would report lower positive affect and higher negative affect scores to reflect their dislike of the music. However, once music enjoyment was statistically controlled for through an analysis of covariance, the results showed a significant difference of post-test negative affect scores between the two music groups. Thus, it is important to note the complicating effect of music enjoyment has on perceived valence for future experiments.

Though there were some limitations and obstacles for manipulating valence, no differences were found for post-test perceived arousal between the two groups. Thus, indicating that by adjusting all music stimuli to a constant tempo (90 bpm) and presenting it at comfortable volumes, arousal can remain relatively constant. However, it is important to note that these data and results are based on a small sample size.

Given that the mood induction task in combination with the music stimuli tested in this experiment partially successfully manipulated valence and keep arousal relatively constant, the stimuli was used and applied to a driving experiment to observe how positive and negative emotions affects driving performance using a driving simulator. The upcoming section will be used to describe the driving experiment carried out during my thesis.
Chapter 5 – Driving Experiment – The effects of Mood–Valence on Driving

The following experiment was designed to assesses driving performance using a driving simulator. The use of a driving simulator exposes participants to a virtual environment and provides many benefits of conducting driving research such as increased flexibility and possibilities in programming specific simulations. At the same time the use of simulators minimizes dangers related to on-road driving such as vehicular and/or pedestrian collision related to distracted driving. By having participants drive in a virtual environment, different emotional states can be applied to observe certain aspects of driving, specifically as it relates to how emotion affects speed, steering, and hazard detection.

Furthermore, this driving experiment included broader range of driving performance by including both central (e.g., leading vehicle braking) and peripheral hazards (e.g., pedestrian crossing the street), where previous driving experiments only used central hazards to assess brake response time (examples of these hazards can be seen in Figure 14 and Figure 15 respectively). During this experiment, participants were exposed to a driving environment where they occasionally encountered either central or peripheral hazard. Both central and peripheral hazards were in the path of the vehicle and occurred at random intervals throughout the drive. Participants were instructed to respond to these hazardous events using the brakes of the vehicle and these braking times were used for assessment. By including both central and peripheral hazards in this experiment, it created more similar conditions to what occurs in natural driving.

The purpose of this driving experiment was designed to test how long term positive and negative emotional valence affects driving performance while controlling arousal using mood inductions and music. This is important because most driving studies (and many other studies as well) tend to confound valence with arousal (positive affect high arousal, negative affect low
arousal). Altogether, these previous experiments made it hard to conclude whether the effects of emotion had on driving performance was of valence or arousal. By controlling arousal, a more thorough understanding on how emotional valence affects driving was achieved given that there is little literature that looks at valence alone.

According to Wickens’ (2002) theory of attention, driving performance consists of two different attentional mechanisms, ambient and focal attention. Because ambient attention is involved with controlling the body’s position in space, it may also be associated with steering. In contrast, focal attention requires intimate eye movements to place information in the fovea of the eye. This fine attention to detail is involved with object recognition and visual search abilities, which are important hazard detection and response. By using a driving simulator for this present study, it allowed us to explore how these different attentional mechanisms (e.g., ambient and focal) relates to driving performance (e.g., steering and hazard response).

Overall, given the “broaden and build” model of positive emotions (Fredrickson, 2001), it was expected that individuals placed in the major music condition (i.e., positive mood) would be better at steering as well as detecting peripheral hazards than those in the minor music condition (i.e., negative mood) and no–music group (i.e., control). These hypotheses would be supported by a main effect of valence such that people in the major music group would have reduced variability in steering (as indicated by the SDLP) given that previous experiments have shown individuals with a wider span of vision (e.g., increased peripheral vision) had lower steering variability and better lateral control while decreasing periphery had the opposite effects (van Erp & Padmos, 2003).
When it comes to hazard response time, I predicted an interaction between valence and hazard type to emerge where positive emotions reduced brake response time for peripheral hazard types but not central hazards because positive emotion is thought to expand peripheral vision based on the “broaden and build” model (Fredrickson, 2001). Similarly, it was possible that negative emotion may reduce response times for central hazards but not peripheral hazards given that negative affect narrows attentional focus (Derryberry & Tucker, 1992; Fredrickson & Branigan, 2005; Wadlinger & Isaacowitz, 2006; Fredrickson, 2001) though this observation was not strongly supported in previous literature.

5.1 Method

Design

Participants were randomly assigned to one of three between valence conditions that used mood induction tasks and music together to manipulate valence. The three conditions consisted of a major key music group (e.g., positive mood) and happy mood induction task, a minor key music group (e.g., negative mood) and sad mood induction task, and a no–music group (e.g., control group) no mood induction task. Prior to analyzing the data, manipulation checks were conducted between the three music conditions to ensure that the stimuli was successful at manipulating valence and controlling arousal as indicated by the self–report scores of perceived valence and arousal at post–tests. One–way ANOVA was conducted on two separate occasions, one to assess post–test perceived valence between the three music conditions and another to analyze post–test arousal scores between the three groups.

For driving performance, multiple one–way analyses of variance were used to analyze how the three music conditions affected mean driving speed (kilometers per hour) and steering
variability (SDLP presented in centimeters). The SDLP represented how much deviation the participants were from the centre of their lane. More variability in SDLP reflected poorer steering performance. Furthermore, a 3x2 mixed factorial design was implemented to assess the combined effects of between factors music group (major, minor, no–music control group) and within subjects variable of hazard type (central, peripheral) on brake response times. Hazard response times were the difference between the time the event occurred and how long it took for the participant to hit the brakes of the vehicle in response to either event.

Participants

A total of 60 participants (13 males, 46 female, and 1 “other”) with a mean age of 19.28 (SD=4.92) were recruited for this experiment. Participants were recruited through the University of Guelph’s Psychology Department Research Pool System (SONA) where they were offered course credit for their participation. Given that this experiment involved a driving simulator, all participants were required to possess a valid G2 or equivalent drivers’ license (20 participants possessed a G-license while 40 participants possessed a G2 license). When it came to the type of road participants drove on most often, 46 participants reported driving on urban (i.e., city, town, etc) roads, 11 reported driving on rural roads (i.e., countryside), and 3 reported driving on highways (i.e., freeway). As for an average of driving distance within a typical week, 37 participants reported driving between 0 – 100 km, 15 reported driving between 101+ km, while 8 participants reported not knowing.

In addition, participants who were screened as high risk of simulator sickness using the Simulator Adaptation Pre–Screening Questionnaire (Kennedy, Fowlkes, Berbaum, & Lilienthal, 1992) prior to the experiment were excluded from this experiment. Simulator sickness or
Simulator Adaptation Syndrome (SAS) is a syndrome that causes participants to feel uneasy while becoming familiar with the driving simulator. Some participants may experience drowsiness, headaches, eyestrains, and discomfort. During extreme cases, participants may feel nauseated. Thus, it is imperative that participants who are at high risk of SAS to be screened out and excluded from the experiment. A total of 8 participants were excluded from the experiment because they either were at high risk of SAS as indicated by the pre-screening or experienced SAS while in the simulator. Following the screening, informed consent was obtained from all participants in accordance to the Research Ethics Board of the University of Guelph.

*Apparatus and Stimuli*

A driving simulator that included a real car surrounded by screens was used. The driving simulator consisted of 6 screens for a 300 degree wrap–around view (5 in the front, 1 in the rear of the car) plus 2 LCD screens for the side–rear mirrors. A total of 8 *HD–BenQ* projectors were used to display the simulation. The car model was a *Pontiac G6* convertible designed by *OKTAL* to reflect the exact characteristics of a real car model with the exception of a missing car engine. The simulated car came equipped with a Bluetooth radio and was surrounded with speakers.

The *SCANeR Studio Driving Simulation* programming software was used to create simulated environments. These environments consisted of four different drives; all contained a straight two–lane highway drive (one lane for each direction) through a scenic countryside with a posted speed limit of 80 kilometers per hour (kilometres per hour (kph)). Consistent ongoing traffic on the other side of the road was also programmed to keep drivers within their lane. Each simulation took approximately 15 minutes to complete (total time of approximately 70 minutes in the driving simulator with resting periods and practice trials). All four simulations were
randomly ordered for each participant and counter-balanced. During the drives participants encountered both central and peripheral hazards that appeared in the path of the driver at random intervals. Central hazards were programmed such that a leading vehicle was to stay 4 seconds ahead of the driver except for braking events where the lead vehicle suddenly decelerated and stopped on the road (red brake lights appeared when this occurs). Drivers had a 4 second response time to hit the brakes to avoid collision with the leading car. Similarly, peripheral hazards were programmed to initiate when drivers reached a 4 second distance between the start of the event and pedestrian crossing the road (which was 88.88m at 80kph, this distance was adjusted accordingly to incorporate different driving speeds). This allowed the driver sufficient time to press on the brakes to avoid collisions. There were a total of 9 central hazards and 9 peripheral hazards making a total of 18 hazard events spanned across 4 simulations.

Following an initial mood induction task where participants were instructed to write down events in their life related to the condition they were assigned to, the same playlist of music tested in the second pilot experiment was applied to this driving experiment (refer to Appendix D). Participants listened to music at moderate and comfortable volume levels (participants were asked if volume level was comfortable) through the radio system and surrounding speakers of the simulated car that connects to a laptop through an auxiliary cable.

There were two questionnaires used to assess Simulator Adaptation Syndrome. The first questionnaire administered prior to the driving task was the Simulator Adaptation Pre–Screening Questionnaire, used to identify participants that were at high risk of simulator sickness. The Simulator Adaptation Pre–Screening Questionnaire included items that asked about the participants’ general health and overall experience with motion sickness (e.g., “Do you have diabetes?”, “Do you experience vertigo?”, “Do you experience motion sickness?” etc.). A
follow–up post–test questionnaire administered after driving task called the “Simulator Sickness Questionnaire” (SSQ) was administered to assess the severity of SAS experienced. The SSQ consisted of a scale of 0 – 3 (0 – none, 1 – slight, 2 – moderate, and 3 – severe) used to rate the severity of each symptom of SAS experienced (e.g., headache, eyestrain, nausea, dizziness, discomfort etc.). The questionnaires used to assess Simulator Adaptation Syndrome can be found in Appendix G.

Following the initial pre–screening of SAS, a pre–test questionnaire package was administered, that included items that asked about driving history, mood, arousal, and general music listening history. Driving history included items that asked what age the participant first started driving, what type of road they drove in the most, as well how far they drove a motor vehicle within a typical week (measured by kilometres). Two separate self–report continuous scales (1 – 100) were used to assess perceived valence and perceived arousal. For valence, scores near 1 indicated “Very Negative” affective state, scores near 50 indicated “Neither Negative or Positive”, while scores near 100 indicated “Very Positive”. Low arousal ratings at 1 indicated “Not at all awake”, 50 indicated “Neutral”, while high ratings at 100 indicated “Very much awake”. Actual scores based on where participants placed the marker on the slider were not visible to them. Furthermore, all initial markers started at the middle of the slider to eliminate potential response bias (Eerola, 2012). General music listening history included any instruments participants were trained on as well as how many minutes a day they listen to music on a daily basis. A full detail of the pre–test questionnaire package can be found in Appendix H.

The same two continuous 1 – 100 scales used in the pre–test questionnaire package was administered after the driving task to record perceived valence and arousal. The post–test questionnaire package also included questions that asked about music familiarity and music
enjoyment as previous music pilot experiments showed these factors to have a complicating effect on perceived valence scores. The music familiarity and music enjoyment questionnaires were only administered to participants in a music condition (major and minor key) given that the no–music control group did not listen to music. Similarly, music familiarity and enjoyment were assessed using a self–report 1 – 100 continuous slider bar scale. Music familiarity (“How familiar did the music sound to you?”), scores near 1 indicated “Not at all familiar” while scores near 100 indicated “Very familiar”. For music enjoyment (“How much did you enjoy listening to the music?”), scores near 1 indicated “Not at all”, near 50 indicated “Neutral”, and near 100 indicated “Very much”. The post–test questionnaire package can be found in Appendix I.

Procedure

When the participant arrived, they were asked to show their G2 or equivalent driver’s license to ensure that they were eligible to participate in this experiment. The informed consent was then administered followed by a screening for risk of experiencing simulator sickness using the Simulator Adaptation Pre–Screening Questionnaire. Individuals who were at high risk of SAS were not permitted to participate and were compensated with the appropriate incentives for their time. Otherwise, the experiment proceeded and participants were administered the pre–test questionnaire package.

Prior to the experiment, participants were assigned to a major key music, minor key music, or no–music control group using a random number generator. Once the pre–test questionnaire package was complete, participants were then directed into the driving room where the research assistant helped set them up with the driving simulator. Participants were then given an approximate 5 minute practice trial using specifically made practice simulations containing
examples of central and peripheral hazards to familiarize themselves with the driving simulator and tasks. During the practice trials, participants were instructed to brake when faced with a hazard. Following the practice trial, participants then performed a mood induction task where they were asked to write down events in their life related to the music condition that they were assigned to. For example, the major music group wrote down happy events while the minor music wrote down sad events. The no–music control group did not perform the mood induction task. Participants were encouraged to think of these events throughout their driving session (see Appendix F). Once the mood induction task was complete, music stimuli was presented and played throughout the drive on repeat and shuffled (random). Prior to driving, participants were asked if music volume was comfortable and was adjusted accordingly if they were not (e.g., if it was too loud, volumes level decreased). Participants were not allowed to adjust music volumes during the drives and volumes were only adjustable by the researcher. They were however, asked about their comfort levels during break intervals between simulations. Participants then engaged in the more challenging full simulations where they experienced long intervals of uneventful events with random encounters of either a central or peripheral hazard. The actual driving trials took approximately 60 minutes to complete with deviations in time that depended on driving speed.

Following their time in the driving simulator, participants were administered the post–test questionnaire. After completing the final questionnaire, individuals in the minor music group were shown an uplifting video to negate the negative affect experienced during the experiment. Debriefing and appropriate incentives were then given for completing the experiment.
5.2 Results

An alpha level of .05 was used for evaluating significant results. In the event of within subject analyses, a conservative procedure was adopted using Geisser–Greenhouse correction for degrees of freedom given that a repeated measures analysis of variance was conducted.

Manipulation Check

Given that this experiment was designed to manipulate valence, creating positive and negative moods, it was expected that participants in the major music group would have significantly higher perceived valence scores when compared to the minor music group based on the 1 – 100 continuous scale administered at post–test. Because I tried to keep arousal constant by keeping music tempo and volumes constant between valence conditions, I expected no significant differences in arousal levels between the major, minor, and no–music groups at post–test as well.

Pre–test analyses of Perceived Valence and Arousal

The first set of analyses were conducted to find out whether the random assignment worked, so that there were no differences between the three music groups at pre–test perceived valence and pre–test perceived arousal. Two separate one–way analyses of variance were used, the first to compare pre–test perceived valence and the another to compare pre–test arousal between the three music conditions (major, minor, no–music).

As predicted, the one–way ANOVA revealed no significant differences for pre–test perceived valence scores between the major key, minor key, and no–music control group, $F(2,57)=.28, p=.75$ (see Figure 16). This was expected as participants were randomly assigned to
their conditions and should have no significant differences in perceived valence prior to mood manipulations (unlike what was observed in the previous music pilot experiments).

Furthermore, as expected analysis revealed no significant differences for pre–test perceived arousal scores between the three music conditions, $F(2,57)=.38, p=.68$, indicating that arousal levels between groups were relatively the same (see Figure 17).

**Post–test analyses of Perceived Valence and Arousal**

Given that there were no significant differences between the three music groups for pre–test perceived valence and pre–test perceived arousal, these factors were not included as covariates when analyzing post–test perceived valence and arousal scores. However, given that the second music experiment showed music enjoyment to be a complicating factor on overall perceived valence, ANCOVA was used to analyze post–test perceived valence scores between the major key and minor key music groups using music enjoyment as a covariate. An additional one–way ANOVA was used to compare the post–test perceived valence means of the three music groups (major, minor, and no–music control group) using Tukey post–hoc tests. As for post–test perceived arousal, a one–way ANOVA was used to analyze these results.

As predicted, ANCOVA results revealed a significant difference of post–test perceived valence scores, $F(1,38)=8.37, p=.01, \eta^2=.18$ (see Figure 18). Specifically, analysis revealed that the mean perceived valence scores was significantly higher in the positively valenced induced group (major music + positive mood induction task) ($M = 66.1$) than the negatively valenced group (minor music + negative mood induction task) ($M= 51.1$). These results confirmed that music stimuli in combination with the mood induction task were able to produce the effects of positive and negative mood.
An additional one–way ANOVA was used to compare post–test perceived means between the three music conditions (major, minor, no–music) using Tukey post–hoc tests. As predicted, analysis revealed a significant mean difference between the three groups, $F(2,57)=4.67, p=.01$. Specifically, post–hoc tests revealed perceived valence scores to differ significantly between the major and minor music group ($p=.02$). Post–test perceived valence scores were marginally different between the minor and no–music control group ($p=.06$) while no significant differences were found between the major and no–music control group ($p=.86$).

When analyzing post–test perceived arousal scores using one–way ANOVA, as predicted the results showed no significant differences between the three music conditions, $F(2,57)=1.09, p=.35$ (see Figure 19). Given that this experiment was designed to keep arousal relatively constant, this outcome was expected.

Driving Performance Data

Two separate one–way ANOVAs were used to assess mean driving speed and steering performance as indicated by the standard deviation of lane variability (SDLP) between all three music conditions.

In addition, a factorial repeated measures analysis of variance was used to compare two independent factors of music condition (major, minor) and hazard type (central and peripheral) on brake response times.

Driving Speed

Given that increasing music tempo was associated with increasing speeds (Brodsky, 2002), mean driving speeds were not expected to differ because music tempo was kept constant
at 90 bpm for all music stimuli. As predicted, the ANOVA revealed no significant differences between groups, $F(2,57)=.46, p=.63$ (see Figure 20). These results indicated that all groups had similar mean driving speed over the course of the driving sessions.

**Steering Performance**

Due to the broadening of peripheral view, it was expected that the major music group to have significantly lower variability in their steering as indicated by lower SDLP when compared to the other music conditions. Contrary to predictions, the one–way ANOVA revealed no significant main effect of music-valence condition on steering variability, $F(2,57)=.91, p=.41$ (see Figure 21). These results failed to confirm the expectation that positive emotions would significantly decrease steering variability.

**Hazard Response Times**

Given the “broaden and build” model (Fredrickson, 2001), it was expected that there would be an interaction between music condition and hazard type such that the major music group would lower response time for peripheral hazards but not central hazards when compared to the other music groups (minor music and no–music). In contrast, it was expected that the minor music group to have significantly lower response time for central hazards when compared to the other music groups as supported by the narrowing of attentional focus.

A factorial repeated–measures ANOVA was used to compare brake response times of music conditions (major, minor, no–music) and hazard type (central vs. peripheral). Results revealed a significant main effect of hazard type on brake response time, $F(1,57)=11.26, p < .01, \eta^2=.17$, where mean brake response times for central hazards ($M=1.07$ s) was significantly lower than for peripheral hazards ($M=1.11$ s). Given that this experiment was the first that
incorporated both central and peripheral hazards in the design, we were unsure if these outcomes were expected.

Furthermore, contrary to predictions, a significant interaction was found between music condition and hazard type, $F(2,57)=3.19, p=.05, \eta^2=.10$, (see Figure 22) where the major key group had significantly lower central hazard response times. As it turns out, although a significant interaction emerged, these results failed to support the hypothesis that positive emotions (i.e., major key) would significantly decrease peripheral hazard response time while negative affect (i.e., minor key) would significantly decrease central hazard response time.

5.3 Discussion

Overall, this experiment was designed to examine how positive and negative emotion affects driving performance while controlling for arousal. Similar to the pilot experiment, the effects of manipulated valence and controlled arousal was replicated using music key, music tempo, and music volume indicating that the music stimuli in combination with a mood induction task was an effective way to produce expected emotional states as previously suggested (Jefferies et al., 2008). Evidence was presented in the manipulation check results, where no significant pre–test perceived valence differences were found as well as post–test perceived valence where the major music group reported significantly greater perceived valence scores than did the minor music group. Although post–test perceived valence scores between the major and minor music differed significantly, the major music and no–music control group did not have significant differences in the perceived valence scores. This may be because music induction of emotion have been shown to only be effective when comparing positive and negative mood states and less effective when comparing a neutral state (e.g., control group).
when using self–report measures (Lench, 2010). In addition to manipulating valence, the results showed no significant differences of arousal at both pre–test and post–tests between conditions indicating that keeping tempo constant and playing it at moderate volumes between music conditions was able to produce the effects of controlled arousal.

When it comes to the driving data, results were unexpected and contrary to predictions. For steering variability it was expected that due to expanded peripheral field of vision that comes with positive emotions (according to the “broaden and build” model), individuals in the positive affect group would have significantly better steering (and thus reduced steering variability) than the negative emotion and control group. However, the results revealed no significant differences among the music conditions. One possible explanation for this outcome is in the rationale of the “broaden and build” model itself. Currently, the “broaden and build” model (Fredrickson, 2001) states that the broadening of attention is an effect of only positive emotions when it is possible that they are underestimating the role arousal have on broadened attention. It is possible that the expanding peripheral view is an effect of both positive emotions and arousal or of arousal itself; thus, when this experiment controlled for arousal effects, it eliminated the broadening effect as well. This is evident in the study conducted by Chan and Singhal (2015) where they found positive emotions to decrease steering variability; however this was based on a confounding effect of positive affect and high arousal. Perhaps steering performance was affected by the high arousal aspect of the stimuli rather than of positive emotion. In fact, the conclusions about emotional valence on lateral control argued by Chan and Singhal (2015) and the results observed in Pêcher et al. (2009) study are actually contradictory to one another. Pêcher et al. (2009) actually found positive music to reduce lateral control in steering as indicated by more deviations from the centre of the lane. However, this observation was a product of confounding positive
affect with high arousal. To complicate things even more, Trick et al. (2012) found interaction effect of valence and arousal on steering performance such that positive and negative groups differed in steering variability but only when it was of low arousal. Taking all this together, it opens the possibility that the “broaden and build” model is not of only positive emotions, but an effect of a combination of valence and arousal.

When it comes to hazard brake response times, a significant main effect of hazard type was found such that response times were in general significantly lower for central than peripheral hazards. This was possibly due to the fact that drivers in natural driving are more likely to encounter central hazards than peripheral hazards. For example, when on the road individuals are more likely to watch out for braking vehicles in front of them because of traffic lights, stop signs, and decelerating vehicles. Given that drivers are more exposed to central hazards while in natural driving, they become more familiar in responding to these hazard types as opposed to encountering an unexpected event such as a pedestrian or animal coming from their periphery. However, the main effect of hazard type on response times may also be a consequence in the methodology of the experiment.

In the design, I confounded type of hazard (vehicle, pedestrian) with position of hazard (central, peripheral). Specifically, vehicles were only used for central hazards while pedestrians were used for peripheral hazards. As a consequence, the confound between hazard type and hazard position could have affected how effectively the driver responded to specific type of hazards given that it is easier to spot a large vehicle than a small pedestrian on the road. Preferably we would want to have multiple types of hazards (animals, pedestrians, vehicles) for both positions of hazards (central, peripheral). However, it may be difficult to present a pedestrian as a central hazard on the road (unless you want to drop the pedestrian from the sky.
directly into the center view of the driver, but that would create other problems). Despite this limitation, this experiment was the first to implement both central and peripheral hazards in a virtual driving experiment. The inclusion of both central and peripheral hazards makes it more reflective of natural driving. As a result, it expanded our knowledge on how emotions affect different types of hazards at different positions on the road.

In addition to the main effect of hazard type on brake response times, an interaction effect was shown between the music condition and hazard type such that the response time for central hazards was significantly faster than peripheral hazards but only in the major music group. These results actually contradict the expected hypothesis that positive emotion would significantly reduce response times for peripheral hazards compared to the minor and no–music groups due to broadened attention. In fact, it was the opposite of what was expected. However, these results again may be a result of the “broaden and build” model underestimating the effect arousal has on attention. In other words, these results may be a product of controlled arousal and by keeping arousal constant we also eliminated the effects seen in broadening attention.

Altogether, this experiment showed that long term positive and negative emotions had no significant effects on mean driving speed and steering performance. However, music valence interacted with hazard type. Contrary to predictions, the major music group had significantly lower central hazard response times compared to the minor music group but not for peripheral hazards. This may be a result of a flaw in the design (such as confounding hazard type and hazard position) or of a flaw in the “broaden and build” model underestimating the role arousal may have on broadening attention. Furthermore, there was evidence that support Wicken’s theory of attention (2002), where driving involves two separate attentional mechanisms. Results show valence to have no effect on steering performance but valence did interact with hazard type
in reducing brake response times. Given that ambient attention requires controlling one’s body position in space (in driving it is lateral control of the vehicle) and focal attention requiring the fovea of the eye most sensitive to detail, valence may have a more important role in focal attention than ambient attention. It is possible that mood–valence while driving is more important in dictating how effectively you can spot and recognize hazards. In contrast, mood–valence may have little role in how you control your body (vehicle) in space. Perhaps it is arousal that governs ambient attention and the differences of steering performance in previous driving experiments are a result of arousal and not of valence. Given that most studies in emotion and driving confound valence with arousal, this is a possibility.

Overall, this driving experiment expanded our understanding on how emotions affected driving performance in a broader aspect by including both central hazards and peripheral hazards on the road. This experiment was also able to look at how long term emotional state (i.e., mood) affects driving performance. This is especially important because many commutes in driving can often last an hour long. Given that the emotional state of the driver can influence their overall driving behaviour and performance, researching mood in driving is required in order to minimize risks of vehicle collisions. Most importantly, this experiment was able to achieve the expected manipulation of valence while controlling arousal. Many previous experiments in emotion and driving tend to confound valence and arousal (positive affect high arousal) making it hard to accurately conclude how these two dimensions of emotion affects driving performance.

Similarly, there is little to no research in music and driving that looks at emotional valence without the confounding of arousal. In fact, when this experiment manipulated valence and controlled arousal, complicating effects occurred where expected hypotheses of the role positive emotions had on steering and hazard response time was not found. These conclusions challenge
the rationale of the “broaden and build” model (Fredrickson, 2001) where it may be underestimating the role arousal has on broadening attention.
Chapter 6 – General Discussion

Every year in Canada, at least 2,000 people are killed and 165,000 are injured while driving on the road (Transport Canada, 2015). Driver related factors such as emotion, has been shown to affect attention while driving, either benefiting drivers by preparing them for a course of action or impairing their performance (Jones et al., 2014; Pêcher et al., 2009). The purpose of this paper was to present a driving experiment designed to examine how positive and negative emotional valence affects driving performance as it relates to driving speed, steering, and hazard detection while controlling for arousal. As it turns out, based on the “broaden and build” model, it was expected that positive emotion would broaden attention and therefore, decrease steering variability as well as decreasing peripheral response times. However, when controlling for arousal, these expectations were not met. In this experiment, a significant interaction between valence condition and hazard type was found such that the positive mood group had significantly reduced brake response times for central hazards. These results were actually contradictory to the expected hypothesis where positive emotion would respond to peripheral hazards faster. It was possible that by controlling the effects of arousal, the broadening of attention effect was eliminated as well. Currently, the “broaden and build” model states that it is an effect of positive emotions that expands peripheral vision and not of arousal (Wadlinger & Isaacowitz, 2006; Fredrickson & Branigan, 2005). However, the results shown here were inconsistent with this theory. Perhaps the effect of broadening attention is not an effect of only positive emotion but a combination of valence and arousal. Thus, the “broaden and build” model (Fredrickson, 2001), may be underestimating the effect arousal has on attention. Based on this assumption, it would explain why the effects of positive emotion on steering variability did not significantly differ than negative and neutral valence as previously predicted. This also raises the possibility that
arousal may have a more significant role in governing steering performance as it relates to broadening attention. By controlling arousal effects in this experiment we may have eliminated the possibility of expanded peripheral view and thus, negated all possible effects it may have on steering performance as well. Furthermore, the significance valence had on hazard detection and not of steering performance raises a possibility that can be explained by Wickens’ theory of attention (2002). It is possible that emotional valence relates more to attentional mechanisms associated with object recognition and visual search tasks that involve focal attention. In contrast, arousal may play a more important role in controlling position in space (i.e., steering) mechanisms that define ambient attention. To test this possibility, further experiments need to be carried out in the driving simulator to examine how both valence and arousal affects hazard detection and steering.

For future directions, it would be ideal to have both vehicles (e.g., cars) and pedestrians at both central and peripheral positions in the driving environment. This would solve the confounding of central hazards with vehicles and peripheral hazards with pedestrians found in my driving experiment. It may be also more ideal if we used vehicles for both central and peripheral hazards in order to prevent potential confounding factors. For example, as opposed to programming peripheral hazards to run out to the road from behind a building, a peripheral hazard can emerge when another vehicle on the road is trying to merge onto the driver’s lane unexpectedly. Furthermore, it would be ideal to utilize the full wrap around view of the simulator when programming hazards. For example, the driving simulator used for this experiment has a total of 6 screens that provides 300 degrees wrap around view (one center screen with two screens to its left and two screen to its right. An additional screen at the back of the vehicle). Although there were 6 screens in total, all peripheral hazards occurred on the central screen of
the vehicle. A more complex but accurate programming of peripheral hazards would be to have them emerging from the blind-spot of the driver and then slowly merging into the drivers’ peripheral field of view. However, given that I had no background in programming, I did the best I could in programming these peripheral hazards.

Expanding on improvements for the programming aspect of this study, it would be nice to have a more urban driving setting that included more turns and buildings to incorporate a more diverse driving environment as opposed to a rural-like setting programmed for this thesis. However, it is important to keep in mind that by including turns and curves into the nature of the simulation, it increases the risk of Simulation Adaptation Syndrome (as observed in other driving studies conducted in our lab). It is also possible that curves on the road may influence overall steering variability as participants may be more likely to turn near the hard shoulder of the lane.

When it comes to methodology, additional research that implements more objective methods in observing driver behaviour such as the electroencephalography (EEG) would be interesting to analyze how the brain reacts to emotional events that occur while driving. For example, how does the brain react when a driver encounters emotional events such as a collision and how does this differ between a vehicle collision and a pedestrian collision? What kind of activity will we find when the driver responds to an unexpected hazard? Currently, a lot of emphasis in driving experiments focuses on the arousal aspects of emotion while driving, but not much is known about valence when it comes to event related potential signaling (ERPs) that represent brain activity. Additionally, other methods such as an eye-tracker can be used to monitor eye movements while driving. For example, previous laboratory studies have used an eye-tracker system to examine how individuals passively view peripheral images (Wadlinger & Isaacowitz, 2006) as it relates to eye fixations (in percentages) and saccades (rapid eye
movements). By implementing an eye-tracker into a driving experiment, we would be able to examine how the participant visually searches for specific events (in this case central and peripheral hazards) as well as how they use eye movements help them steer, given that previous experiments have found increased peripheral vision to be associated with better steering performance (van Erp & Padmos, 2003).

When improving on sample group, future experiments need to incorporate a more generalized population such as more experienced drivers. At present, the sample group tested in this driving experiment were relatively young adults that had low experience driving on the road. In fact, previous literature has found that more experienced drivers tend to use their peripheral vision for steering and factors that reduced their periphery also impaired their steering performance (Higgins et al., 1998; Summala, Nieminen, & Punto, 1996; Summala, Lamble, & Laakso, 1998; van Erp & Padmos, 2003). Given that the sample group used for this experiment were relatively inexperienced drivers, they may be less likely to use their periphery for steering despite inductions of specific emotional states (positive and negative mood). Thus, it may explain why the data in this experiment found no significant differences between groups in terms of steering performance data. By recruiting a wider range of inexperienced and experienced drivers, we can examine how experience affects overall driving performance in terms of driving speed, steering performance, and hazard response times. In addition, if we implement an eye-tracking monitor as mentioned above, we may also look at how driving experience influences eye-movement behaviour while driving.

Nevertheless, the present driving experiments provided a better understanding on how emotions affect driving performance as it relates to driving safety. The results suggest emotional valence and emotional arousal to influence different attentional mechanisms as supported by
Wickens’ theory of attention (2002). For example, by manipulating valence into positive and negative emotions, there was a valence and hazard type interaction. The ability to recognize and respond to hazards involve focal attention in accordance to the Wickens’ theory of driving attention. In contrast, when arousal was held relatively constant, no significant differences were seen for steering performance between conditions. Given that steering is related to ambient attention, it raises the possibility that arousal may be related to ambient attention while driving. This thesis also calls into question the theory of the “broaden and build” model (Fredrickson, 2001), where the researchers may be underestimating the effects arousal has on broadening of attention. Previous emotion literature (in both laboratory and driving studies) tend to confound valence and arousal, and this makes it difficult to conclude whether or not it is valence or arousal that is producing the observed effects on attention. As shown in the results, when controlling the effects of arousal, it produced complicating effects. With more recent literature finding support that valence and arousal interact to produce certain effects of attention (Jefferies et al., 2008; Trick et al., 2012), there is reason to expect both valence and arousal are important for broadening attention and not of positive emotion alone as argued by the “broaden and build” model (Fredrickson, 2001).

Ultimately, having a better understanding on how the emotional state of the driver affects their driving performance is important as driving is common activity done on a daily basis. Given that driving requires a significant amount of attention, it is important to understand how emotion affects attention as implications for driving safety.
References


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Experiment 1. Mean Pre-test Positive Affect Scores

Figure 2. Mean pre–test positive affect scores according to the PANAS (Watson et al., 1988). Error bars reflect +/- 1 standard error (SE). No significant differences were found between music conditions.
Experiment 1. Mean Pre-test Negative Affect Scores

* $p < .05$

*Figure 3.* Mean pre-test negative affect scores according to the PANAS (Watson et al., 1988). Error bars reflect +/- 1 SE. Unexpectedly, the major music group reported significantly lower negative affect than the minor music group.
Experiment 1. Mean Pre-test Arousal Scores

Figure 4. Mean pre-test self-report arousal scores. Error bars reflect +/- 1 SE. No significant differences were found between music groups.
Experiment 1. Mean Post-test Positive Affect Scores

Figure 5. Mean post-test positive affect scores. Error bars reflect +/- 1 standard error (SE). Differences between major and minor music conditions were marginal.
Figure 6. Mean post-test negative affect scores. Error bars reflect +/- 1 standard error (SE). Differences between major and minor music conditions were not significant.
Experiment 1. Mean Post-test Arousal Scores

Figure 7. Mean post-test self-report arousal scores. Error bars reflect +/- 1 standard error (SE). There was a significant difference between the two music conditions where the major-key music group reported significantly higher level of arousal than did the minor-key music group.

* p < .05
Experiment 2. Mean Pre-test Positive Affect Scores

Figure 8. Mean pre-test positive affect scores according to the PANAS (Watson et al., 1988). Error bars reflect +/- 1 SE. Unexpectedly, the major music group reported significantly lower positive affect than the minor music group.

* $p < .05$
Experiment 2. Mean Pre-test Negative Affect Scores

Figure 9. Mean pre-test negative affect scores according to the PANAS (Watson et al., 1988). Error bars reflect +/- 1 SE. No differences were found between the music conditions.
Experiment 2. Mean Pre-test Arousal Scores

Figure 10. Mean pre–test self–report arousal scores. Error bars reflect +/– 1 SE. No differences were found between the music conditions.
Experiment 2. Mean Post-test Positive Affect Scores

Figure 11. Mean post-test positive affect scores. Error bars reflect +/- 1 standard error (SE). Unfortunately, no differences were found between the major and minor music conditions.
Figure 12. Mean post-test negative affect scores. Error bars reflect +/- 1 standard error (SE). As expected, the major music group reported significantly lower negative affect scores than the minor music group after valence manipulations.

* $p < .05$
Experiment 2. Mean Post-test Arousal Scores

Figure 13. Mean post-test self-report arousal scores. Error bars reflect +/- 1 standard error (SE). No differences were found between the major and minor music conditions.
Figure 14. An example of a central hazard. At random intervals the leading vehicle would suddenly brake which requires the participant to respond by braking as well.
Figure 14. An example of a peripheral hazard. Pedestrians would randomly run out (as indicated by the arrow) from behind a building and stop in the middle of the road.
Figure 16. Mean pre-test self-report valence scores. Error bars reflect +/- 1 standard error (SE). No differences were found between the three music conditions.
Figure 17. Mean pre–test self-report arousal scores. Error bars reflect +/- 1 standard error (SE). No differences were found between the three music conditions.
Experiment 3. Mean Post-test Valence Scores

** Figure 18. Mean post-test self-report valence scores. Error bars reflect +/- 1 standard error (SE). As expected, the major music group reported significantly higher positive affect compared to the minor music group. While the differences in valence between the minor and control group were marginal, no significant differences were found between the major and control group.

** p = .01
Figure 19. Mean post–test self–report arousal scores. Error bars reflect +/- 1 standard error (SE). As expected, no significant differences were found between all three music conditions.
Figure 20. Mean driving speed between the three music conditions. Error bars reflect +/- 1 standard error (SE). As expected, no significant differences were found.
Experiment 3. Mean Steering Variability (SDLP)

Figure 21. Mean SDLP (steering variability) between the three music conditions. Error bars reflect +/- 1 standard error (SE). Contrary to predictions, no significant differences were found.
Experiment 3. Mean Brake Hazard Response Times

![Bar chart showing mean brake response times for central and peripheral hazards across different music conditions.]

* \( p < .05 \)

*Figure 22.* Results showed a significant main effect of hazard type on mean brake response time where response times for central hazards (\( M = 1.07 \) s) were significantly faster than for peripheral hazards (\( M = 1.11 \) s). Furthermore, an interaction emerged between music valence and hazard type.
Chapter 7 – Appendices

Appendix A – Pilot 1 Music Stimuli

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<th>Duration</th>
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Appendix B – Pilot (1 & 2) Music Experiment Pre-test Questionnaire Package

Gender:
- Male
- Female
- Other: ___________

Age:

Positive and Negative Affect Schedule (PANAS)

(Watson et al., 1988)

This scale consists of a number of words that describe different feelings and emotions. Read each item and then select the number from the scale that best indicates to what extent you feel this way right now, that is, at the present moment.

1 – very slightly or not at all

2 – very slightly

3 – moderately

4 – quite a bit

5 – extremely

1. Interested
2. Distressed
3. Excited
4. Upset
5. Strong
6. Guilty
7. Scared
8. Hostile
9. Enthusiastic
10. Proud

11. Irritable
12. Alert
13. Ashamed
14. Inspired
15. Nervous
16. Determined
17. Attentive
18. Jittery
19. Active
20. Afraid
How awake do you feel right now, that is, at the present moment?

1 – very slightly or not at all
   2
   3
   4
   5
   6
7 – extremely

The Goldsmiths Musical Sophistication Index (subset)
(Müllensiefen et al., 2014)

Please select the most appropriate option:

I have engaged in regular, daily practice of a musical instrument (including voice) for _____ years:

- 0
- 1
- 2
- 3
- 4-5
- 6-9
- 10 or more

At the peak of my interest, I practiced _____ hours per day on my primary instrument (including voice):

- 0
- 0.5
- 1
- 1.5
- 2
- 3-4
- 5 or more

I have attended _____ live music events as an audience member in the past twelve months:

- 0
- 1
- 2
- 3
- 4-6
- 7-10
- 11 or more
I have had formal training in music theory for _____ years:

- 0
- 0.5
- 1
- 2
- 3
- 4-6
- 7 or more

I have had _____ of formal training on a musical instrument (including voice) during my lifetime:

- 0
- 0.5
- 1
- 2
- 3-5
- 6-9
- 10 or more years

I can play _____ musical instruments:

- 0
- 1
- 2
- 3
- 4
- 5
- 6 or more

The instrument I play best (including voice) is:

What type of music do you typically listen to?

I listen attentively to music for ______ per day:

- 0-14 min
- 15-29 min
- 30-59 min
- 60-89 min
- 1.5-2 hrs
- 2-3 hrs
• 4 hrs or more

Do you have any additional comments you would like to add?
Appendix C – Pilot 1 Music Experiment Post–test Questionnaire Package

Did any of the music pieces sound familiar to you?

- Yes
- No

How familiar did the music sound to you?

1 – Very slightly or not at all
2
3
4
5
6
7 – Extremely
Positive and Negative Affect Schedule (PANAS)

(Watson et al., 1988)

This scale consists of a number of words that describe different feelings and emotions. Read each item and then select the number from the scale that best indicates to what extent you feel this way right now, that is, at the present moment.

1 – Very slightly or not at all
2 – Very slightly
3 – Moderately
4 – Quite a bit
5 – Extremely

1. Interested
2. Distressed
3. Excited
4. Upset
5. Strong
6. Guilty
7. Scared
8. Hostile
9. Enthusiastic
10. Proud
11. Irritable
12. Alert
13. Ashamed
14. Inspired
15. Nervous
16. Determined
17. Attentive
18. Jittery
19. Active
20. Afraid
How awake do you feel right now, that is, at the present moment?

1 – Very slightly or not at all
2
3
4
5
6
7 – Extremely

Feel free to leave your email to be contacted for future studies in the DRIVE lab.

Student email:

Do you have any additional comments you would like to add?
<table>
<thead>
<tr>
<th>#</th>
<th>Composition</th>
<th>Composer</th>
<th>Duration</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brandenburg Concerto No. 3</td>
<td>Bach</td>
<td>6:29</td>
<td>Positive</td>
</tr>
<tr>
<td>2</td>
<td>Hungarian Dance No. 7</td>
<td>Johannes Brahms</td>
<td>2:15</td>
<td>Positive</td>
</tr>
<tr>
<td>3</td>
<td>Eine kleine Nachtmusik KV. 525 – I. Allegro</td>
<td>Mozart</td>
<td>5:04</td>
<td>Positive</td>
</tr>
<tr>
<td>4</td>
<td>Waltz of the Flowers from &quot;The Nutcracker&quot;</td>
<td>Tchaikovsky</td>
<td>4:20</td>
<td>Positive</td>
</tr>
<tr>
<td>5</td>
<td>Four Seasons: Spring (1st movement)</td>
<td>Vivaldi</td>
<td>4:15</td>
<td>Positive</td>
</tr>
<tr>
<td>6</td>
<td>Four Seasons: Spring (3rd movement)</td>
<td>Vivaldi</td>
<td>6:13</td>
<td>Positive</td>
</tr>
<tr>
<td>7</td>
<td>Adagio in G Minor</td>
<td>Albinoni</td>
<td>5:11</td>
<td>Negative</td>
</tr>
<tr>
<td>8</td>
<td>Prelude in E–Minor (op.28 no. 4)</td>
<td>Chopin</td>
<td>2:38</td>
<td>Negative</td>
</tr>
<tr>
<td>9</td>
<td>Violin Concerto: Adagio di Molto</td>
<td>Sibelius</td>
<td>7:53</td>
<td>Negative</td>
</tr>
<tr>
<td>10</td>
<td>Russia Under The Mongolian Yoke</td>
<td>Prokofiev</td>
<td>2:06</td>
<td>Negative</td>
</tr>
<tr>
<td>11</td>
<td>Adagio for Strings</td>
<td>Samuel Barber</td>
<td>6:26</td>
<td>Negative</td>
</tr>
<tr>
<td>12</td>
<td>Four Seasons: Summer (2nd movement)</td>
<td>Vivaldi</td>
<td>1:51</td>
<td>Negative</td>
</tr>
</tbody>
</table>
Appendix E – Pilot 2 Music Experiment Post–test Questionnaire Package

Did any of the music pieces sound familiar to you?

- Yes
- No

How familiar did the music sound to you?

1 – Very slightly or not at all
2
3
4
5
6
7 – Extremely

Did you enjoy listening to the music?

1 – Very slightly or not at all
2
3
4
5
6
7 – Extremely
Positive and Negative Affect Schedule (PANAS)
(Watson et al., 1988)

This scale consists of a number of words that describe different feelings and emotions. Read each item and then select the number from the scale that best indicates to what extent you feel this way right now, that is, at the present moment.

1 – Very slightly or not at all
2 – Very slightly
3 – Moderately
4 – Quite a bit
5 – Extremely

1. Interested
2. Distressed
3. Excited
4. Upset
5. Strong
6. Guilty
7. Scared
8. Hostile
9. Enthusiastic
10. Proud
11. Irritable
12. Alert
13. Ashamed
14. Inspired
15. Nervous
16. Determined
17. Attentive
18. Jittery
19. Active
20. Afraid
How awake do you feel right now, that is, at the present moment?

1 – Very slightly or not at all
2
3
4
5
6
7 – Extremely

Feel free to leave your email to be contacted for future studies in the DRIVE lab.

Student email:

Do you have any additional comments you would like to add?
Appendix F – Mood Induction Task

(Jeffries et al., 2008).

Before we begin driving I am going to ask you to get into a mood that makes you as [say happy if they are in condition 1] [say sad if they are in condition 2] as you feel comfortable. You can do this by writing down events in your life where you felt especially (same mood word). I know that this may not be the easiest thing to do, but it is very important for our research. Do not worry, this information will not be looked at and will be destroyed after the experiment.

Now I’m going to turn on some music that would help you get into that mood and get the driving experiment prepared. Are you ready?
Appendix G – Questionnaires for assessing Simulator Adaption Syndrome

Simulator Adaptation Pre–Screening Questionnaire (SAS)

(Kennedy et al., 1992)

Is there anything you would like to add about your driving experience?

**Part A: General Medical History Questionnaire**

Do you have heart problems or have you had a heart attack?

Do you experience lingering effects from stroke, brain tumour or head trauma?

Do you suffer from epileptic seizures?

Do you have inner ear problems (vertigo)?

Do you have diabetes for which insulin is required?

Do you have problems with low blood sugar (hypoglycaemia)?

Are you currently taking any medications that make you feel extremely dizzy or nauseated?

**Part B: Specific Predictors**

Some participants feel uneasy after participating in studies using a simulator. To help identify people who might be prone to this feeling we would like you to answer the following questions.

Do you experience migraine headaches?

Do you experience claustrophobia?

Do you have any history of motion sickness?

(If yes, please describe where and when)

Have you ever experienced dizziness or nausea while looking at a wide screen (e.g. Silver City or Omnimax Theatre)?

Do you experience dizziness or nausea while reading in a moving car?

Do you experience dizziness or nausea on carnival rides?

Do you prefer to be the driver rather than the passenger, because otherwise you experience dizziness or nausea?
Simulator Sickness Questionnaire (SSQ)  
(Kennedy, Lane, Berbaum, & Lilienthal, 1993)

There is a small risk associated with driving in the driving simulator. Some individuals experience feelings of dizziness or nausea, and an increase in body temperature, which are symptoms of a temporary condition called Simulator Adaptation Syndrome. We are tracking the severity of any discomfort felt by those who drive in the driving simulator.

1. How many times have you been in the driving simulator? (Check one)
   - First time______
   - Second Time______
   - More than two times______

2. Please rate the following symptoms of discomfort on a scale of 0 to 3, where 0 = none, 1 = slight, 2 = moderate, and 3 = severe.

   For Experimenter Use Only

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Rating</th>
<th>Nausea</th>
<th>Oculomotor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disorientation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Discomfort</td>
<td>____</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fatigue</td>
<td>____</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Headache</td>
<td>____</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Eyestrain</td>
<td>____</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Difficulty Focusing</td>
<td>____</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Increased Salivation</td>
<td>____</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Sweating</td>
<td>____</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Nausea</td>
<td>____</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Difficulty</td>
<td>____</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Concentrating</td>
<td>____</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Fullness of Head</td>
<td>____</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Blurred Vision</td>
<td>____</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Dizzy (Eyes Open)</td>
<td>____</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dizzy (Eyes Closed)</td>
<td>____</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vertigo</td>
<td>____</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Stomach Awareness</td>
<td>____</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Burping</td>
<td>____</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

   Totals ______  ______  ______ = _______
Appendix H – Drive Experiment Pre–test Questionnaire Package

Gender:

- Male
- Female
- Other: ___________

Age:

Do you have a license to drive a car, truck or motorcycle?

- Yes
- No

What kind of license do you have? (e.g., G, G1, G2, M, M1 etc.)

At what age did you first start driving? ______

When was the last time you drove? ______

Where do you drive most often?

- Urban (i.e., city, town etc.)
- Rural (i.e., countryside)
- Highway (i.e., freeway)

Please think of all the driving you do. Remember to include any driving you have done in a car, motorcycle, ATV, boat, van or truck.

Count vehicles you own, borrowed, rented or used for work:

- Less than 10km
- 11 to 100km
- 101 to 500km
- 501 to 1,000km
- More than 1,000km
- Don’t know
On average, how many hours do you spend driving a motor vehicle in a typical week? ______

If you use a cell phone while you are driving a motor vehicle, how often do you use a hands-free device to do so?

- Always
- Most of the time
- Rarely
- Never

Compared to other drivers, would you say you usually drive:

- Much faster
- A little faster
- About the same speed
- A little slower
- Much slower

Compared to other drivers, would you say you usually drive:

- Much more aggressively
- A little more aggressively
- About the same
- A little less aggressively
- Much less aggressive
Slide the bar that best represents your current affective state (i.e., mood).

1 – 100 (slider bar)

How awake do you feel right now, that is, at the present moment?

1 – 100 (slider bar)
The Goldsmiths Musical Sophistication Index (subset)  
(Müllensiefen et al., 2014)

Please select the most appropriate option:

I have engaged in regular, daily practice of a musical instrument (including voice) for _____ years:

• 0
• 1
• 2
• 3
• 4-5
• 6-9
• 10 or more

At the peak of my interest, I practiced _____ hours per day on my primary instrument (including voice):

• 0
• 0.5
• 1
• 1.5
• 2
• 3-4
• 5 or more

I have attended _____ live music events as an audience member in the past twelve months:

• 0
• 1
• 2
• 3
• 4-6
• 7-10
• 11 or more

I have had formal training in music theory for _____ years:

• 0
• 0.5
• 1
• 2
• 3
• 4-6
• 7 or more
I have had _____ of formal training on a musical instrument (including voice) during my lifetime:

- 0
- 0.5
- 1
- 2
- 3-5
- 6-9
- 10 or more years

I can play _____ musical instruments:

- 0
- 1
- 2
- 3
- 4
- 5
- 6 or more

The instrument I play best (including voice) is:

What type of music do you typically listen to?

I listen attentively to music for ______ per day:

- 0-14 min
- 15-29 min
- 30-59 min
- 60-89 min
- 1.5-2 hrs
- 2-3 hrs
- 4 hrs or more

Do you have any additional comments you would like to add?
Appendix I – Drive Experiment Post-test Questionnaire Package

How much did you enjoy listening to the music?

1 – 100 (slider bar)

How familiar did the music sound to you?

1 – 100 (slider bar)

Slide the bar that best represents your current affective state (i.e., mood).

1 – 100 (slider bar)

How awake do you feel right now, that is, at the present moment?

1 – 100 (slider bar)
Feel free to leave your email to be contacted for future studies in the DRIVE lab.

Do you have any additional comments you would like to add?