THE IMPACT OF EMOTIONS AND PREDOMINANT EMOTION REGULATION TECHNIQUE ON THE CARDIAC AND MOTOR MECHANISMS UNDERLYING EXPERTISE IN DRIVING

By

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While driving, emotional stimuli abound both within the driver and in the immersive roadway environment. Inadequately coping with these influential factors can result in unsafe behaviors (such as speeding & compromised control of the wheel) which in turn can cause aversive and fatal consequences (i.e., injury & death due to traffic collisions). To better understand the etiology of such large-scale outcomes, my thesis focused on how different emotions and drivers' predominant emotion regulation technique effect emotional reactivity (as measured by the functioning of the human cardiovascular and motor systems) during the dual-task of simulated driving and attending to emotional stimuli at both the expert and non-expert levels of performance.

Primary dependent measures were heart period (milliseconds between R-spikes) and an index of co-contraction (electrical muscular activity) in the muscle groups responsible for steering wheel control. The presence of valenced stimuli produced significant changes in both the cardiac and motor systems during driving. Heart period results were sensitive to different emotional valences, indicating that the stimuli were processed and perceived differently. Muscular activity was likewise affected by the

presence of emotional images. However, co-contraction values did not vary according to emotional valence, suggesting that despite the differential processing proposed by the changes in cardiac function, mental strategies (i.e., predominant emotion regulation techniques) regulated muscle control in the face of affective scenes to maintain a safe lane position. Results corroborate previous research indicating that physiological metrics are sensitive to stimulus-driven reactions and increases in attentional demand to a greater extent than driving measures alone (Lenneman & Backs, 2009).

Findings additionally highlighted the superior performance of experts regardless of their sex or predominant emotion regulation technique, specifically when exposed to stimuli relevant to their domain of expertise. Key differences in performance are, however, seen in non-experts as they acquire their expertise. Adaptive (task-focused) females drove more safely than maladaptive (emotion-focused) females, while maladaptive males had superior performance when compared to adaptive males. Males, therefore, seem to establish effective yet maladaptive emotion regulation strategies early in their pursuit of expertise which eventually become long-standing maladaptive patterns of behavior.

Drivers' end goals appear to be safety and efficiency. How well the driver performs, how they regulate their emotions and the type of stimuli they encounter have significant effects on their performance. Present findings may therefore influence the amount or variety of training necessary for drivers to be licensed or certified. Therefore, future research should not only take into account both pleasant and unpleasant valences when assessing emotional effects on physiological functioning and driving performance, but also the strategy individuals use to mitigate their reactions.

CHAPTER 1
INTRODUCTION

While driving a motor vehicle is typically routine and often mundane, driving can also be an emotionally intense experience due to the potentially severe and unpredictable consequences associated with failures in driving aptitude or lack of adherence to laws and regulations. Driving during highly emotional states is common. Traffic collisions, which often accompany these emotional episodes, bear significant costs in terms of life, limb, and revenue. The National Highway Transportation and Safety Administration (NHTSA) reported in excess of 5,000,000 traffic accidents in 2008, of which more than 34,000 were fatal (NHTSA, 2008). Despite these alarming numbers, NHTSA recently reported a steady decline in traffic fatalities since a peak in 2005 (NHTSA, 2010a). Notwithstanding this encouraging downward trend, the National Center for Injury Prevention and Control (NCICP) consistently reported traffic-related fatalities as the most common cause of death of individuals aged 1 to 44 years, regardless of race and gender (WISQARS, 2010). Additionally, NHTSA estimated the economic expense of all reported and unreported crashes since the beginning of the last decade to be in excess of $230 billion (NHTSA, 2008). Driving therefore constitutes a highly risky pursuit with potentially grave mortal and monetary ramifications.

Stress and Driving

Driving is a complex psychomotor task, requiring cognitive competence and skillful movement control. Both the psychological and physical components of the driving task can vary as a function of emotional state (Pêcher, Lemercier & Cellier, 2009). Driving unquestionably entails emotional fluctuations due to the intrinsic risk of injury and death but also owing to extraneous concerns that arise while driving (NHTSA, 2010b).

Matthews (2002) recently proposed a conceptual model of interactive relationships among psychological factors that are known to be altered when driving under “stress” to guide further empirical efforts to understand how emotional reactions and coping methods impact driver performance.

Matthews’s Transactional Model of Driver Stress

Matthews (2002) postulated a transactional model of driver stress and fatigue that provides a theoretical framework to account for the dynamic relationships among the personal, cognitive and environmental factors which contribute to objective and subjective driving outcomes (Figure 1-1).

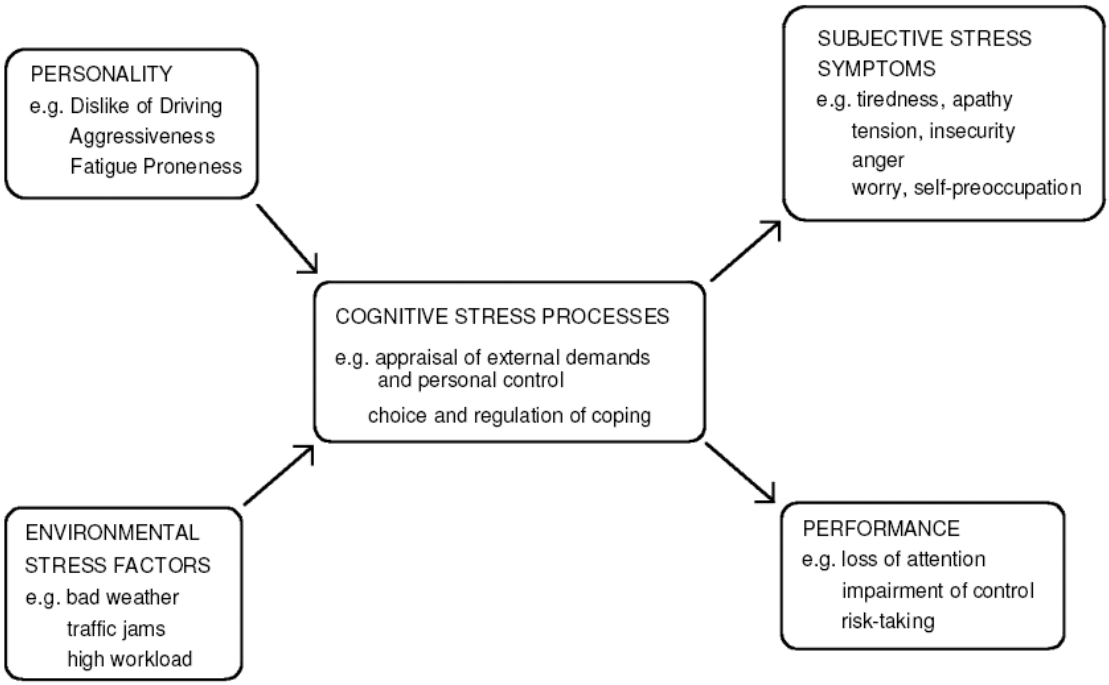

Figure 1-1. Matthews’s outline transactional model of driver stress and fatigue. *Note:* From “Toward a transactional ergonomics for driver stress and fatigue,” by G. Matthews, 2002, *Theoretical Issues in Ergonomics Science, 3,* p. 197. Copyright 2002 by Taylor & Francis, Ltd. Reproduced with permission.

Matthews suggests that environmental stress factors (unpredictable environmental stimuli) and personality factors (predispositions guiding the manner in which stimuli are

interpreted) bias an individual's cognitive stress processes (perceptions and responses to stress). These cognitive stress processes influence both subjective and performance outcomes of the driving task. Certain individuals (i.e., experts) are theorized to perform the driving task better because their cognitive stress processes (i.e., predominant methods of regulation) are more adapted to situational demands than those of non-experts or novices. The focus of this investigation was on comparing adaptive (task-focused coping) and maladaptive (emotion-focused coping) driving-specific emotion regulation strategies. Task-focused coping involves channeling emotional reactivity in productive, task-related ways while emotion-focused coping leads drivers to dwell on their emotional reactivity, distracting them from performing effectively. Understanding drivers' choice of regulation style is vital as the use of adaptive strategies is a prerequisite for the development of expertise (Johnson, Tenenbaum & Edmonds, 2006).

Expertise in Driving

Experts outperform other drivers because they possess the characteristics, skills and knowledge necessary to anticipate and respond in a superior fashion, both psychologically and physically (Ericsson, 2006a). Expert drivers can only develop their skills and gain knowledge through extensive experience-based learning which involves the accumulation of mastery experiences and the gradual development of confidence that comes from successful practice (Victoir, Eertsman, Van den Bergh & Van den Broucke, 2005). While not explicitly a focus of past work on expertise, emotion regulation (ER) represents one such critical skill that experts must arguably develop to manage performance-altering cognitive stress processes.

Emotion Regulation and Driving

Individuals must be able to cope with the myriad emotional influences innate to driving so as to safely and successfully navigate a motor vehicle (Matthews, 2002). Successful performance hinges on the gradual accumulation of mastery experiences (Victoir et al., 2005). Enhanced ER skills may therefore facilitate expertise acquisition by fostering the mastery experiences which underlie superior performance. In fact, Keating and Halpern-Felsher (2008) advocated that inexperienced drivers have an increased risk of death and injury because of their underdeveloped attentional and emotional regulatory systems which leave such individuals ill-equipped to effectively function in the "complex and distracting contexts" pervasive in the real world. Anecdotal evidence bolsters this position in that emotions, when left unchecked, are most often linked to dangerous driving behaviors such as "exceeding the posted speed limit, following too closely, erratic or unsafe lane changes, improperly signaling lane changes, [and] failure to obey traffic control devices" (NHTSA, 2006). Experimental evidence likewise found that emotions are related to detriments in performance (Groeger, 1997), unsafe behaviors (Arnett et al., 1997), and an increased likelihood of accidents (Carbonell et al., 1997). More specifically, drivers in unpleasant moods (i.e., anger) exhibited less control of the vehicle through more extreme use of both pedals (Stephens & Groeger, 2006) and the steering wheel (Stephens & Groeger, 2009). Such behaviors lead to erratic driving at faster and more variable speeds (Arnett, 1997) which in turn increase the likelihood of an accident (Stephens & Groeger, 2009).

The potential for ER to directly impact (optimize or compromise) driving performance is clear, yet studies of emotion and driving have placed a heavy emphasis on emotional reactivity rather than regulation. Whether in the real world or in a

simulator, efforts have focused on determining the type of emotions experienced as well as when they are likely to occur (see Desmond & Matthews, 2009; Matthews & Desmond, 1998). Also, research to date has mainly focused on the psychological portion of the psychomotor driving task. Studies which have explored the motoric (or behavioral side) of driving have chiefly investigated large-scale driving outcomes such as vehicle velocity and position in the driving lane (Mesken, Hagenzieker, Rothengatter & de Waard, 2007). How emotion influences the small-scale movements necessary for sustained driving efficiency and effectiveness remains unknown. Moreover, how the choice of emotion regulation technique influences the impact of emotional reactivity on driving specific movement has not been studied. In the current study, I sought to address these limitations by evaluating the motor performance of drivers who favor different emotional regulation strategies. Using an index of muscle co-activation (i.e., co-contraction of upper limb muscles), my objective was to determine how the critical motor functions necessary for effective vehicle operation may be affected by emotional reactivity and regulation.

Movement and Driving

To successfully complete any goal-directed movement (or ongoing execution of complex movements) such as driving, it is essential for the muscles involved to activate in the correct sequence. Should the necessary muscles fail to contract, or if they contract in an inappropriate order, at an inappropriate force, or with too much variability, the resultant motor output will be suboptimal, leading to overt movement alterations that could precipitate inefficient and potentially unsafe driving behavior. Co-contraction, a phenomenon in which agonist and antagonist muscles activate simultaneously, represents such a suboptimal motor pattern, and was the focus of the present

investigation. Indeed, this type of contraction is a hallmark symptom of movement disorders such as Parkinson's Disease and Cerebral Palsy, which are characterized by motor difficulties (Jankovic & Kapadia, 2001; Poon & Hui-Chan, 2009).

According to the Neuromotor Noise Theory of goal-directed movements (van Galen and van Huygevoort, 2000), muscular co-contraction often results when individuals are asked to perform in affectively unpleasant environments rich with external stressors. This postulate, which assumes top-down processing, has been experimentally supported (Meulenbroek, Van Galen, Hulstijn, Hulstijn & Bloemsaat, 2005). Not only do unpleasant conditions produce co-contractions, they can also indirectly lead to contractions of greater magnitude via the activation of defensive circuitry (Coombes, Cauraugh & Janelle, 2006). Based on prior related work, therefore, one would expect elevated levels of muscular co-contraction to occur in the primary upper arm muscles (biceps brachii and triceps brachii) during the driving task. The resulting immobilization of a particular joint, in this case of the elbow, would signify less control over the manual operation of the vehicle which requires both elbow flexion and extension. Essentially, the less co-contraction of upper arm muscles, the greater the facilitation of multi-joint movement necessary for control over the vehicle (Gribble, Mullin, Cothros & Mattar, 2003). Co-contraction has previously been used as a means of investigating motor efficiency in other domains of human performance, mainly athletic pursuits such as cycling (Johnston, Barr & Lee, 2007). However, emotion induced co-contraction has not been studied with driving specific behaviors, or with regard to questions of how emotion regulation might differentially impact muscle activation patterns.

Limitations of Previous Work

Past research has traditionally investigated performance outcomes of the vehicle system (i.e., what the car is doing during the drive) as opposed to driver performance (i.e., what the human body is doing during the drive). Also, experimental studies have explored how emotions impact drivers' psychological states, but have neglected to consider the valence and arousal dimensions of emotional reactivity or how emotions influence the physical system that in turn executes driving movements. Finally, emotions have typically been studied as byproducts of engaging in the driving task (emotional reactivity), without considering potential dispositional factors that could influence the regulation of emotional experience, whether adaptive or maladaptive. Each of these limitations provided the motivation for this project and was considered in its design.

Purpose

The purpose of the current study was two-fold. The first aim was to determine how motor components of human driving performance are affected by emotions. The second aim was to discern how different emotion regulation strategies can act to modify emotional reactivity tendencies. These aims were investigated in the context of a dual-task paradigm consisting of simulated driving and coincident processing of affective stimuli. Emotional reactivity was assessed using the analysis of both cardiac and muscular physiological measurements (i.e., heart period and co-contraction of upper arm muscles). Participants' predominant emotion regulation strategy was gauged via the completion of validated questionnaires.

The Current Study and Hypotheses

No known studies have directly evaluated the effect of emotions on motor output necessary for driving. I analyzed participants' motor behavior in response to domain-specific and non domain-specific pleasant, unpleasant and neutral affective stimuli in a dual-task simulated driving protocol. Previous research consistently demonstrates that unpleasant emotional states result in greater force production (Coombes, Gamble, Cauraugh & Janelle, 2008) and reduced accuracy (Coombes, Janelle & Duley, 2005) of fine motor tasks. Pleasant emotional states also adversely affect movement accuracy, though not to the extent of unpleasant emotions (Coombes, Janelle & Duley, 2005). Additionally, the observed increases in force production resulting from the manipulation of emotional state (Coombes, Gamble, Cauraugh & Janelle, 2008) could be driven by muscular co-contraction (Coombes, Naugle, Barnes, Cauraugh & Janelle, in press). Elevated levels of muscular co-contraction were therefore expected under conditions of extreme emotional saliency (Coombes, Naugle, Barnes, Cauraugh & Janelle, in press). Second, no known studies have yet assessed the effects of different emotion regulation techniques on motor output. While initial efforts are underway (Hancock & Beatty, 2010); they address neither driving-specific ER techniques nor driving-specific motions.

Heart Period

To determine the extent of emotional reactivity and to assess the effectiveness of different ER strategies, reactivity must be quantified. Heart period (R-R interval) was employed as an index of physiological arousal. Heart period was quantified as the "time in milliseconds between successive R-peaks (or spikes) of the ECG, so that an increase in heart rate results in shortening of heart period" (Lenneman & Backs, 2009). Heart period has proven sensitive to arousal fluctuations in response to stimuli presented

during dual-task simulated driving (Lenneman & Backs, 2009). Unpleasant stimuli typically elicit a rapid initial heart deceleration (Dunn, Billotti, Murphy & Dalgliesh, 2009), which would correspond with a larger than normal heart period. Those who are more successful at controlling their physiological responses to emotional stimuli are therefore expected to exhibit a smaller (closer to baseline) heart period. I therefore hypothesized that (1) participants would exhibit a longer heart period in the six seconds after stimulus onset. Additionally, (2) expert drivers, who report using adaptive ER strategies, would demonstrate a shorter (closer-to-baseline) heart period as compared to non-experts during this same time period.

Co-contraction.

The second dependent measure was muscular co-contraction, which was monitored by surface EMG activity of the biceps brachii and triceps brachii (medial head) and quantified as [(2 X TRICEPS EMG)/ (TRICEPS EMG + BICEPS EMG)] X 100 (Olney & Winter, 1985). Co-contraction varies in magnitude between phasic and tonic activity. Of interest in this study was participants' difference measure between phasic responses to emotional stimuli during the drive and baseline physiological activity. Previous research has shown that the co-contraction ratio of upper extremity muscles (i.e., biceps and triceps brachii) increases in relation to amount of mental workload when tapping key finger patterns and recalling auditory tones (Bloemsaat, Meulenbroek & Van Galen, 2005). Past studies have also shown that improved force accuracy is associated with lower levels of antagonist co-contraction while modulating muscular contraction to a target force (Patten & Kamen, 2000). I therefore hypothesized that participants' co-contraction ratio of upper extremity muscles would increase in the six seconds after stimulus onset in response to exposure to affective versus neutral stimuli.

Moreover, expert drivers, again who report using adaptive ER techniques, would exhibit a diminished increase in co-contraction as compared to non-experts.

Self-report scores of images' valence and arousal.

Participants were asked to rate the images in terms of their valence (pleasant, unpleasant and neutral) and arousal level (very stimulating to very calming) using the Self-Assessment Manikin, an instrument that allows participants to rate images using a visual continuum (Bradley & Lang, 1994). I hypothesized that I would find no significant differences between experts' and non-experts' ratings of either the domain-specific or non domain-specific images.

Driving performance

I hypothesized that experts would perform better than non-expert participants by exhibiting smaller mean driving speeds (adhering more closely to the speed limit) and less lane excursions than non-expert drivers.

Findings from the proposed project could have a significant bearing on how people learn to drive; while also providing a theoretical basis on which to found specialized and effective practice regimens (Dahl, 2008; Glendon, Dorn, Davies, Matthews & Taylor, 1996; Keating & Halpern-Felsher, 2008). More specifically, traditional driver's education programs which now emphasize procedural knowledge could incorporate the instruction of adaptive emotion regulation strategies to further develop students' psychological and physical driving skills. Such enhanced training methods, at earlier ages, could help minimize counterproductive episodes of high emotional saliency and establish life-long, safe and effective driving habits such as efficient hazard monitoring (McKenna & Crick, 1991; Mourant & Rockwell, 1972),

greater situational awareness (Lansdown, 2002; Chapman & Underwood, 1998) and effective collision avoidance (Evans, 1991).

Hypotheses

Cardiac measure (heart period):

1a) Exposure to affective images (pleasant and unpleasant) would result in a longer heart period (and consequently positive mean difference scores) compared to neutral images in all participants. 1b) Experts would display a shorter heart period (smaller mean difference scores) in response to affective stimuli compared to non-experts. 1c) Task-focused experts would exhibit the smallest mean difference scores of any group. 2) Exposure to domain-specific images would result in smaller mean difference scores compared to non domain-specific (IAPS) images in experts compared to non-experts. 3) Females would display a shorter heart period (smaller mean difference scores) in response to affective stimuli compared to males.

Muscular co-contraction:

4a) All participants would demonstrate an increase in the co-contraction index following exposure to affective images (pleasant and unpleasant) as compared to neutral images. 4b) Experts would exhibit a smaller index of co-contraction (smaller mean difference scores) in response to affective stimuli as compared to non-experts. 4c) Task-focused experts would display the smallest mean difference scores of any group. 5) Exposure to domain-specific images would result in smaller mean difference scores compared to non domain-specific (IAPS) images in experts compared to non-experts. 6) Females would exhibit a smaller index of co-contraction (smaller mean difference scores) in response to affective stimuli as compared to males.

Driving measures:

7a) Experts would exhibit significantly smaller mean driving speed values (closer adherence to the speed limit) as compared to non-experts participants. 7b) Task-focused experts would display the smallest mean driving speed values of any group. 8a) Experts would have significantly fewer lane excursions than non-expert drivers. 8b) Task-focused experts would display the smallest number of lane excursions of any group.

CHAPTER 2
REVIEW OF LITERATURE

There are more expert drivers than there are experts in any other domain of expertise (Durso & Dattel, 2006). It is difficult to think of another task that adults engage in with more frequency or which constitutes a greater everyday risk. Furthermore, the life-or-death consequences inherent to the driving task provided a clear imperative to study driving expertise and realize how drivers improve their performance.

The driving task consists of several subtasks that are composed of numerous interdependent psychological and physical processes. Many factors may influence performance of the subtasks involved in driving, thereby affecting the acquisition and execution of overt driving skill. Of particular interest here was the impact of emotional state on the psychomotor skills that permit one to execute the complex movements needed to safely and effectively drive an automobile. Driving is arguably one of the most relevant tasks with which to investigate how emotions impact expertise as it occurs in exceptionally dynamic environments that are abundant with affective stimuli (Durso & Dattel, 2006). Efforts to comprehend (1) the effect of emotion on driving performance and (2) how emotion regulation strategies may serve to counteract maladaptive emotional reactivity during driving are vital for developing safe driving habits. I therefore begin this review with a discussion of expertise, particularly as related to the driving task, to illustrate the quality of motor performance necessary for safe and efficient driving. To elucidate how emotions affect motor behavior, common emotions and their effects on small-scale movements and driving performance are also addressed. Special consideration is then devoted to the process of emotion regulation and the different regulation techniques that can facilitate or inhibit the impact of emotion on

motor performance. I then explain how regulating emotions can either help or hinder the driver's effective and efficient allocation of attentional resources necessary for safe, superior performance. Finally, I subsume how these previous discussions of expertise, emotions and attention may influence any relationship between emotion regulation and basic driving movements.

Safe driving requires a great degree of psychological and physical dexterity in order to perform a task in such a dangerous and unpredictable environment as the modern roadway. Not only is it difficult to drive while being repeatedly exposed to pervasive affective influences from both intra and extra-vehicular sources, but driving also involves several – and often concurrent – subtasks between which drivers must divide their limited attention. Drivers' ineffective allocation of attention (NHTSA, 2010c) or failure to manage powerful emotional influences (McMurray, 1970) can have potentially fatal consequences. In the current study, therefore, I proposed to determine how emotions impact the movements necessary for driving, and how emotion regulation techniques may affect such movement alterations.

Expertise and Driving

Considering the associated risks of death and injury, driving is an activity in which expertise and experience are important factors. Existing research suggests an inverse relationship between crash rates and level of expertise, wherein crash rates decrease as drivers further develop their driving skills, become more knowledgeable of traffic rules and risks, and accumulate sufficient experience (Board on Children, Youth, and Families, 2007). However, as with all correlational research, it is difficult to establish a direct causal relationship between expertise and safe driving performance (and see

Evans, 1991). To better understand the relationship, one requires a more in-depth examination of the nature of expertise, its antecedents, and developmental course.

What is Driving Expertise?

Expertise is considered to be the objective and subjective characteristics, skills and knowledge that distinguish experts from novices and less experienced people (Ericsson, 2006a). Considering the driving task, driving expertise would be reflected in the motor skills, procedural knowledge, and practical experience that distinguish expert drivers from their non-expert and novice cohorts. An implied coda to Ericsson's definition is that experts have achieved the highest level of mental and physical functioning in their field. Driving, however, is predominantly a satisficing task (see Hancock, Mouloua & Senders, 2008). One need not drive somewhere in an optimal fashion to be considered an expert. Safety and efficiency therefore seem to be the ultimate aspirations in the pursuit of driving expertise. Researchers attempting to operationalize expert driving performance use the following behavioral criteria: successful collision avoidance (Evans, 1991), active monitoring for hazards (McKenna & Crick, 1991; Mourant & Rockwell, 1972), greater situational awareness (Lansdown, 2002; Chapman & Underwood, 1998) and superior manual control over the vehicle (Gershon, Shinar & Ronen, 2009; Weafer, Camarillo, Fillmore, Milich & Marczinski, 2008; Treffner, Barrett & Petersen, 2002; Recarte & Nunes, 1996).

Adverse driving events such as traffic accidents are typically the result of unintentionally poor control over the vehicle in response to unexpected situational demands with which the driver may be (albeit temporarily), poorly equipped to cope. Control of the vehicle, however, is contingent upon the driver's control over the body and its reactions. The current study therefore focused on motoric emotional reactivity

while driving and how emotion regulation may offset any maladaptive control tendencies. As small-scale motoric adjustments in driving can produce potentially fatal consequences, it is critically important to know how emotional reactivity can impact movements necessary for driving.

Acquisition of Expertise: Prerequisites and Experience

The skills and knowledge necessary for driving expertise can only be achieved through extensive on-road experience. To become experts, drivers must engage in experience-based learning which comprises both the accumulation of mastery experiences and the feelings of confidence these experiences instill in the driver (Victoir, Eertsman, Van den Bergh, & Van den Broucke, 2005).

Experience alone, however, cannot solely account for the acquisition of expertise in driving (Duncan, Williams & Brown, 1991). According to Johnson, Tenenbaum and Edmonds (2006), experience on the road must be coupled with the following factors to result in expertise: (1) high effort, (2) adaptive physical and psychological predispositions, (3) a well-established support system and, of principal concern in this study, (4) facilitative coping strategies. Mastery experiences selectively reinforce these four attributes, leading to adaptations in functioning and eventually, expertise (Figure 2-1 and see Ericsson, 2007).

The generally proposed time frame for the completion of the expertise acquisition process is a period of approximately ten years (Chi, Glaser & Farr, 1988). Notable exceptions to this ten-year rule are child prodigies who attain the highest levels of achievement at extremely young ages (e.g., Mozart independently composed symphonies before age ten). A potential reason for the rarity of child prodigies could be that self-regulatory systems are still under-developed during the childhood years.

Furthermore, the adolescent years are a sensitive period for the development of both biological and cognitive self-regulatory systems (Dahl, 2008). During this same time period, people typically begin their acquisition of driving expertise. Individuals' increasingly mature emotion regulation capacities may therefore facilitate the acquisition of expertise in driving as the sensitive periods of their development coincide (Shavinina, 2007).

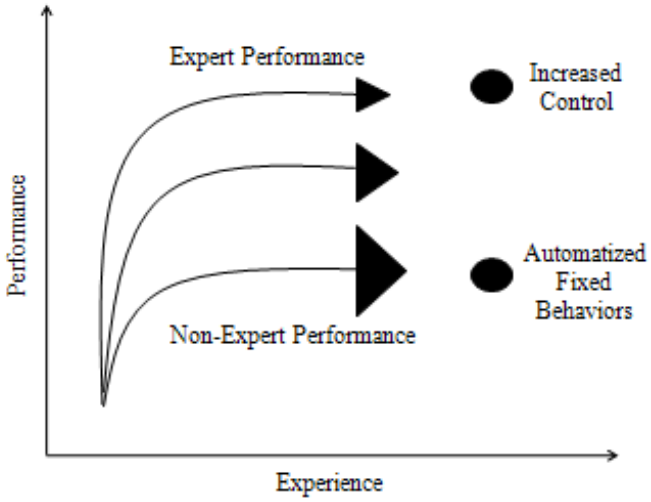

Figure 2-1. Developmental course of expertise. A graphical representation of the qualitative difference between the developmental courses of expert performance versus everyday activities. Once everyday activities are learned to the level of automaticity, individuals rarely if ever overcome automaticity for further improvement, as they prefer to perform these tasks while keeping energy expenditure at a minimum. Experts, on the other hand, will take advantage of their effort, predispositions, support systems and coping strategies to achieve greater control over their performance and prevent premature automation of skills[1]. *Note*: From "The scientific study of expert levels of performance: General implications for optimal learning and creativity," by K.A. Ericsson, 1998, *High Ability Studies, 9,* p. 90. Copyright 1998 by European Council for High Ability. Adapted with permission.

[1] Driving, as an automated everyday activity, does not easily correspond with this Ericssonian view of expertise. However, driving constitutes a significant exception to this conceptualization as it is a satisficing task; there is no one optimal performance outcome as in other domains. Therefore, the main aspects of interest in this representation are the depiction of the progressive nature of expertise acquisition as well as certain key characteristics of expertise (i.e., increased control) which are of vital importance to this study.

Self-Regulation and its Role in Expertise

Self-regulation, one of the first skills humans learn (Cooper, 2007), is the ability of several interpersonal systems to continually monitor and modify cognitive, sensory and motor capacities to compensate for unexpected and dynamic environmental demands (Charlton, Oxley, Fildes & Les, 2001). Continual self-regulation is required for various psychological and physiological processes fundamental for the acquisition and execution of expert driving performance (Donorfio, D'Ambrosio, Coughlin & Mohyde, 2009; Bandura, 1986, Zimmerman, 2006; Zimmerman, 1989). Active monitoring for hazards (Wikman, Nieminen & Summala, 1998) and decision-making (Mather et al., 2009) represent two critical psychological processes in the driving domain which require such ongoing mental management. Perhaps the most important factor in need of regulation is emotional reactivity. Emotional reactions can influence both the psychological and physiological systems that underlie the psychomotor task of driving. As discussed below, a critical yet largely ignored factor that might also be affected by emotional reactivity is the planning and control of the motor actions that are relied upon for effective vehicle control.

Emotions and Emotion Regulation

Emotions are valenced responses to internal and/or external stimuli, and can be measured across multiple behavioral, physiological, and cognitive / experiential response systems. They are distinct from moods in that they are responses to specific triggers and can implicate several types of appraisal procedures so as to assign significance to certain stimuli (Ochsner & Gross, 2005). An individual's emotional reactivity to affective environmental stimuli can bias cognitions and actions necessary for driving (Matthews, 2002). Herein, common affective states that typically arise during

the driving interval (e.g., anxiety, anger, fatigue and happiness) are summarized. Of specific interest was to describe the impact of these affective states on small-scale movement patterns and large-scale driving behaviors. Techniques for emotion regulation and their proposed subsequent effects on movement and driving performance are also discussed.

Emotions' Effects on Small-Scale Movement

Somatic nervous system arousal associated with valenced emotions leads to changes in physiological functioning (Fairclough, Tattersall & Houston, 2006; Malta, Blanchard, Freidenberg, Galovski, Karl & Holzapfel, 2001). Such physiological manifestations of emotional reactivity can be indexed through behavioral measures that embody the emotional reactions. For example, pleasant and unpleasant emotional responses lead to greater force production in small-scale movements, such as a pinch grip task (Coombes, Gamble, Cauraugh & Janelle, 2008). Such evidence suggests that emotions, regardless of valence (but at sufficient intensity), excite the motor system similarly. Further studies have shown that sustained negative emotional valence can amplify force production, expedite speed, and reduce accuracy of motor control (Coombes, Cauraugh & Janelle, 2006; Coombes, Janelle & Duley, 2005). Is emotion therefore beneficial or detrimental to fine-motor tasks? The answer ultimately depends on the goal of the movement. Clearly, however, the micro behavioral alterations in movement characteristics that occur due to emotional reactivity may have severe consequences on driving performance given the extensive fine-motor actions necessary for vehicle control.

Emotions' Effects on Large-Scale Driving Performance

The aforementioned smaller-scale movements coalesce into large-scale and long-term driving coordinated behaviors, which are similarly susceptible to emotional manipulation. The effects of both unpleasant (i.e., anxiety, anger, fatigue) and pleasant (i.e., happiness) emotions on driving performance are overviewed next.

Anxiety is the most frequently occurring emotion in the driving context (Mesken, Hagenzieker, Rothengatter & de Waard, 2007) and is defined as a state in which individuals are unable to effectively remove or alter a stimulus which is perceived as threatening (Power & Dalgliesh, 1997). During driving, anxiety typically arises in response to evaluative conditions or events affecting safety such as driving in hazardous and unfamiliar conditions (Fairclough et al, 2006; Mesken et al., 2007). Anxious feelings are strongly associated with accident involvement (Beirness, 1993; Matthews, Tsuda, Xin & Ozeki, 1999) and result in adverse effects on performance (Shahar, 2009). Fairclough and colleagues (2006) investigated anxiety's effects on drivers performing under pressure (due to evaluation). Findings from this and other studies revealed that increases in state anxiety lead to greater somatic nervous system arousal as indexed by heart rate, which could potentially be internally distracting (Fairclough et al., 2006; Mesken et al., 2007).

Anger is an important emotion as it is characterized by an unpleasant emotional valence and an approach orientation, whereas most unpleasant emotions motivate avoidance behaviors. Drivers who are angry exhibit elevated levels of muscle tension, even while merely listening to anger-provoking driving vignettes (Malta et al., 2001). Tense muscles would produce suboptimal motor output, thereby affecting the effectiveness and efficiency of motor performance. Anger typically overtly manifests as

aggressive driving behavior (Mesken et al., 2007; Malta, 2001), and is normally produced by situations that the driver perceives as impeding progress. Anger is also the emotion most associated with such illegal driving operations as exceeding the speed limit (Mesken et al., 2007) and more frequent and more error-prone overtaking (Matthews, Dorn, Hoyes, Davies, Glendon & Taylor, 1998). Angry drivers' unsafe patterns of behavior contribute to the fact that they are twice as likely to crash as non-angry drivers (Deffenbacher, Deffenbacher, Lynch & Richards, 2003). Interestingly, there are no gender differences in terms of reported anger while driving (Lonczak et al., 2007; Deffenbacher, 2008). However, males seem to act upon these feelings more often than females, as indexed by aggressive behavior (Björklund, 2008), traffic citations and traffic-related injuries (Lonczak et al., 2007).

Findings that both sexes report similar emotional reactivity to anger-provoking stimuli but different resultant behaviors associated with that emotion suggest the possibility of interesting gender effects in terms of emotion regulation abilities. Females may be superior emotional regulators as they pay greater attention to their emotions than males (Thayer, Rossy, Ruiz-Padial & Johnsen, 2003). Perhaps females' heightened awareness of their own emotional state facilitates their efforts to regulate emotional influences. Females additionally employ significant higher levels of a number of cognitive emotion regulation strategies (Martin & Dahlen, 2005). If females are more effective at regulating emotions, there could be implications for training. Young male drivers may potentially need more extensive ER training than their female counterparts.

Fatigue is a vague term encompassing involuntary sleep onset while driving, and poor performance efficiency because of circadian rhythms or long-term task

engagement (Matthews, 2002). Despite the difficulties in defining the term, the phenomenon itself is of critical importance to driver safety as it is a major cause of serious accidents (Connor, Whitlock, Norman & Jackson, 2001). Fatigue has a pronounced diminishing effect on performance efficiency (Taylor & Dorn, 2006), specifically impairing vehicular control by reducing steering activity (Matthews, 2002). Fortunately, there are certain behavioral tasks in which one can engage to counteract this tendency. Gershon, Ronen, Oron-Gilad and Shinar (2009) concluded that active participation in cognitive tasks, such as answering trivia questions, can neutralize the symptoms of fatigued drivers. As emotion regulation is a cognitive task, it may potentially prove an effective method of maintaining safe driving performance.

Unlike the abovementioned emotions, happiness is characterized by pleasant emotional valence. Given the findings of unpleasant emotions' effects on driving, one might erroneously assume that pleasant emotions will facilitate safe driving behavior. Instead, Pêcher and colleagues (2009) found that when drivers were primed to be happy, they were more distracted, drove slower and displayed compromised lateral control of the vehicle. Mesken et al. (2007) also investigated happiness but found that it had no discernable effect on drivers' behavior or physiology. Recent research is therefore inconclusive regarding pleasant emotions' effects on driving performance. The current study served to more clearly indicate positive emotions' influence on driving-specific movement.

Taking into account the research investigating emotions' effect on large-scale driving behaviors, it seems that emotions, regardless of their valence, can severely affect the operator's ability to drive; and drivers should take steps to mitigate these

effects to ensure safe and effective driving performance. Drivers should consequently develop their emotion regulation skills as early as possible in the process of learning to drive. Consistent with this notion, Johnson, Tenenbaum and Edmonds (2006) proposed the establishment of adaptive coping strategies as central to acquiring driving expertise.

Common Emotion Regulation Strategies

Emotion regulation is defined as the processes by which people influence which emotions they have, when they have them, and how those emotions are experienced and expressed (Gross, 1998a). Management of emotional reactivity is the end goal of several different emotion regulation techniques. Two of the most popular emotion regulation strategies include cognitive reappraisal and expressive suppression (Gross, 1998b). Cognitive reappraisal acts to reduce the saliency of emotional influence by prompting individuals to re-evaluate stimuli in more objective terms. Expressive suppression, rather, seeks to reduce the outward behavioral symptoms of emotional reactivity (such as facial expressions) (Goldin, McRae, Ramel & Gross, 2008). Experimental studies have shown that reappraisal is the more effective of the two strategies as it reduces both emotion experience and expression without the accompanying impact on memory that suppression has (Gross, 2002). Reappraisal is also associated with more beneficial, long-term health outcomes (Haga, Kraft & Corby, 2009).

Matthews and colleagues (1996a; 1996b) identified five strategies, specific to driving, that individuals use to regulate emotional responses: reappraisal, task-focused, emotion-focused, avoidance and confrontive coping. Prior to discussing these techniques in detail, it is important to first distinguish between emotion regulation (ER) and coping.

Distinguishing ER and Coping

ER is the process by which individuals attempt to control which emotions they have, when they experience them, and how emotions are subsequently felt and expressed (Gross, Richards & John, 2006). Coping, however, encompasses all efforts on behalf of an individual to successfully interact with their demanding environment (Lazarus & Folkman, 1984). Emotion need not necessarily be involved. Considering a graphic surgery as necessary for healing is an example of emotion regulation (cognitive reappraisal more specifically; the re-evaluation of emotional stimuli in more objective terms). Studying to pass a difficult exam would be an example of coping where no emotion is directly concerned. ER and coping therefore overlap. However, ER is exclusively concerned with emotions while coping additionally incorporates non-emotional actions used to accomplish non-emotional goals (Gross, Richards & John, 2006).

Matthews and colleagues have therefore accurately labeled the five techniques as coping strategies as they comprise both emotional and non-emotional facets. However, as each strategy addresses aspects of emotion in driving, they also qualify as emotion regulation techniques.

Driving Specific Emotion Regulation Strategies and Their Effects on Driving Performance

Desmond and Matthews (2009) detailed five distinct, driving-specific ER styles: reappraisal, avoidance, task-focused, emotion-focused and confrontive coping. They also provided great detail concerning how these coping styles serve to assuage interactions between personality factors, environmental conditions, objective, and subjective driving outcomes (Figure 2-2).

Researchers endorse the adoption of appraisal and task-focused coping and advise against using avoidance, emotion-focused and confrontive coping to most effectively combat the effects of stress while driving (Desmond & Matthews, 2009). The two former strategies are encouraged as they foster safe driving habits such as hazard monitoring, whereas the latter three techniques are discouraged as they entail unsafe behaviors such as threatening other drivers.

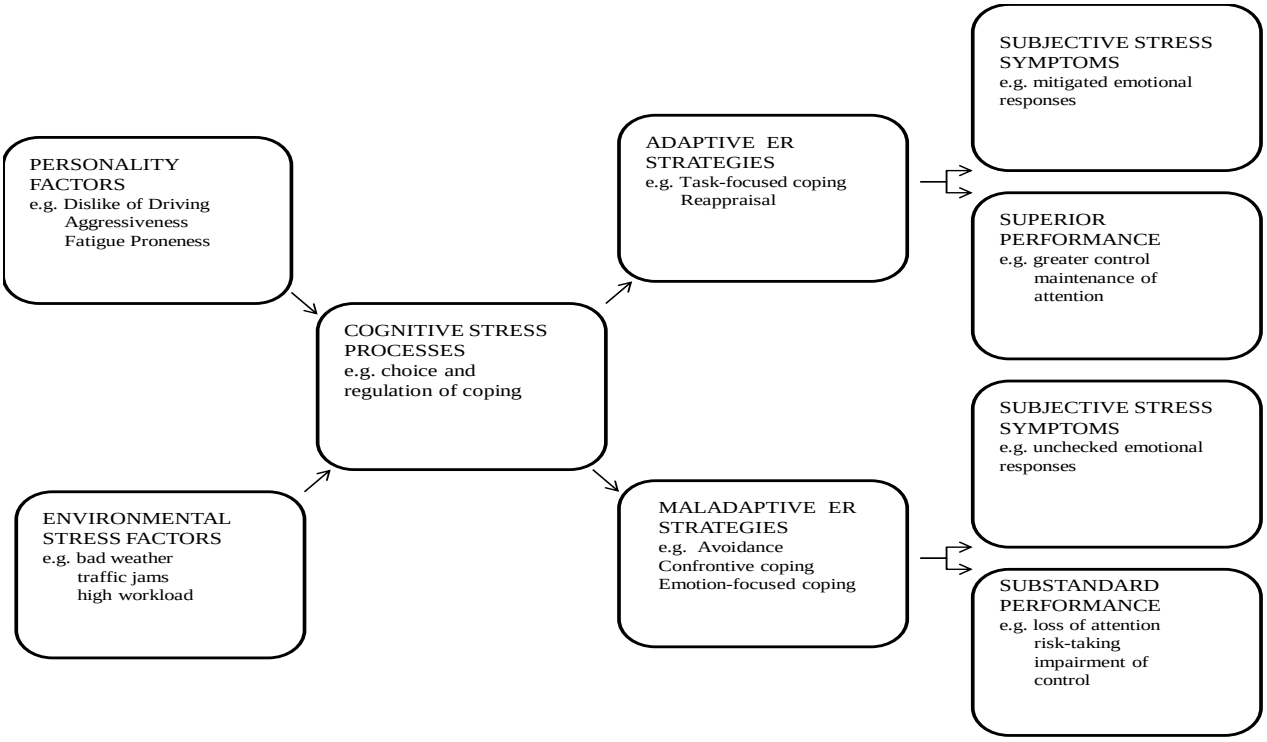

Figure 2-2. Modified transactional framework for driver stress. This framework illustrates differential subjective affective and objective performance outcomes based on choice of emotion regulation strategy. *Note:* From "Toward a transactional ergonomics for driver stress and fatigue," by G. Matthews, 2002, *Theoretical Issues in Ergonomics Science, 3,* p. 197. Copyright 2002 by Taylor & Francis, Ltd. Adapted with permission.

Appraisal

Appraisal is similar to the aforementioned notion of cognitive reappraisal as it involves actively altering perceptions of stimuli. As a strategy, appraisal in the driving context principally involves viewing the stressful drive as a valuable learning experience, a useful guide to preparing future responses (Matthews, 2002). According to Johnson and colleagues (2006), the use of appraisal, as one of the most facilitative coping strategies (Desmond & Matthews, 2009), would foster the development of driving expertise. Likewise, when using the appraisal strategy, motorists often drive slower and feel that they are “becoming a more experienced driver” (Matthews, 2002; Matthews et al., 1996). According to Victoir and colleagues (2005), the fostering of feelings of mastery while developing driving experience is instrumental in expertise acquisition.

Task-focused coping

Task-focused coping involves diligent monitoring for potential hazards as well as consistent self-examination of driving performance (Matthews et al., 1996). Drivers using task-focused coping actively seek to minimize their feelings of recklessness or impulsiveness (which could have adverse results) by focusing solely on the task at hand. Task-focused coping is, in addition to appraisal, considered one of the most facilitative coping strategies as it promotes safe driving behaviors (Matthews et al., 1996). Drivers who are task-focused report fewer errors, fewer violations and driving at lower speeds (Matthews, 2002). According to Johnson and colleagues (2006), the use of adaptive coping strategies is a prerequisite of expert performance. Experts, as superior drivers, will therefore report using these two facilitative ER strategies (appraisal and task-focused) in favor of the alternative methods.

Avoidance

Avoidance is the refusal to acknowledge feelings or events while driving (Matthews et al., 1997). In response to stress, avoidant drivers will remain detached from the situation opting instead to think about completely different things (Matthews, 2002). Avoidance is a maladaptive strategy associated with more errors, more traffic violations and driving at faster speeds (Matthews et al., 1997; Matthews, 2002). Drivers who spend their time and energy disregarding aspects of their environment are severely hampered in their efforts to successfully cope with that environment. If avoidant drivers are being intentionally inattentive, they are more error prone given that safe driving requires continual monitoring of the environment and modifications based on those observations. Unsafe operation of the vehicle additionally accounts for avoidant drivers' higher prevalence of traffic violations.

Emotion-focused coping

Emotion-focused coping is characterized by self-criticism and worry (Desmond & Matthews, 2009). Self-critical thoughts cause cognitive interference, which by definition interrupts task-relevant activity and serves to diminish the quality and level of performance (Sarason, Sarason & Pierce, 1995). Self-criticism undermines drivers' confidence in their abilities to cope with their demanding environment (Matthews, 1993; Matthews et al., 1997) thus compromising safe driving performance. Emotion-focused coping is therefore considered a maladaptive ER technique as its use results in obsessive thoughts about the emotions themselves instead of channeling the emotions in a manner which promotes better driving. Emotion-focused drivers report committing more errors and driving at lower speeds (Matthews, 2002).

Confrontive coping

Confrontive coping involves regulating emotions by engaging in risky behaviors (Matthews, 2002). Behaviorally, confrontive drivers often antagonize their fellow drivers, drive at faster speeds, flash lights and honk horns in an effort to regulate their feelings. As a result of these behaviors, confrontive coping is highly correlated with traffic violations, driving errors and driving at faster speeds (Matthews, 2002). Confrontive coping is therefore maladaptive due to the promotion of unsafe driving practices.

Regardless of which technique the driver employs, the establishment of emotion regulation strategies can profoundly impact drivers' affective state, physical well-being and performance (Machin & Hoare, 2008). While there exists a large body of literature devoted to explaining the effects of emotion regulation on various physiological measures including heart rate, skin conductance and the eyeblink startle response (Driscoll, Tranel & Anderson, 2008), no research has investigated the effects of emotion regulation on motor output, although efforts are currently underway (Hancock & Beatty, 2010). The current study looks to fill this gap in the literature by investigating ER techniques and their effects on the motor behavior necessary for driving.

Is Emotional Regulation Beneficial or Detrimental to Driving Performance?

Given the previous discussion of effectiveness and long-term health benefits, (re)appraisal would seem to be the best option for drivers to use when in the traffic environment. However, emotion regulation would require attentional resources when performed deliberately. Emotion regulation might help overcome maladaptive emotional reactivity tendencies but would likely do so at the cost of limited attentional resources which could be devoted elsewhere.

Attention and Distraction

Attention is the cognitive process of selectively focusing on relevant environmental stimuli while ignoring extraneous information (Anderson, 2004). Attention is a malleable construct as it can be divided between multiple tasks or sustained over periods of time in response to environmental demands (Parasuraman & Davies, 1984; Hancock & Warm, 1989). Selective attention, the most relevant to driving, filters out non-pertinent input thus ensuring only essential information is processed (Abernethy, Maxwell, Masters, Van der Kamp & Jackson, 2007). Failure to attend to salient information in a timely manner can have disastrous consequences (Parasuraman & Nestor, 1991) and inappropriate continuous resource allocation results in unnecessary expenditure of effort. The optimal amount of attention drivers must devote to the task therefore varies as a function of subject-task parameters which include elements of the driving task, the roadway environment, and the permanent or dynamic characteristics of the operator.

The demand for attentional resources subsequently increases when individuals must engage in multiple tasks, such as concomitant driving and emotion regulation. Emotion-focused coping, for example, would be a wasteful secondary task to perform while driving as it is detrimental to performance. As attentional resources are limited, regardless of whether they originate from one central pool or multiple resources, the most common result of concurrent task engagement is a tradeoff between quality performance on one task for performance on the second task. The extent of this trade off (measured via an experimental protocol called a dual task paradigm) depends on several factors such as similarity of demands between tasks and the sensitivity of performance to resource availability, among others. Discrepancies between perceived

supply and demand of attentional resources cause stress which can significantly affect performance (Matthews & Wells, 1996; Matthews, Sparkes & Bygrave, 1996).

Limited Attentional Resources Cause Stress

The performance-resource function, defined as the efficiency of performance in relation to the amount of resources invested, is graphically represented as performance operating characteristics (POCs) first introduced by Norman and Bobrow (1975). An illustrated example of a POC curve is presented in Figure 2-3.

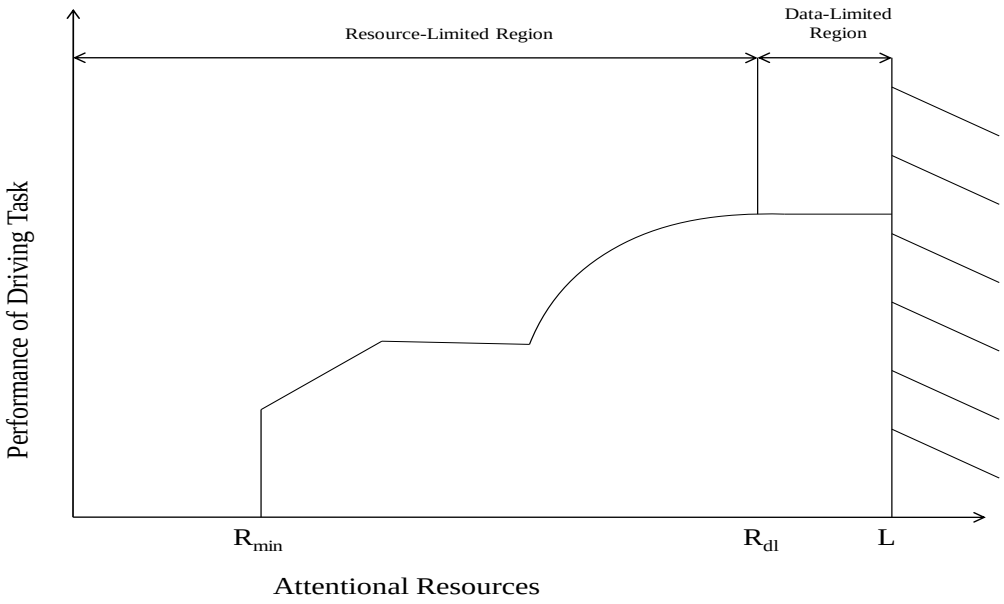

Figure 2-3. Norman and Bobrow's (1975) performance-resource function represents the relationship between performance on a single task and the amount of resources employed to complete it. The upper bound of consumable attentional resources is signified by L. Performance is represented by a plateau in the data-limited region as it occurs independent of processing resources. The specific form of the curve in the resource-limited region is dependent upon the operation of component processes. *Note:* From "On data-limited and resource-limited processes," by D.A. Norman and D.G. Bobrow, 1975, *Cognitive Psychology, 7,* p. 48. Copyright by Academic Press, Inc. Adapted with permission.

Performance operating characteristics depict the limits of concurrent task performance given a fixed set of task demands and holding with the assumption that the system is working at full capacity. All potential points either on or beneath the curve represent feasible scenarios in which attentional resources are sufficient for successful dual-task performance (Figure 2-3).

Navon and Gopher (1979) expanded upon these seminal POCs by conceiving of multiple resources of attention as opposed to one exhaustible pool. The updated POCs illustrate how increasing the task load of the prioritized driving task affects performance on the secondary picture viewing task (Figure 2-4).

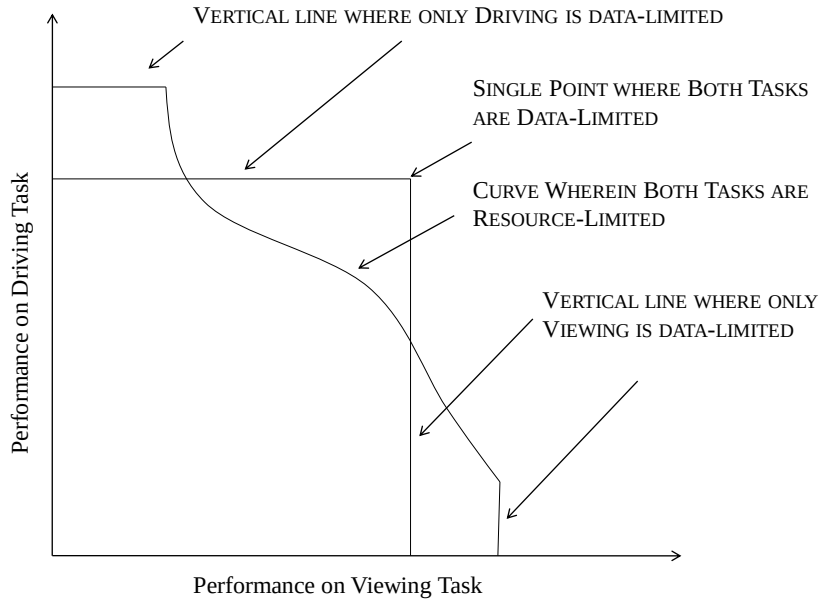

Figure 2-4. Norman and Bobrow's (1975) potential Performance Operating Characteristics (POCs). The curves demonstrate how performances on dual tasks co-vary as a function of resource allocation strategies. *Note:* From "On data-limited and resource-limited processes," by D.A. Norman and D.G. Bobrow, 1975, *Cognitive Psychology, 7,* p. 51. Copyright by Academic Press, Inc. Adapted with permission.

Attending to affective stimuli has previously been considered an actual task per dual task paradigms. Pêcher, Lemercier and Cellier (2009) investigated performance outcomes of participants' drive (primary task) while attending to valenced musical stimuli (secondary task).

Performance decrements in either task (represented by discontinuous POCs) manifest when drivers perceive their resources as insufficient to satisfy task demands, creating elevated levels of stress. Perception is therefore the key determinant of the stress response. Regardless of available resources, if the driver *perceives* them as inadequate, stress will ensue and performance will suffer. Concurrence cost, the term used to describe this reduction in total capacity, results from attempting to perform multiple difficult tasks simultaneously (Figure 2-5).

Navon and Gopher's discontinuous POC curves therefore reflect a maladaptive example of Matthews's (2002) cognitive stress processes. When the individual perceives that external demands outstrip their available resources, subjective and performance outcomes are compromised. It is therefore at this 'cognitive stress processes' level of functioning where emotion regulation can reshape perceptions and responses to facilitate rather than hinder successful driving performance.

Relevant then to the discussion of expertise, expert drivers would theoretically have a lower concurrence cost because they have become so skilled at driving that is has essentially become automated (Fitts & Posner, 1967), requiring significantly less attentional resources, thereby permitting the remaining resources or 'spare capacity' to be applied toward processing other stimuli. Training can, in a number of ways (Figure 2-6), effectively and beneficially shift these POC curves to produce superior performance

on both the driving and viewing tasks. Practice can lead to superior execution of one of both tasks, shifting the POC curve to the right (Figure 2-6A).

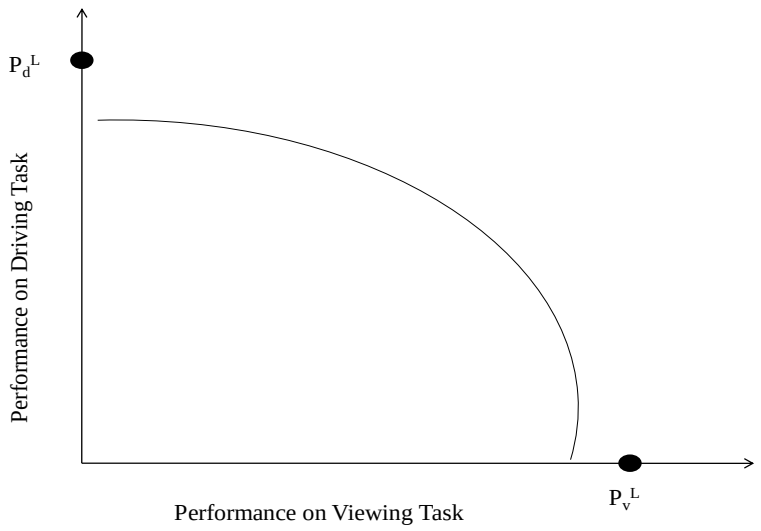

Figure 2-5. Navon and Gopher's (1979) discontinuous POC, representing a concurrence cost. The points on the axes represent optimum performance on each task. The discontinuous curve falls short of optimum in both cases, demonstrating that simultaneous performance of two tasks results in performance decrements on one or both tasks. *Note:* From "On the economy of the human-processing system," by D. Navon and D. Gopher, 1979, *Psychological Review, 86,* p. 224. Copyright 1979 by American Psychological Association, Inc. Adapted with permission.

Alternatively, individuals can, through practice, develop a more effective attention allocation strategy between the two tasks, leading to better performance on one or both tasks (Figure 2-6B). Additionally, increased automation of task performance, represented by a shrinking concurrence cost, would shift the curve to the right (Figure 2-6C). Finally, if the amount of overlap between task demands decreases, leading to less strain on attentional resources, the curve will also be pushed to the right (Figure 2-6D). In fact, according to Navon and Gopher (1979), if two tasks compete for attentional

resources (as driving and attending to roadside stimuli do); the only way to improve is to minimize the conflict by training the two tasks simultaneously.

Distractions, which are inevitable in the driving environment, represent additional strains on scarce attentional resources. Extra burdens upon attention will give rise to unpleasant emotions, such as “road rage” and anxiety, and will eventually affect performance detrimentally; a hypothesis which has received perfunctory support in the driving context (Lonczak, 2007; Harms, 1986). Emotion regulation can help curtail this decline in performance (Figure 2-7).

Collet and colleagues (2009) employed a dual task paradigm in an attempt to investigate the specific physiological and behavioral changes associated with secondary task performance during driving. Driving was the primary task while participants were asked to either (1) listen to the radio, (2) conduct a conversation with a passenger or (3) carry out a conversation on a cellular telephone. The authors chose these tasks based on the precept that two tasks utilizing the same resources will result in greater stress. Physiological findings demonstrated that dual task engagement led to increases in arousal. Couple these conclusions with the previous discussion regarding the elevated arousal levels associated with emotional experiences and it becomes evident that increases in arousal can quickly stem from several origins, influencing performance.

Empirical studies have clearly shown that emotions can affect the cognitive, physiological and motor systems critical for driving. Attention (Pachecho-Unguetti, Acosta, Callejas & Lupiáñez, 2010), cardiac measures (Lenneman & Backs, 2009), skin conductance, muscle tension (Collet, Clarion, Morel, Chapon, & Petit, 2009) and motor systems (Coombes, Higgins, Gamble, Cauraugh & Janelle, 2009) are all subject to

emotional influences, making the processing of affective stimuli an ecologically valid secondary task in which to engage during a simulated drive (Pêcher et al., 2009).

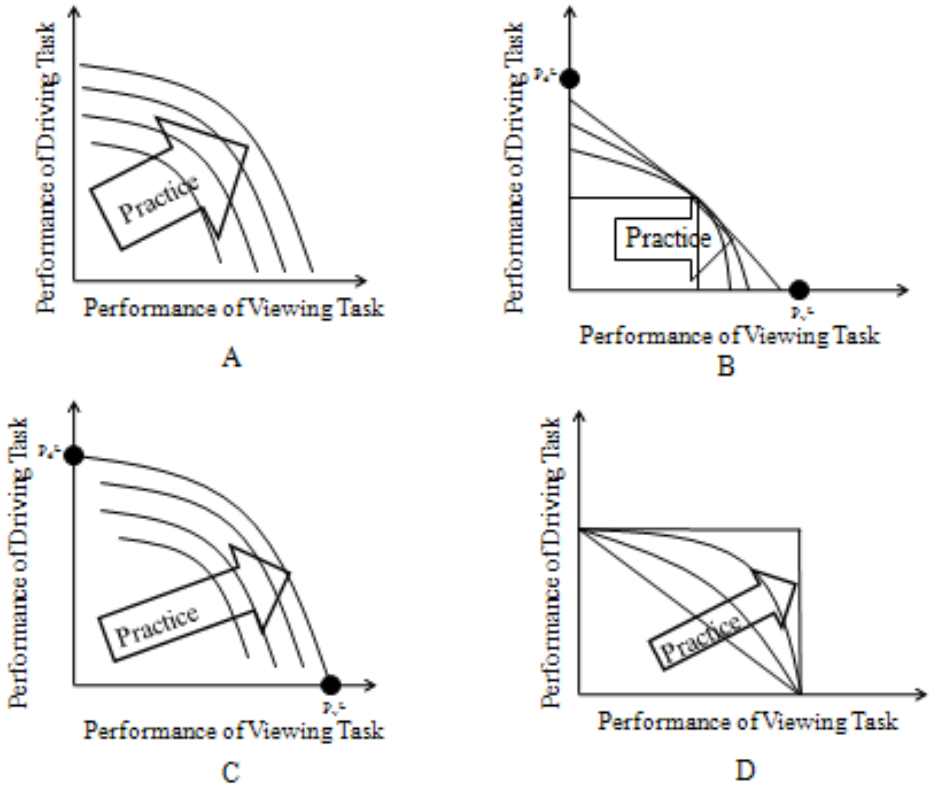

Figure 2-6. Graphical representations of four potential effects of practice on dual task performance. A) Improvement in performing both tasks. B) More effective strategy of attentional resource allocation between the tasks. C) Diminishing concurrence cost. D) Reduction in overlap between task demands. *Note:* From "On the economy of the human-processing system," by D. Navon and D. Gopher, 1979, *Psychological Review, 86,* p. 246. Copyright 1979 by American Psychological Association, Inc. Adapted with permission.

Concerns Regarding Dual Task Paradigms

Young and Stanton (2007) addressed a number of criticisms regarding the practice of adding a secondary task to investigate its effects on dual task performance during simulated driving. They advocated that the method of responding for secondary tasks must not interfere with the primary task of driving. For example, participants

having to take their hand(s) off of the wheel in order to press a button in response to stimuli would create an artificial performance decrement as the driver would normally keep both hands on the wheel. The authors additionally contended that the choice of secondary task must be considered carefully to preserve construct validity. Attending to affective stimuli thus constituted a viable secondary task as it does not artificially interfere with the motions of driving and it is representative of a common task that must be completed during typical driving. Expert drivers excel at effectively allocating their attentional resources between driving and a secondary task, producing superior performance on both. But what are expert drivers actually attending to during the drive?

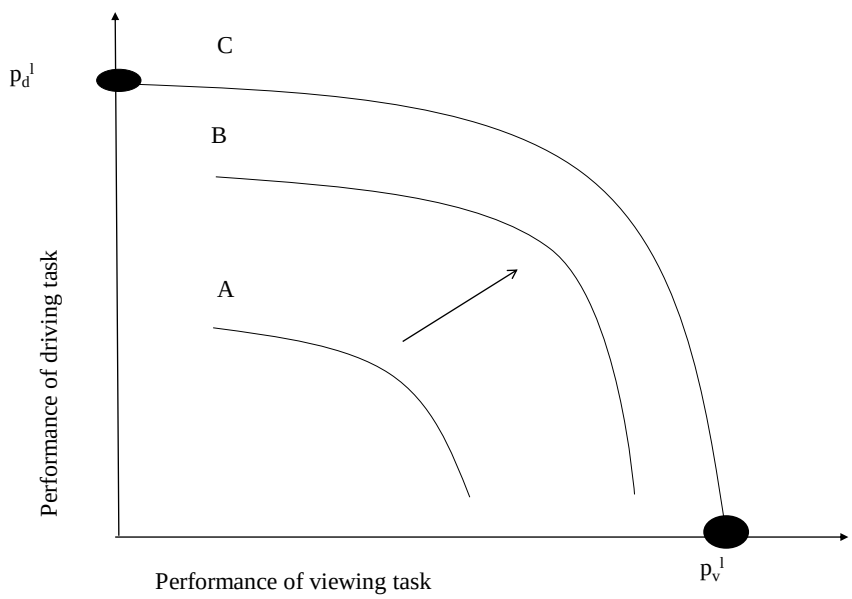

Figure 2-7. Graphical representations of A) a concurrence cost resulting from engagement in a dual task paradigm. B) A lower concurrence cost signifying better performance on both tasks. C) A POC depicting ideal performance on both tasks. Emotion regulation represents a possible mechanism by which performance may shift from curve A to curve B so as to progress as close as possible to curve C.

What Do Experts and Non-experts Attend To?

Do experts and non-experts attend to the same stimuli while driving? Do experts primarily dedicate their attention to features or events related to the primary task of vehicle operation or the secondary task such as reading road signs or looking at maps? Do novices allocate their attention to the same stimuli as experts? Lansdown (2002) used verbal protocols and visual behavior in an attempt to answer these questions. Lansdown's protocol involved driving while adjusting the in-car entertainment system. The adjustments range from (1) low complexity: turn the radio on or off, to (2) intermediate complexity: turn a cassette tape over, fast forward it, change the channel, eject the tape and adjust the volume, and (3) high complexity: search for a particular frequency/channel, change the balance to the right, change the fader to the front, etc. Verbal report results demonstrated that experts primarily attend to the surrounding environment, peripheral objects on the road, traffic signs and markings, while novices attend to vehicle operations (i.e., primary task considerations) more often. Lansdown's findings are in keeping with the assertion that expert drivers have automated their vehicle operations behavior, which allows spare attentional resources to be devoted to a secondary task. Novices, on the other hand, concentrate on performing the driving behavior they have not yet mastered. Visual behavior findings were similar, revealing that experts tended to glance less frequently and with less duration at secondary task controls during all levels of task complexity. Expert drivers have automated driving skills and are therefore able to focus on automating ER, unlike non-experts and novices who must consciously operate the vehicle. The more automated the driver's ER skills, the less stress they will experience which will allow them to more effectively allocate their

attention to relevant stimuli thus leading to safer driving behavior. Emotional regulation and the amount of attention devoted to its execution during driving is therefore a novel element unseen in the current literature. Having now discussed the complex relationships between attention, emotions, emotion regulation and movement, these concepts can now be applied to Matthews's (2002) Transactional Model of Driver Stress to appreciate how each of these elements culminate in superior driving performance.

Conclusion: A Return to the Transactional Model

Matthews's (2002) Transactional Model of Driver Stress, as previously discussed, attempts to illustrate the multifaceted interactions between personal and environmental factors that influence objective and subjective driving performance outcomes (Figure 2-2). The crux of this model rests in 'cognitive stress processes', which are coping styles, intended to mitigate the effects of the former factors on the latter measures. Safe driving expertise therefore depends on motorists instituting adaptive versus maladaptive ER styles as early and as often as possible in their driving experience. The adaptive ER techniques (i.e., task-focused coping and appraisal) incorporate the regulation of emotional influences in productive ways such as allocating limited attention to the learning experience and vehicle control. Experts who use these adaptive strategies more often than non-experts will therefore display less physiological emotional reactivity to domain-specific stimuli while maintaining superior driving performance.

Future Directions in Research

A solid comprehension of how the human body operates (i.e., motor behavior outcomes) is critical to understanding how individuals operate a vehicle (i.e., driving

performance outcomes). Little research has specifically explored how the human body performs during driving. The few studies which have investigated these effects, while useful in their investigation of emotional reactivity, are limited due to their (1) use of patient populations instead of healthy drivers (Dawson, Anderson, Uc, Dastrup & Rizzo, 2009), (2) examination of general motor abilities instead of task-specific motor performance (Dawson et al., 2009), and (3) consideration of movements as a diagnostic tool of attentional resource allocation or as responses to specific traffic events, as opposed to a means of carrying out the driving task (Lenneman & Backs, 2009; Robertson, 1987).

In sum, the current literature is limited in at least two vital areas: (1) the effects of emotions on movements necessary for driving behavior and (2) choice of emotion regulation technique and its effects on driving-specific movements. Regarding the first limitation, few studies have investigated the effects of emotions on movement specific to vehicle control. Additionally, experiments which have examined the effects of pleasant emotions have yielded equivocal conclusions (Pêcher et al., 2009; Mesken et al., 2007). In the current study, this limitation was addressed by indexing muscle efficiency through assessment of muscle co-contraction during driving while presented with pleasant and unpleasant emotional stimuli in the peripheral visual field.

Concerning the second limitation, while Matthews's model claims that choice of regulation technique significantly impacts subjective and objective performance outcomes, no experimental evidence exists that ER techniques alter the movement necessary to execute the driving task. In the current study I purposefully selected the groups of interest based on their expertise level and predominant regulation style to

determine how adaptive and maladaptive ER techniques impact emotional reactivity when confronted with emotionally salient cues.

In closing, current knowledge is limited by a lack of understanding regarding the role of emotions in the human movement necessary for driving performance as well as an inability to account for how emotion regulation may alter this relationship. My objective, therefore, was to determine how emotional reactivity and regulation contribute to the quality of movement execution that is necessary for safe and efficient driving.

CHAPTER 3
METHODOLOGY

Participants

Seventy-two drivers (36 females, 36 males), as determined via a power analysis using G*Power 3 (Faul, Erdfelder, Lang & Buchner, 2007), were recruited from the environs of a major university campus and participated as unpaid volunteers. The participants ranged in age from 18 to 37 years (M = 22.8 years). Eighteen years was selected as the lower bound for age so as to ensure participants had a minimum of two years of experience, as most people begin driving at 16 years old. The upper age limit was set at forty years to avoid the biased emotional responses of older individuals. Older adults 1) respond more slowly to unpleasant stimuli compared to neutral and 2) remember pleasant images more effectively than unpleasant images (Mather & Carstensen, 2003). The participants' level of experience (expert or non-expert) was determined by the following objective criteria: i) possession of a valid, state-issued driver's license, ii) years of driving experience, iii) driving frequency, iv) self-reported total lifetime mileage driven, v) number of accidents in the past three years, and vi) number of self-reported citations in the past three years (as specified in Table 3-1). Additional performance measures of safe, superior driving include a driver's mean driving speed and lane excursions (Table 3-2). Participants' performance on these measures was assessed during the two minute practice session. A participant had to fulfill "expert" criteria in at least four of the six experience-based categories and both "expert" performance-based categories to qualify as an expert in the experiment. Participants were specified if they reported any history of emotional disorders and were

asked to disclose whether or not they are taking any medication for their treatment. Any individuals with a history of emotional disorders were considered in a separate analysis.

Table 3-1. Experience-based measures of driving expertise.

Level of Expertise	Possession of Drivers License	Experience (years)	Frequency (days/week)	Total Mileage Driven (miles)	Accidents in Past 3 Years	Citations in Past 3 Years
Expert	Yes	> 2	4-7	> 500k	0-1	0-1
Non-Expert	Yes	> 2	0-3	< 500k	> 2	> 2

Participants were excluded from the study if they were taking any medication that affects the cardiovascular system and/or if they reported any past or present simulator sickness or discomfort, as this could bias the physiological data. All participants reported normal or corrected-to-normal vision to be eligible for participation

Table 3-2. Objective performance measures of expertise in driving (and see Jamson, Wardman, Batley, & Carsten, 2008).

Level of Expertise	Mean Driving Speed (% of Speed Limit)	Lane Excursions (# of Crosses Over the Line)
Expert	± 5	0
Non-Expert	± 10	1 or more

Additionally, driving performance is subject to significant diurnal influences. Lenné, Triggs & Redman (1997) found significant impairments in driving performance in the early morning, early afternoon and late evening. However, significant limitations to this experiment include a sample of only eleven young drivers and a complete lack of female participants. Reimer, D'Ambrosio & Coughlin (2007), in their study which

incorporated both sexes with a much wider age range, found driving decrements only in the late afternoon. Based, therefore, on the work of Reimer and his colleagues (2007), participants in the current study drove exclusively in the morning and early afternoon

Materials and Apparatuses

Driving Simulator

A fixed-base driving simulator (ISim, software version 4.0.85) was used to present the testing scenario (Figure 3-1). The simulator incorporated the driver seat, dashboard and major controls of a Ford Crown Victoria sedan and operated via five inter-connected computers. The simulator monitored the driver's inputs and adjusted the vehicle trajectory within the simulated environment accordingly. These modifications were then projected through three image channels (each with a video output of 800 x 600 resolution) onto three screens located approximately 1.0 meter from the participant's eyes. The driver therefore had an uninterrupted horizontal field of view of approximately 120°. All communications within the simulator network were synchronized at 60 Hz, and logged by specially developed measurement software for subsequent off-line analysis.

A Hewlett Packard mini notebook laptop computer (Model HP Mini 1000, Hewlett-Packard Company, Palo Alto, CA, US) was used to present the images positioned slightly to the right of the driver atop the dashboard, abutting the simulation screens (Figure 3-3).

Measurement Software

To manage the presentation of stimuli within the simulation and to obtain accurate measures of driving performance, an interface to the network was adapted using the LabVIEW programming language (National Instruments, Software Version 8.20). In

addition to supervising the simulation network, this program also supplied the means with which to oversee the presentation of driving-specific stimuli into the simulation. A custom LabVIEW program also logged all data for subsequent off-line analyses. The relevant variables were measured, synchronized with each other and time-locked in relation to stimulus onset. After ensuring collected data were within reasonable response ranges, the software package tabulated the raw data which was then exported for further analysis by a standard statistical package.

Physiological Data Measurement

All physiological data was collected via a BioPac system (Model MP150) and Acqknowledge software 3.9.1 (BioPac Systems, Inc., Aero Camino Goleta, CA, US). Cardiac data and muscular activity were collected at a rate of 1000 Hz. All electrodes were BioPac EL503 disposable, silver-silver chloride electrodes which were 1 cm in diameter (BioPac Systems, Inc., Aero Camino Goleta, CA, US). For all physiological data analysis, stimulus onset was time stamped via an electronic signal to the data collection window.

Heart period (R-R wave interval)

Electrocardiogram (ECG) data were collected with a gain of 500 via one electrode placed approximately 5 centimeters to the left of the jugular notch on each participant's chest (just inferior to the left clavicle) and two additional electrodes placed over the tenth ribs on the left and right sides of the participant's thorax. The left thoracic electrode acted as the ground. The ECG variable of interest was heart period, defined as the time period in milliseconds between subsequent spikes in the ECG (Figure 3-2 and see Lenneman & Backs, 2009).

An increase in heart rate therefore produced a shorter heart period. Heart period was preferable to other cardiac measures such as inter-beat interval or heart rate because of its greater flexibility as a biometric (Berntson, Cacioppo & Quigley, 1995). Heart period data has the advantage of being analyzed in either cardiac time units (beats) or in real-time units (seconds) unlike alternative cardiac measures (i.e., heart rate) limited to real-time analysis. Additionally, heart period has previously been established as a sensitive measure for assessing reactivity in a simulated driving environment (Lenneman & Backs, 2009).

Co-contraction

Electromyography (EMG) data were collected at a gain of 1000, by electrodes placed on the surface of the skin over the bellies of the biceps brachii and triceps brachii (medial head) muscles. The EMG variable of interest was the mean difference scores of co-contraction ratio between phasic (responses to affective stimuli) and baseline (responses to neutral, detour images) activity. The co-contraction ratio was quantified as [(2 X TRICEPS EMG)/ (TRICEPS EMG + BICEPS EMG)] X 100 (and see Olney & Winter, 1985). Through use of this metric, the contribution of the agonist muscle group (triceps) to task execution (i.e., the muscular control of the steering wheel necessary for successful lane maintenance during forward, straight driving) is compared to the overall muscular activity in the upper arm (triceps and biceps). As the total integrated activity of surface EMG is proportional to both the positive and negative portions of the EMG waveform – and cannot distinguish between genuine muscle potentials and artifacts – all trials during which an artifact occurs were omitted from analysis (as suggested by Andreassi, 2006).

Emotion Manipulation

At randomized intervals during the simulated drive, participants viewed eighteen digitized photographs taken from the International Affective Picture System[2] (IAPS: Lang, Bradley & Cuthbert, 2008 and Table 3-3). Each image represented one of four emotional categories: smiling faces, animals, mutilation, or neutral. Images were chosen based on affective normative ratings in order to differentiate emotional valence across categories (pleasant, unpleasant and neutral).

A set of driving-related photographs were assembled and validated by matching emotional valence and arousal scores with IAPS images (Table 3-4). A set of driving-related photographs were assembled and validated by matching emotional valence and arousal scores with IAPS images (Table 3-4). Image content was either neutral (open road or another vehicle at a safe distance), unpleasant (crashes or emergency responses to collisions) or pleasant (smiling motorists and passengers, scenic roadways, etc.). Eighteen of these images were presented during the drive. Thirty six total images (18 IAPS, 18 driving-specific) were presented in randomized order and counterbalanced between participants. In order to gauge domain-specific emotion regulation abilities, participants' reactions to the driving-specific versus non driving-specific images were compared. For example, comparing participants responses to a depiction of a dead body which was evidently caused by a hit and run accident (domain-specific image) versus their reactions to a dead body which was evidently caused by a non-driving related event such as being shot in the head (non-domain specific IAPS image). Experts and non-experts are expected to score the images similarly in terms of emotional valence and arousal. However, if discrepancies become evident, and experts and non-experts perceive the images differently, a finding of different subjective ratings,

in conjunction with participants' objective physiological scores, may serve as further proof that experts' and non-experts' emotion regulation skills are fundamentally different.

Questionnaires

The Driving Stress Inventory (DSI) is a 53-item questionnaire used to assess participants' coping strategies, driving history, driving behaviors, and attitudes towards driving. Developed by Gulian and colleagues (Gulian, Matthews, Glendon, Davies & Debney, 1989) as the Driving Behaviour Inventory, it has evolved to include measurements concerning personality factors. The DSI has since passed rigorous tests of validity and reliability (Glendon, Dorn, Matthews, Gulian, Davies & Debney, 1993).

The Driver Coping Questionnaire (DCQ) is a 35-item questionnaire concerned with how people typically react to difficult or stressful driving scenarios. Participants are instructed to indicate the frequency with which they engage in certain activities by circling a number on a Likert scale ranging from 0 'not at all' to 5 'very much'. The DCQ has also passed validity and reliability tests (Matthews, Desmond, Joyner, Carcary & Gilliland, 1996a).

The State-Trait Anxiety Inventory for Adults (STAI) is the world's most widely used self-report measure of anxiety (Spielberger, Gorsuch & Lushene, 1970). Comprised of two parts, both containing twenty questions, this questionnaire differentiates between immediate reactionary anxiety and long-standing personality-based anxiety via a 4 point Likert scale ranging from 1 'not at all' to 4 'very much so'. The STAI has repeatedly proved a valid and reliable instrument (Tilton, 2008).

Procedure

In accordance with APA guidelines, participants began by providing their written informed consent on the University approved consent form. Participants then filled in a demographic form, the DCQ, the DSI, and the trait and state forms of the STAI. Questionnaire answers specified a participant's level of expertise and determined whether or not they were fit to proceed with the remainder of the experiment.

Participants were seated comfortably in the simulator's driver seat approximately 1.0 meter from the screen. The experimenter prepared the participant's skin for the EMG electrodes by shaving, abrading and swabbing the appropriate area with rubbing alcohol. Electrodes were then be placed upon the bellies of the biceps brachii and triceps brachii muscles of the left limb with the ground electrode positioned upon the tenth rib on the left side of the thorax. ECG monitors were placed on the tenth rib of the right side of the thorax and approximately 5 centimeters to the left of the jugular notch of the sternum and inferior to the clavicle.

Participants were instructed to drive for two minutes so as to acclimatize themselves to the controls and the virtual world. During this time, the BioPac system collected readings of ECG and EMG activity. Additionally, objective driving data collected during this interval classified the driver as an expert or a non-expert. Participants were instructed to drive with their hands at the "ten and two" positions on the steering wheel at all times. After this period of adjustment, the experimenter gave the dual task instructions. The primary task was to drive as safely as possible in the simulated road environment while maintaining a constant speed of 30 mph. As a secondary task, participants were instructed to attend to any stimuli which appeared on the laptop screen outside what would essentially be the right side of their windshield

(Figure 3-2). The laptop was positioned in this location as (1) most drivers must look through the windshield in this general area to see road signs and (2) in-vehicle devices, such as navigational tools, are also typically situated in this spot. Drivers were told to view all images for detour signs which would indicate which direction they must follow at the next intersection. Baseline data were derived from drivers' responses to these neutral, detour images. Participants were instructed to remember the content of all images as they would be asked a series of questions regarding their content at the end of the experiment.

A total of 36 trials were presented during the 13 minute session. The duration of each trial was 12 seconds; 6 seconds of a fixation cross followed by 6 seconds of stimulus presentation. The inter-trial interval duration varied between 6 and 10 seconds.

After the simulated drive, all electrodes were removed from the participant. The drivers were asked to complete the DCQ and the state portion of the STAI once again based on how they just performed during the simulated drive. Finally, upon being escorted into an adjacent room, participants were asked to rate the images they saw based on emotional valence and arousal. Following the completion of the forms, the experimenter debriefed the participants, thanked them for their cooperation and asked if they have any final questions or concerns regarding their participation.

Data Reduction

Heart period

Given that maximal reactivity takes place a few seconds after image onset in past picture viewing protocols, a 2-4 second window after stimulus onset was extracted and difference scores (phasic – baseline) computed for analysis.

Co-contraction

The raw EMG data were rectified, smoothed and averaged over the trials of each photo category (and see van Loon et al., 2001). Background muscle activity (necessary for the calculation of co-contraction) was calculated as the integrated EMG activity during the six seconds after stimulus onset. Co-contraction was quantified as [(2 X TRICEPS EMG)/ (TRICEPS EMG + BICEPS EMG)] X 100 (and see Olney & Winter, 1985). The measure of interest was the difference score of co-contraction ratio between phasic and baseline values. Past studies recommend dividing background muscle activity for each participant in each condition by the activity in the muscles during the acclimatization period as a reference value (van Loon et al., 2001). All trials during which participants were turning during image presentation were excluded from analysis (due to movement artefact).

Self-report of valence and arousal scores

Participants rated each image in terms of emotional valence and arousal via the Self-Assessment Manikin (Bradley & Lang, 1994). Average scores, for both emotional valence and arousal, were computed and compared to ensure that both groups reacted similarly.

Driving performance

Mean driving speed values were derived by observing participants' instantaneous speed at regular intervals throughout the drive and quantifying that speed as a percentage of the speed limit. The number of lane excursions was determined by tallying the number of times the vehicle's wheels crossed over either the middle line of traffic or the outside line bordering the shoulder of the road.

Statistical Analyses

To determine whether emotion regulation alters movements necessary for driving performance, each dependent measure (i.e., heart period mean difference scores [phasic-baseline activity], co-contraction mean difference scores [phasic-baseline activity], mean driving speeds, lane excursions) was separately analyzed via a 2 (SEX: male, female) x 2 (LEVEL OF EXPERTISE: expert, non-expert) x 3 (IMAGE VALENCE: pleasant, unpleasant, neutral) x 2 (PREDOMINANT EMOTION REGULATION TECHNIQUE: adaptive [task-focused coping], maladaptive [emotion-focused coping]) mixed-model analysis of variance (ANOVA). Additionally, Tukey's Post Hoc tests were run on any significant main effects or interactions.

To gauge the domain-specificity of emotion regulation abilities, each dependent measure (i.e., heart period mean difference scores, co-contraction mean difference scores, mean driving speeds, lane excursions) was separately analyzed in two 2 (SEX: male, female) x 2 (LEVEL OF EXPERTISE: expert, non-expert) x 3 (IMAGE VALENCE: pleasant, unpleasant, neutral) x 2 (PREDOMINANT EMOTION REGULATION TECHNIQUE: adaptive [task-focused coping], maladaptive [emotion-focused coping]) mixed-model ANOVA. One ANOVA analyzed responses to domain-specific driving images, while the other analyzed responses to non domain-specific (IAPS) images. Greenhouse Geisser adjusted degrees of freedom were reported in those cases where the sphericity assumption was violated.

To ensure that all participants react similarly to the stimuli, the images' emotional valence and arousal scores were analyzed via two separate 2 (SEX: male, female) x 2 (LEVEL OF EXPERTISE: expert, non-expert) x 3 (VALENCE: pleasant, unpleasant,

neutral) x 2 (PREDOMINANT EMOTION REGULATION TECHNIQUE: adaptive [task-focused coping], maladaptive [emotion-focused coping]) ANOVA.

To determine which group has superior performance, two separate 2(SEX: male, female) x 2 (LEVEL OF EXPERTISE: expert, non-expert) x 3 (VALENCE: pleasant, unpleasant, neutral) x 2 (PREDOMINANT EMOTION REGULATION TECHNIQUE: adaptive [task-focused coping], maladaptive [emotion-focused coping]) ANOVA were conducted. One comparing mean driving speed scores and the other comparing lane deviation scores. An acceptable probability value of $p < .05$ was assumed for all analyses.

Table 3-3. List of selected International Affective Picture System images. Ratings taken from Lang, Bradley & Cuthbert's (2008) sample for all individuals.

Slide category	Valence mean (standard deviation), arousal mean (standard deviation)	Slide category	Valence mean (standard deviation), arousal mean (standard deviation)	Slide category	Valence mean (standard deviation), arousal mean (standard deviation)
Pleasant	6.78 (0.30), 5.26 (0.24)	Unpleasant	2.51 (0.64), 5.91 (0.39)	Neutral	5.26 (0.23), 2.83 (0.36)
2346	7.05 (1.53), 5.28 (2.28)	3216	3.28 (1.64), 5.37 (2.00)	2235	5.64 (1.27), 3.36 (1.92)
2070	6.82 (1.22), 5.08 (2.01)	3225	1.82 (1.22), 5.95 (2.46)	7052	5.33 (1.32), 3.01 (2.02)
4599	7.12 (1.48), 5.69 (1.94)	6212	2.19 (1.49), 6.01 (2.44)	7053	5.22 (0.75), 2.95 (1.91)
4601	6.82 (1.22), 5.08 (2.01)	6244	3.09 (1.78), 5.68 (2.51)	7059	4.93 (0.81), 2.73 (1.88)
4606	6.55 (1.62), 5.11 (2.15)	6250	2.83 (1.79), 6.54 (2.61)	7080	5.27 (1.09), 2.32 (1.84)
5622	6.33 (1.78), 5.34 (1.96)	9433	1.84 (1.19), 5.89 (2.60)	7090	5.19 (1.46), 2.61 (2.03)

Table 3-4. List of Domain-Specific images.

Slide category	Valence mean (standard deviation), arousal mean (standard deviation)	Slide category	Valence mean (standard deviation), arousal mean (standard deviation)	Slide category	Valence mean (standard deviation), arousal mean (standard deviation)
Pleasant	6.83 (0.52), 4.96 (0.61)	Unpleasant	2.64 (0.22), 6.03 (0.22)	Neutral	5.37 (0.32), 3.37 (0.08)
P1	6.88 (1.15), 5.08 (1.91)	U1	2.79 (1.69), 6.11 (2.13)	N1	5.39 (1.09), 3.40 (2.12)
P2	6.42 (1.21), 4.88 2.05)	U2	2.77 (1.42), 5.90 (2.15)	N2	5.13 (0.98), 3.21 (1.99)
P3	6.88 (1.68), 4.88 (2.15)	U3	2.54 (1.56), 6.13 (2.51)	N3	5.08 (1.36), 3.41 (1.99)
P4	6.63 (1.34), 4.71 (1.65)	U4	2.25 (1.67), 6.34 (2.27)	N4	5.68 (1.37), 3.45 (2.22)
P5	7.80 (1.50), 6.04 (2.33)	U5	2.65 (1.42), 5.70 (2.17)	N5	5.14 (1.19), 3.41 (2.12)
P6	6.38 (1.53), 4.17 (2.04)	U6	2.83 (1.76), 6.03 (2.61)	N6	5.83 (1.53), 3.38 (2.10)

Figure 3-1. The fixed-base ISim driving simulator. Photo courtesy of the author.

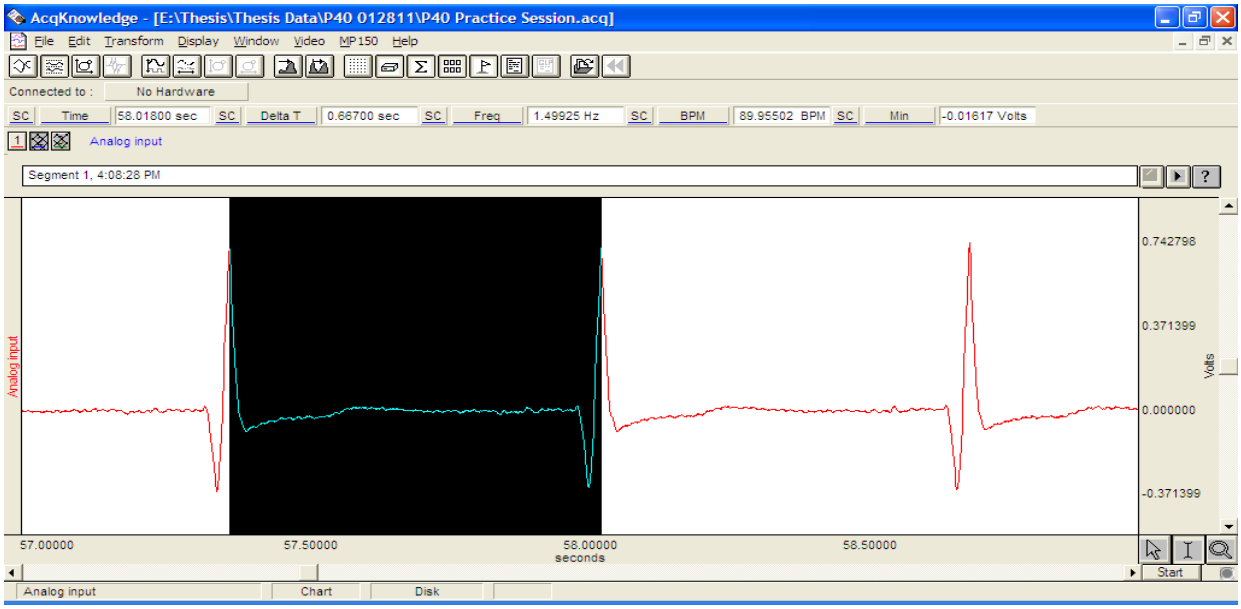

Figure 3-2. Example of heart period. As the trial began at 55 seconds, data were extracted from the two second time window as shown (57-59 seconds). Two complete heart periods are visible and recorded via measuring the time between R spikes (visible in the Delta T window). The number of heart periods in this 2 second window typically ranged between two and four. Photo courtesy of the author.

Figure 3-3. The experimental protocol in progress. The primary task entailed driving while obeying the 30 mph speed limit. The secondary task was attending to stimuli presented on the computer screen to find driving directions or so as to recall content at a later time. Located above the in-vehicle controls, below the rearview mirror and between the side mirrors, stimuli on the screen represent objects or events occurring outside the right, front windshield. Photo courtesy of the author.

CHAPTER 4
RESULTS

Participants

Data were collected from a total of 93 participants recruited from a university campus. Seventeen participants were excluded from the final sample due to their falling outside the preset age range or a medicated heart condition; one female was excluded as she did not have a driver's license; and three participants withdrew due to simulator sickness (which they reported no history of prior to participation). The final sample therefore included thirty-six experts (18 male, 18 female) and thirty-six non-experts (18 male, 18 female). Drivers ranged in age between 18 and 37 years old with a mean age of 22.8 years. Four individuals reported having had a diagnosed emotional disorder (1 expert female, 1 expert male, 2 non-expert males). Of these, two indicated that their disorder was currently being treated with medication (1 expert female, 1 non-expert male). Demographic information and salient affective scores can be found in Table 4-1.

Experts' and non-experts' experience-based and objective performance data are presented in Table 4-2. With regards to experience-based measures, despite their similar ages, experts had more experience (7 versus 5 years; over 100,000 miles driven versus less than 100,000 miles driven), were more successful in terms of collision avoidance (0.42 versus 0.67 accidents) and had received fewer citations (0.39 versus 0.67) than their non-expert counterparts. While experts received significantly fewer citations ($F = 4.310$, $p = .042$), no other experience-based measures reached significance.

I delineated participants as either task-focused or emotion-focused via their DCQ scores. All individuals with emotion-focused scores higher than task-focused scores

were automatically appointed as an emotion-focused driver. Following this initial delegation, the remaining participants were separated via a median split. Drivers were therefore designated as emotion-focused if they scored over 30 on the emotion-focused scale and a task-focused driver if their scores fell short of 30.

Table 4-1. Participant Characteristics and Affective States and Traits

	Expert group (n=36)		Non-expert group (n=36)	
	Mean	Standard deviation	Mean	Standard deviation
Age	23.5	4.59	22.2	3.42
Trait Anxiety (STAI-T)	35.1	9.48	34.0	7.52
State Anxiety (STAI-S) Pre-Drive	31.3	9.82	30.7	9.15
State Anxiety (STAI-S) Post-drive	32.2	7.72	35.25	11.29

Table 4-2. Participant Experience-based and Objective Performance Measures of Driving Expertise

	Expert group (n=36)		Non-expert group (n=36)	
	Mean	Standard deviation	Mean	Standard deviation
Possession of driver's license	Yes		Yes	
Years of experience	7.17	4.43	5.81	3.12
Frequency (days/week)	6.03	2.04	5.88	1.98
Total self-reported lifetime mileage driven	117,111	140,888	72,861	64,467
Number of accidents (in the last 3 years)	0.42	0.77	0.67	0.96
Number of citations (in the last 3 years)	0.39	0.49	0.67	0.63
Mean driving speed (% of speed limit)	0.25	3.92	-9.50	17.38
Lane Excursions	0.00	0.00	0.22	0.64

Experts and non-experts did not differ in terms of videogame experience (F = 2.197, *p* = .143), nor did task-focused and emotion-focused drivers (F = 2.533, *p* =

.116). However, males had more videogame experience than females (F = 5.518, *p* = .022).

Heart Period

I predicted that exposure to both pleasant and unpleasant affective images would result in a longer heart period (and consequently positive mean difference scores) compared to neutral images in all participants (hypothesis 1a). Data partially supported this hypothesis as there was a main effect for emotional valence for all images (F= 3.869, *p* = .027) as shown in Figure 4-1. Responses to valenced stimuli resulted in longer heart periods in all participants given the resulting positive mean difference scores. Similarly, and as predicted, unpleasant images triggered mean differences scores larger than neutral images indicating the slowing of heart rate in response to unpleasant stimuli previously observed by Dunn and colleagues (2009). However, contrary to the stated hypothesis, heart period mean difference scores decreased after exposure to pleasant images relative to neutral images, indicating a less severe deceleration of heart rate. Participants' heart period responses to pleasant versus unpleasant stimuli differed significantly (mean difference = 6.745, *p* = .013).

I also hypothesized that experts would have a shorter heart period (smaller mean difference scores) in response to affective stimuli compared to non-experts (hypothesis 1b). The data did not support this hypothesis although the effect approached significance (F= 3.402, *p* = .070). As shown in Figure 4-2, experts displayed larger mean difference scores than non-experts across all three emotional valence groups. However, participants' reactions followed the same pattern regardless of expertise level consistent with the findings in Figure 4-1: pleasant images elicited the weakest reaction,

neutral scenes caused a greater reaction, and unpleasant images elicited the largest reaction.

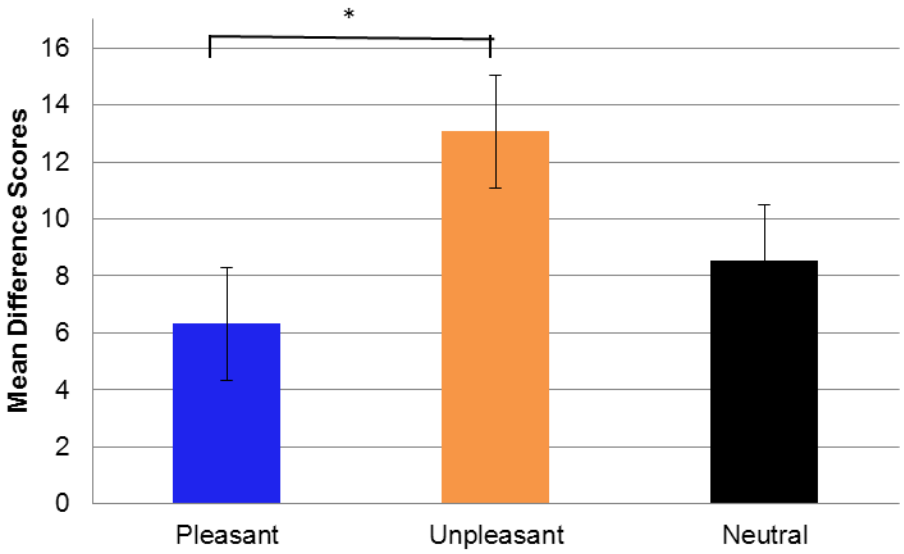

Figure 4-1. Heart period mean difference scores across emotional valences. Error bars are standard errors.

Additionally, I hypothesized that task-focused experts would have the smallest mean difference scores of any group (hypothesis 1c). The data failed to support this hypothesis (F=1.067, p = 0.305) as illustrated in Figure 4-3.

Exposure to domain-specific images was hypothesized to result in smaller mean difference scores compared to non domain-specific (IAPS) images in experts compared to non-experts (hypothesis 2). As shown in Figure 4-4, the data do not support this hypothesis. However, a significant between-subjects effect for expertise existed only in response to domain-specific images (F= 6.662, p = .012) indicating that experts react significantly more than non-experts; a finding which is a direct contradiction to the hypothesis (Figure 4-2).

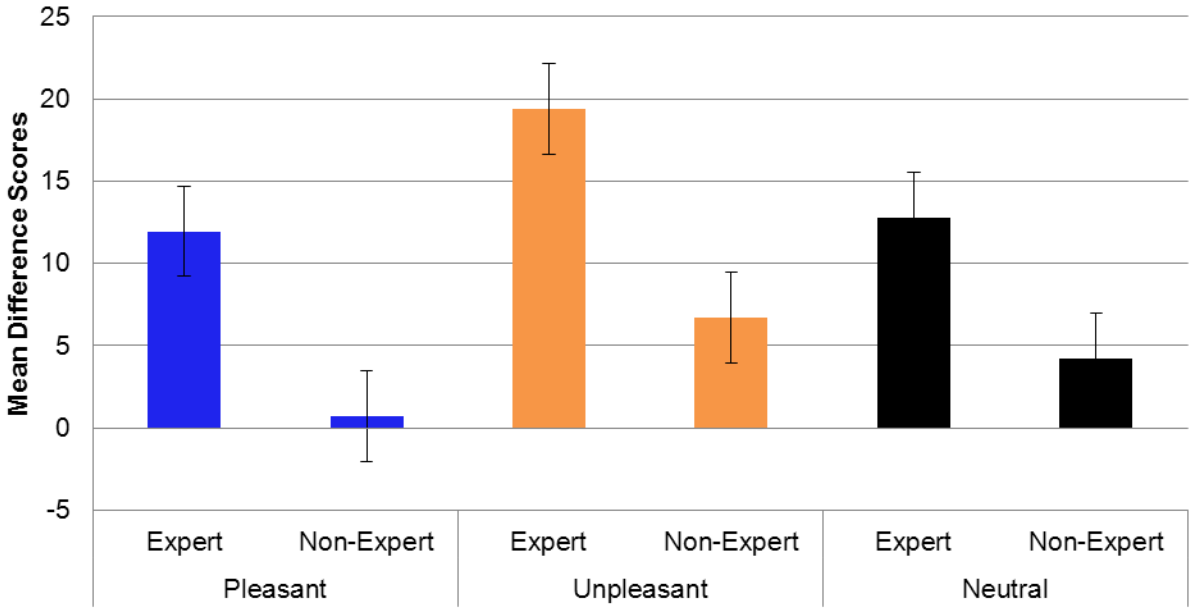

Figure 4-2. Heart period mean difference scores across emotional valences comparing experts' versus non-experts' reactions. Error bars are standard errors.

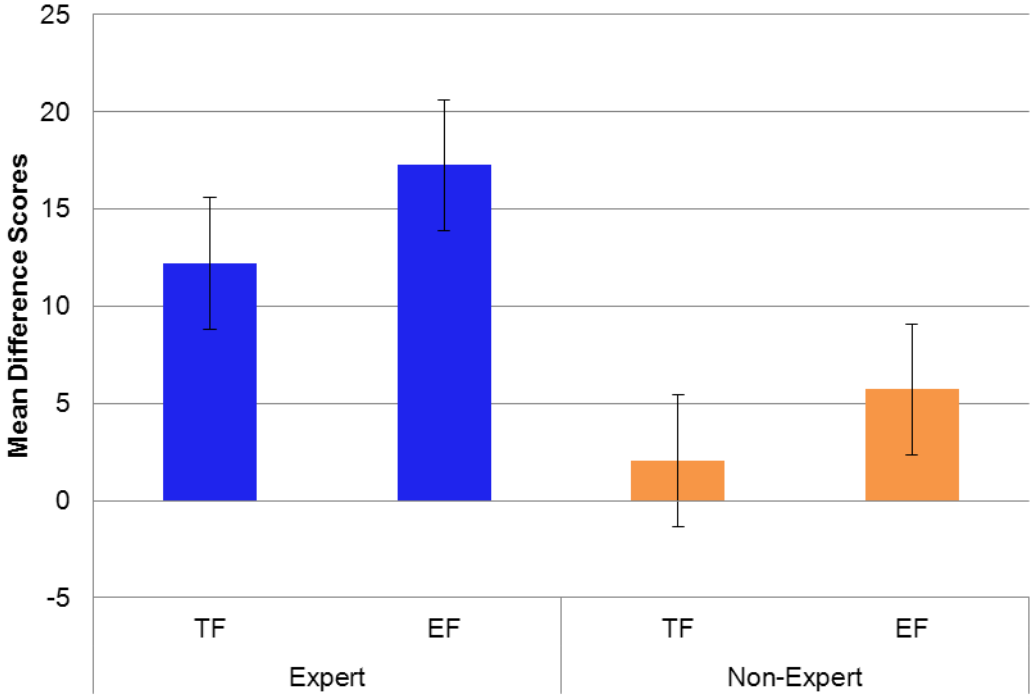

Figure 4-3. Heart period mean difference scores across emotional valences comparing task-focused and emotion-focused expert and non-expert drivers. Error bars are standard errors.

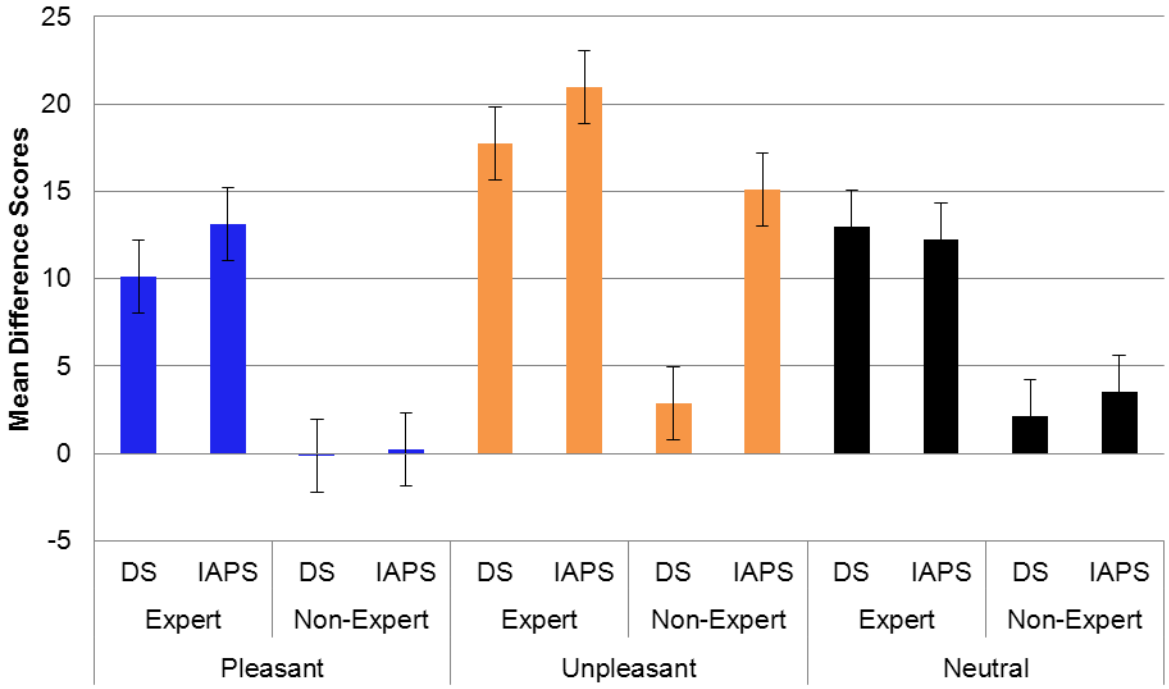

Figure 4-4. Heart period mean difference scores across emotional valences comparing experts' versus non-experts' responses to domain-specific and non domain-specific (IAPS) images. Error bars are standard errors.

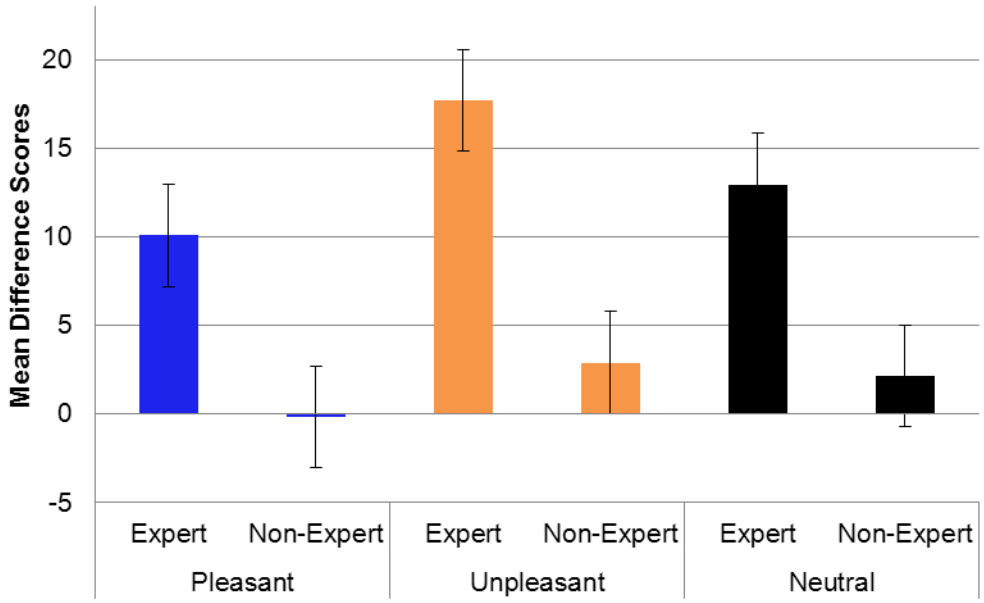

Figure 4-5. Heart period mean difference scores in response to domain-specific images showing a significant effect for expertise level. Error bars are standard errors.

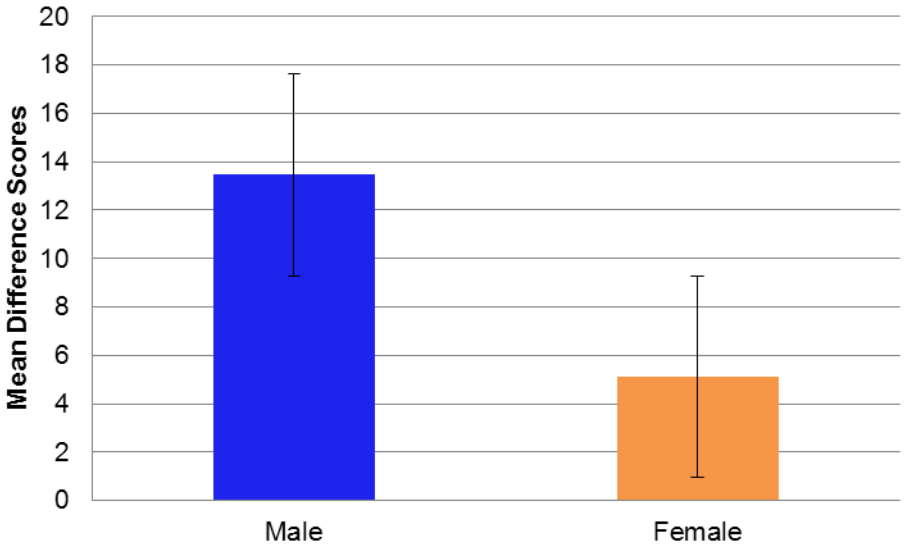

Figure 4-6. Sex differences in heart period mean difference scores. Error bars are standard errors.

Additionally, I hypothesized that females would display a shorter heart period (smaller mean difference scores) in response to affective stimuli compared to males (in hypothesis 3). Despite the trend displayed in Figure 4-6, the effect is not statistically significant (F = 2.019, *p* = .160).

Co-contraction

I predicted that all participants would demonstrate an increase in the co-contraction index following exposure to affective images (pleasant and unpleasant) as compared to neutral images (hypothesis 4a). The data do not support this hypothesis (Figure 4-7). All participants exhibited positive mean difference scores, indicating an increase in co-contraction during exposure to the valenced pictures relative to the detour (baseline) signs. However, mean difference scores do not vary significantly in response to different emotional valences (F = .262, *p* = .771).

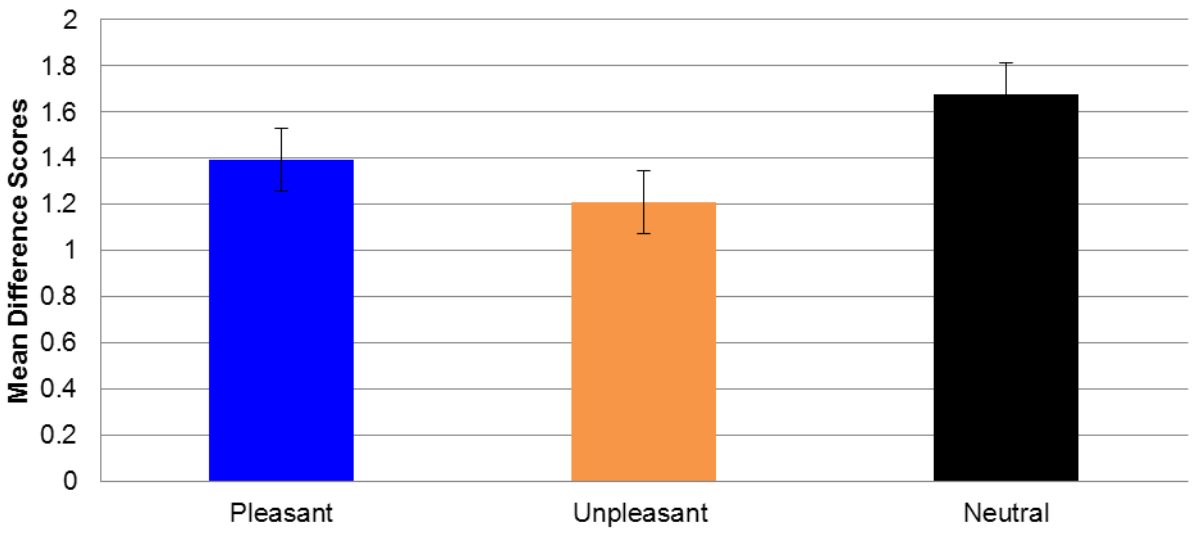

Figure 4-7. Co-contraction mean difference scores across emotional valences. Error bars are standard errors.

Experts were predicted to exhibit a smaller index of co-contraction (smaller mean difference scores) in response to affective stimuli as compared to non-experts (hypothesis 4b). The data do not support the hypothesis (F = 3.415, *p* = .069) of an overall between-subjects effect for expertise (Figure 4-8).

Furthermore, I hypothesized that task-focused experts would have the smallest mean difference scores of any group (hypothesis 4c). As depicted in Figure 4-9, the data do not support this hypothesis (F = .001, *p* = .973).

I anticipated that exposure to domain-specific images would result in smaller mean difference scores compared to non domain-specific (IAPS) images in experts when compared to non-experts (hypothesis 5). As seen in Figure 4-10, the data do not support this hypothesis (domain-specific: F = 2.442, *p* = .123; IAPS: F = 3.841, *p* = .054).

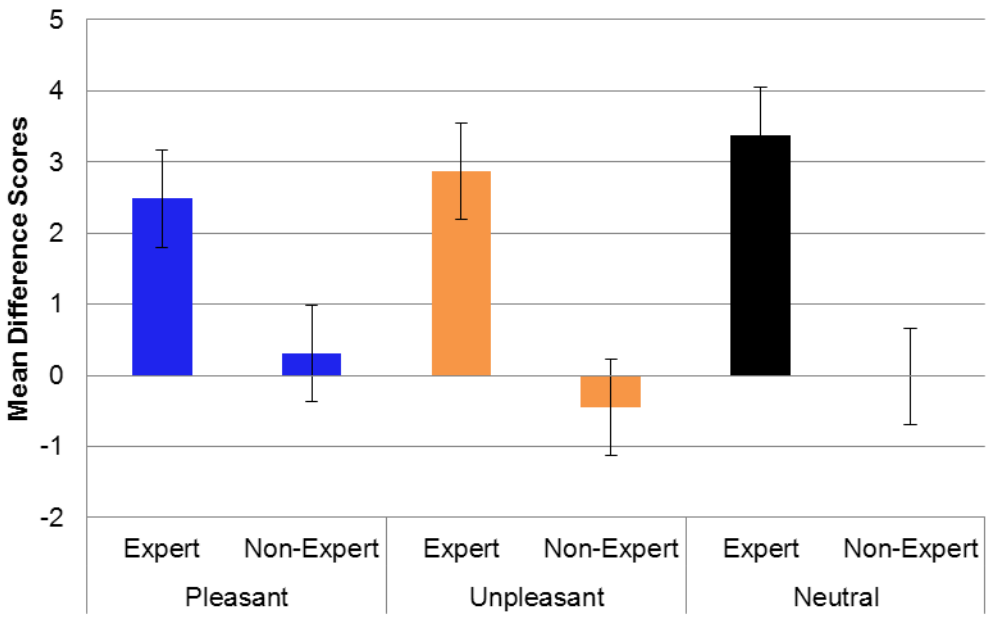

Figure 4-8. Co-contraction mean difference scores across emotional valences comparing the responses of experts and non-experts. Error bars are standard errors.

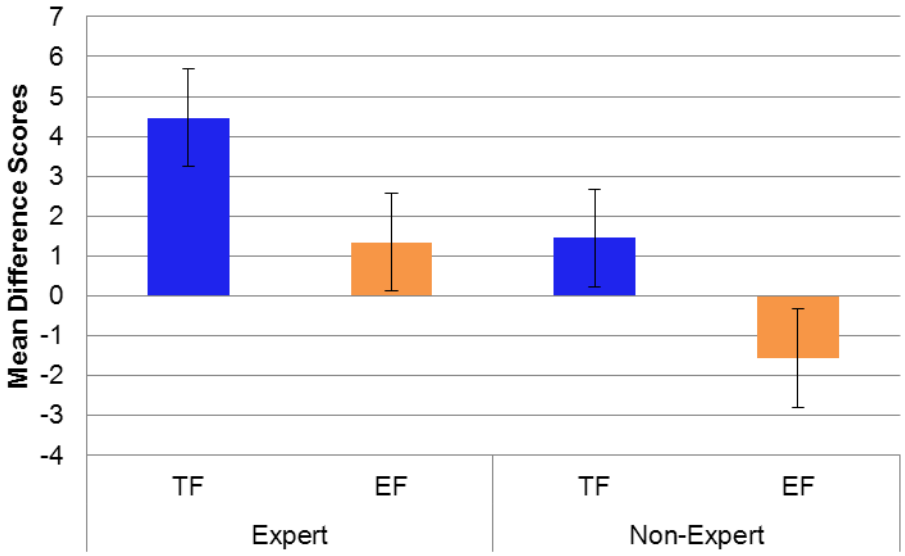

Figure 4-9. Co-contraction mean difference scores comparing between expertise levels and emotion regulation techniques. Error bars are standard errors.

Further, I hypothesized that females would display less co-contraction (i.e., smaller mean difference scores) in response to affective stimuli compared to males. The data partially support this hypothesis. While the main between-subjects effect of sex on co-

contraction values was not significant (F = 2.50, *p* = .119), EMG data revealed a significant Sex x Valence interaction (F = 5.171, *p* = .008). Data showed that males' and females' patterns of reactivity differed in response to affective stimuli (Figure 4-11). Males consistently increased co-contraction when exposed to valenced images, with the greatest increase being in response to pleasant scenes followed by unpleasant and neutral pictures. Females, on the other hand, experienced a decrease in co-contraction after seeing pleasant images while displaying an increase in co-contraction under unpleasant and neutral conditions.

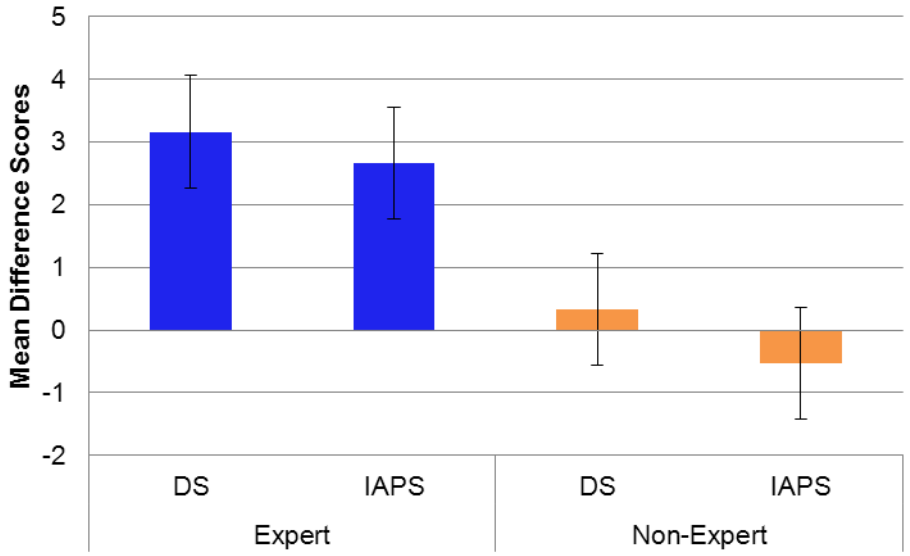

Figure 4-10. Co-contraction mean difference scores comparing expertise levels and domain-specificity of images. Error bars are standard errors.

Finally, there was also a significant three-way interaction (F = 3.301, *p* = .043) of Sex x Valence x PERT on co-contraction levels (Figure 4-12). Females' reactivity followed the same pattern across emotional valences: increasing co-contraction if task-focused and decreasing co-contraction if emotion-focused. On the other hand, males (whether task-focused or emotion-focused) reacted in the same pattern in response to pleasant and neutral images, namely with increases in co-contraction; whereas, under

unpleasant conditions, males experienced an increase in co-contraction if task-focused and a decrease in co-contraction if emotion-focused.

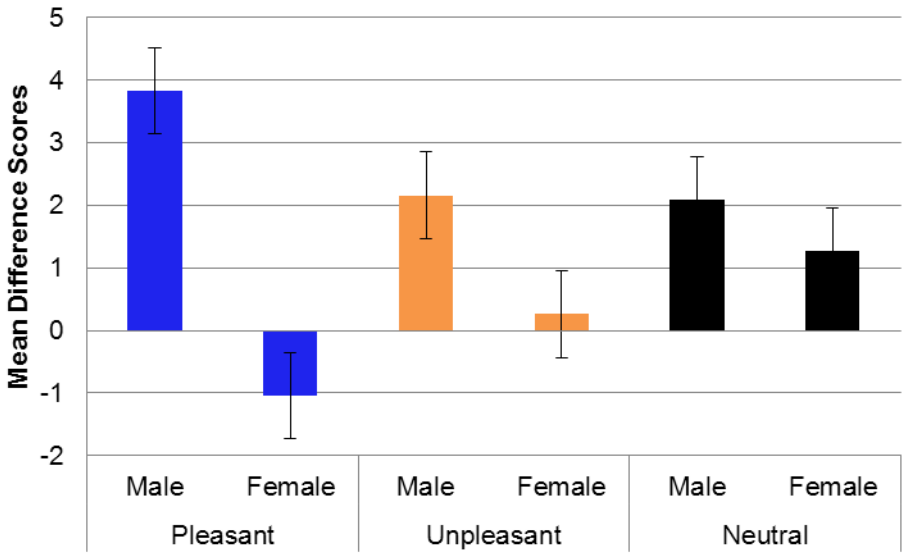

Figure 4-11. Co-contraction mean difference scores across emotional valences comparing males and females. Error bars are standard errors.

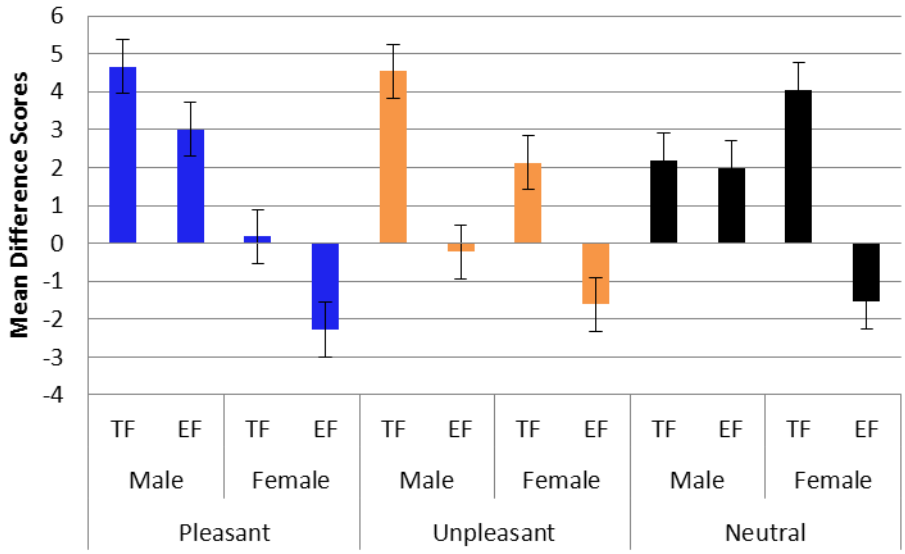

Figure 4-12. Co-contraction mean difference scores illustrating a significant interaction between emotional valence, sex and predominant emotion regulation technique. Error bars are standard errors.

Driving Performance: Practice Session

Mean Driving Speed

As predicted in hypothesis 7a, experts exhibited significantly smaller mean driving speed values (F = 10.78, *p* = .002) as compared to non-experts participants during the practice drive (Figure 4-13).

Hypothesis 7b stated that task-focused experts will display the smallest mean driving speed values of any group. However, as seen in Figure 4-14, the effect was not significant (F = .298, *p* = .587).

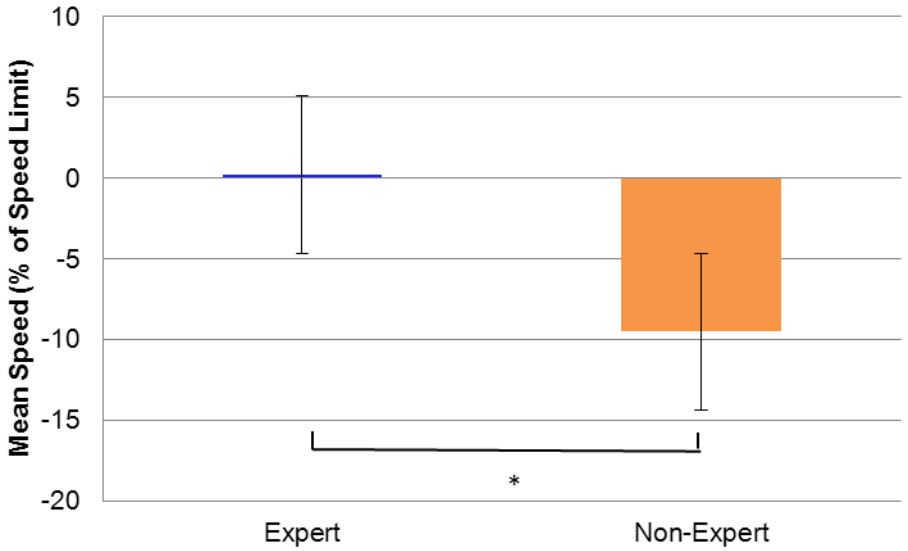

Figure 4-13. Experts' versus non-experts' mean driving speed values during the practice session. Error bars are standard errors.

Lane Excursions

In hypothesis 8a, I predicted that experts would have significantly fewer lane excursions than non-expert drivers. The data support this hypothesis (Figure 4-15). Experts had significantly fewer lane excursions than non-experts during the practice session (F = 4.375, *p* = .040).

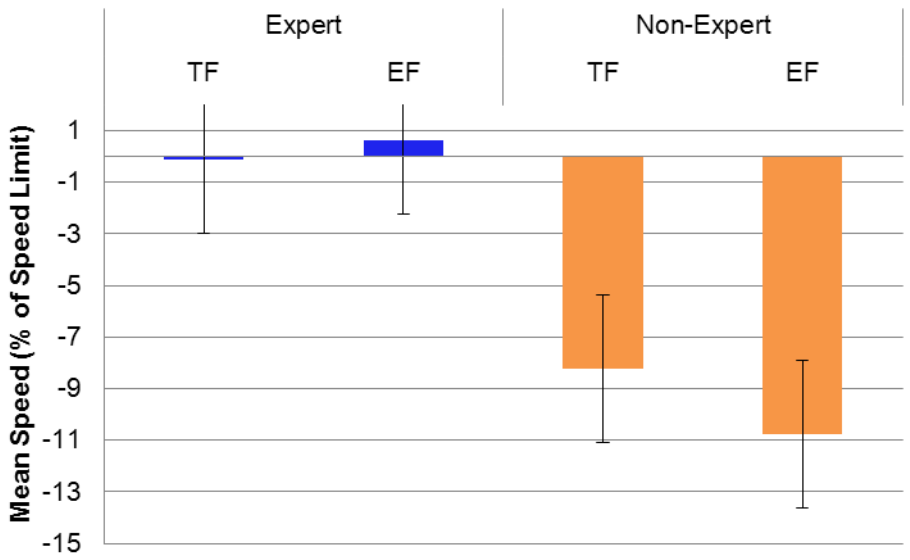

Figure 4-14. Mean driving speed values by predominant emotion regulation technique and level of expertise during the practice session. Error bars are standard errors.

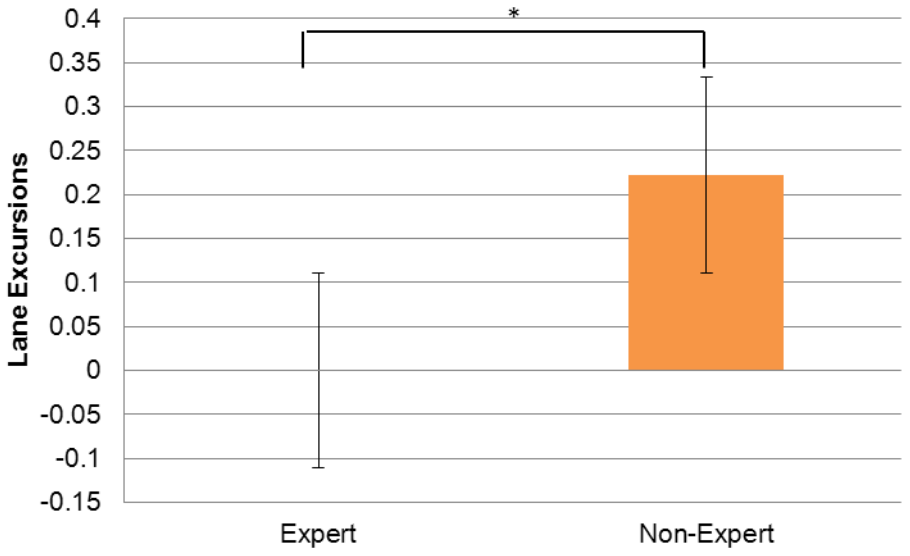

Figure 4-15. Comparative lane excursions between experts and non-experts during the practice session. Error bars are standard errors.

Additionally, task-focused experts were predicted to display the smallest number of lane excursions of any group (in hypothesis 8b). Again, the data were not significant (F = .000, *p* = 1.000) as seen in Figure 4-16.

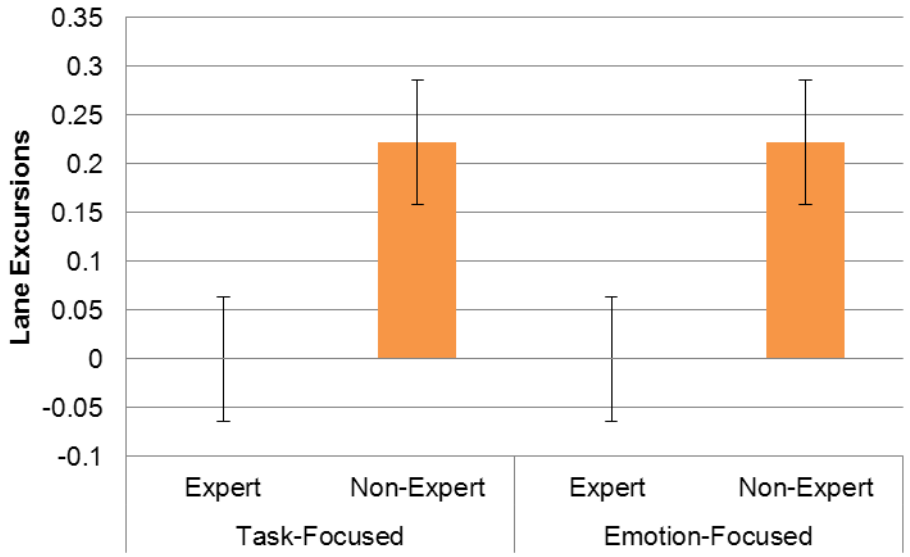

Figure 4-16. Lane excursions by predominant emotion regulation technique and level of expertise during the practice session. Error bars are standard errors.

Driving Performance: Experimental Session

Mean Driving Speed

As predicted in hypothesis 7a, experts exhibited significantly smaller mean driving speed values (F = 39.50, *p* < .001) as compared to non-expert participants during the experimental drive (Figure 4-17).

In hypothesis 7b, I predicted that task-focused experts will display the smallest mean driving speed values of any group. However, despite the trend seen in Figure 4-18, the effect was not significant (F = 3.503, *p* = .066).

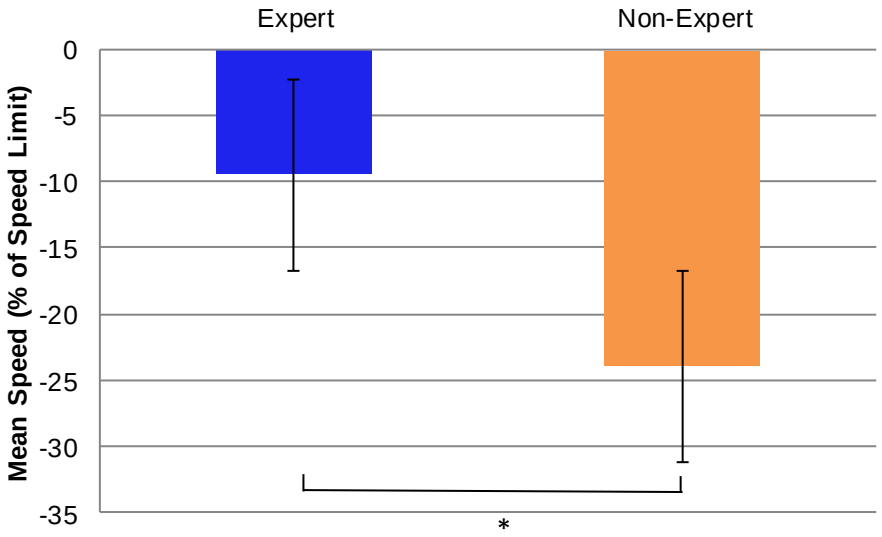

Figure 4-17. Mean driving speeds comparing expert and non-expert drivers during the experimental session. Error bars are standard errors.

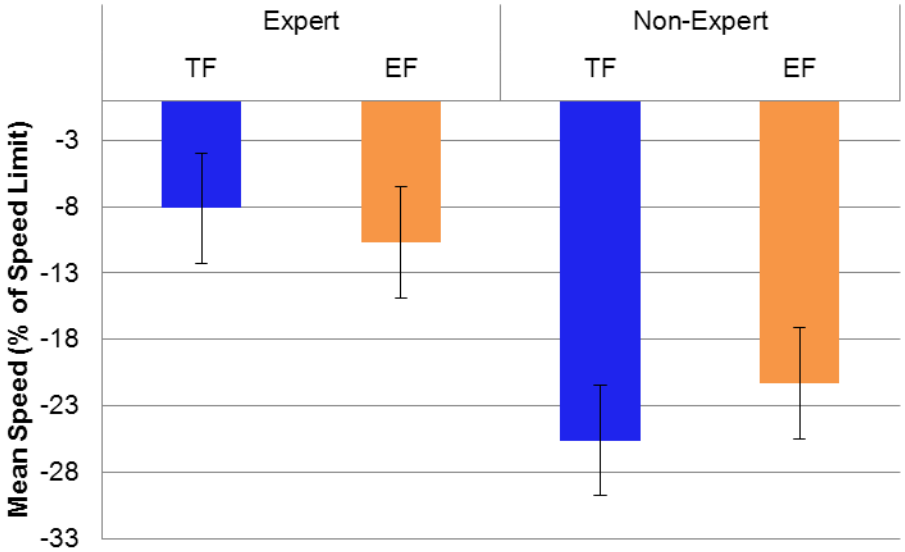

Figure 4-18. Mean driving speeds by predominant emotion regulation technique and level of expertise during the experimental session. Error bars are standard errors.

The effects of emotions on mean driving speed

All images.

There was a significant main effect for emotional valence (F = 6.047, *p* = .004) on mean driving speeds (Figure 4-19). Pairwise comparisons revealed that participants

drove significantly slower in response to pleasant (M = -29.34) as compared to unpleasant (M = -22.37) images (MD = 6.97, *p* = .003).

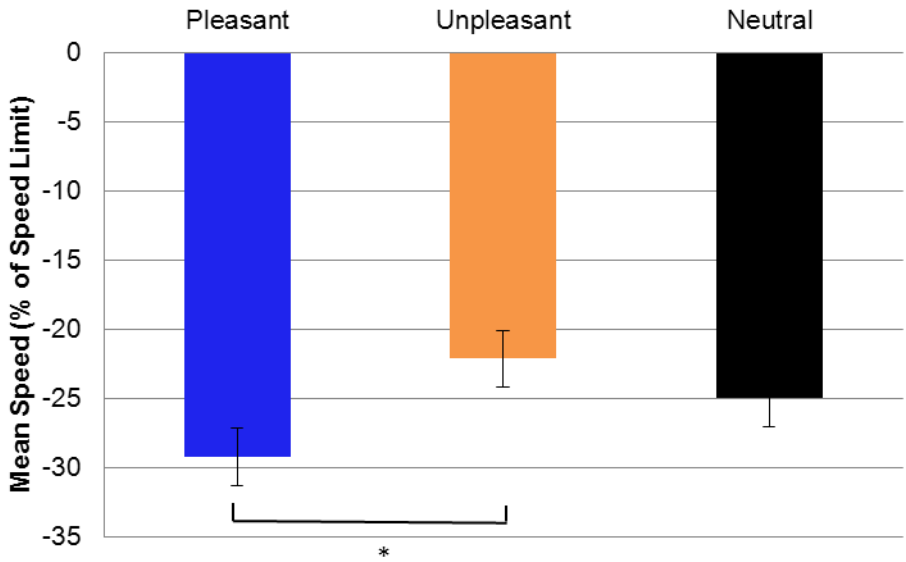

Figure 4-19. Mean driving speeds across emotional valences during the experimental drive. Error bars are standard errors.

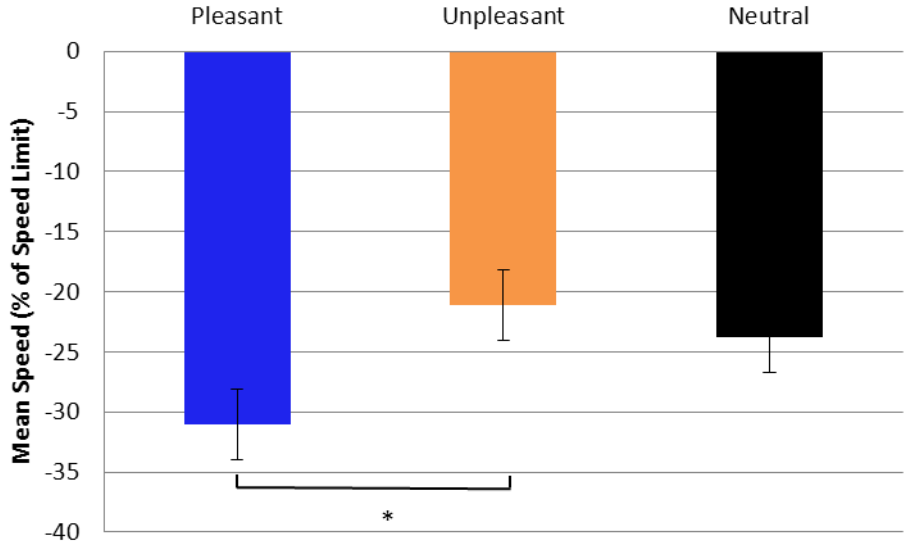

Figure 4-20. Mean driving speeds in response to domain-specific images across emotional valences during the experimental drive. Error bars are standard errors.

Domain-specific images.

There was a significant main effect for emotional valence on mean driving speeds in response to domain-specific images (F = 5.394, *p* = .008). Figure 4-20 illustrates once again that participants drove significantly slower after seeing pleasant (M = -31.3) as compared to unpleasant (M = -21.4) images (mean difference = 9.955, *p* = .005).

There was, additionally, a significant main effect for expertise (F = 6.786, *p* = .012) on mean driving speeds (Figure 4-21). Experts drove significantly closer to the speed limit than non-experts.

Non domain-specific (IAPS) images.

There were no significant between or within subjects effects on mean driving speeds in response to IAPS images.

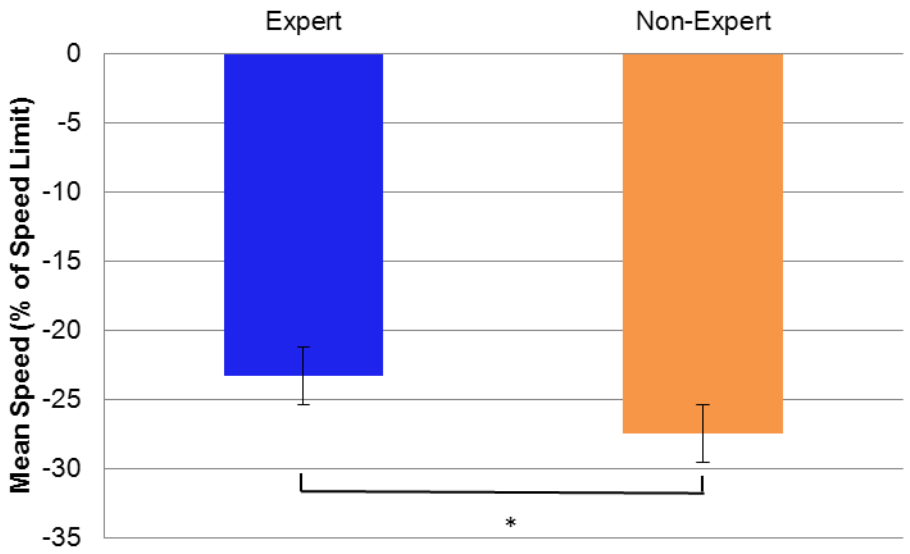

Figure 4-21. Mean driving speeds across levels of expertise in response to domain-specific images. Error bars are standard errors.

A significant Sex x PERT interaction was also present (F = 10.551, *p* = .002). As seen in Figure 4-22, emotion-focused males drove closer to the speed limit than task-

focused males; whereas task-focused females drove closer to the speed limit than emotion-focused females.

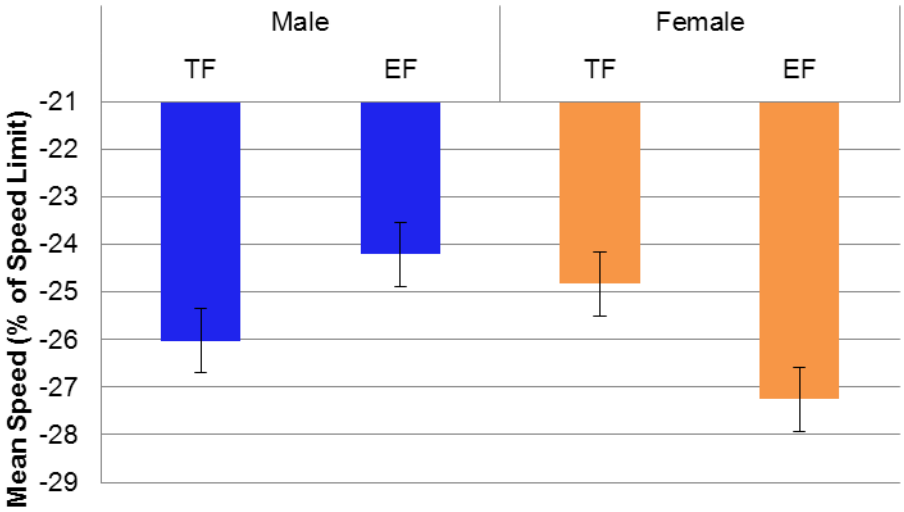

Figure 4-22. Mean driving speed values by sex and predominant emotion regulation technique. Error bars are standard errors.

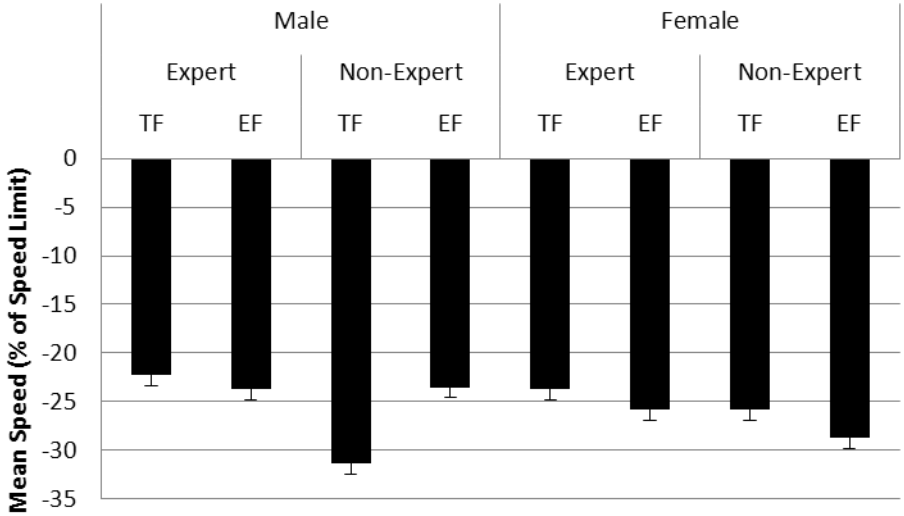

Figure 4-23. Sex x Expertise x PERT interaction on mean driving speed values. Error bars are standard errors.

Finally, there was a significant Sex x Expertise x PERT interaction (F = 6.244, *p* = .015) on mean driving speed values. Task-focused drivers tended to drive closer to the speed limit than emotion-focused drivers; the exception being non-expert males,

who instead tended to drive closer to the speed limit when emotion-focused (Figure 4-23).

Lane Excursions

I hypothesized that experts would have significantly fewer lane excursions than non-expert drivers (in hypothesis 8a). The data from the experimental drive, unlike the practice session, do not support this hypothesis (F = 2.151, *p* = .147).

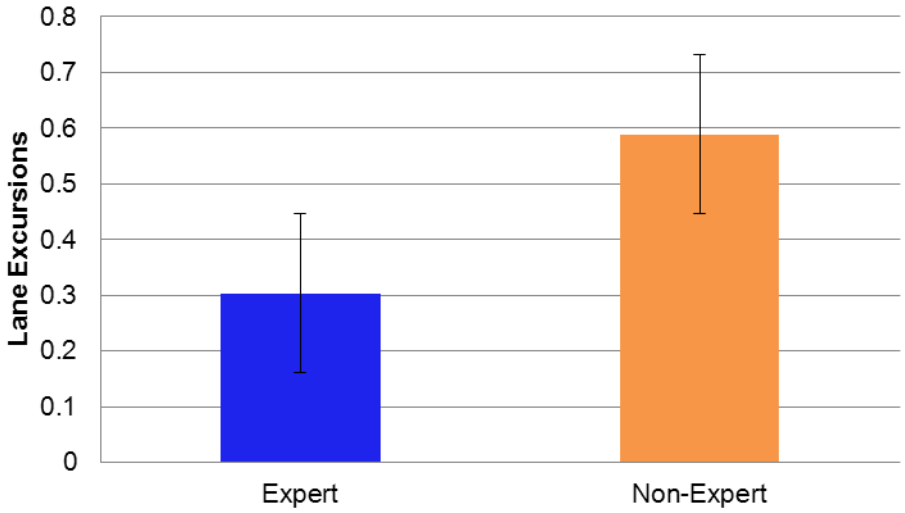

Figure 4-24. Lane excursions by level of expertise during the experimental session. Error bars are standard errors.

As before, I thought task-focused experts would display the smallest number of lane excursions of any group (in hypothesis 8b). The data, however, did not support this hypothesis (F = .018, *p* = .507) as seen in Figure 4-25.

The effects of emotions on lane excursions

All images

There was a significant main effect for emotional valence on lane excursions (F = 6.910, *p* = .006). As illustrated in Figure 4-26, pairwise comparisons revealed that

participants violated the boundaries of their lane significantly more when exposed to unpleasant as compared to neutral images (mean difference = .222, p = .006).

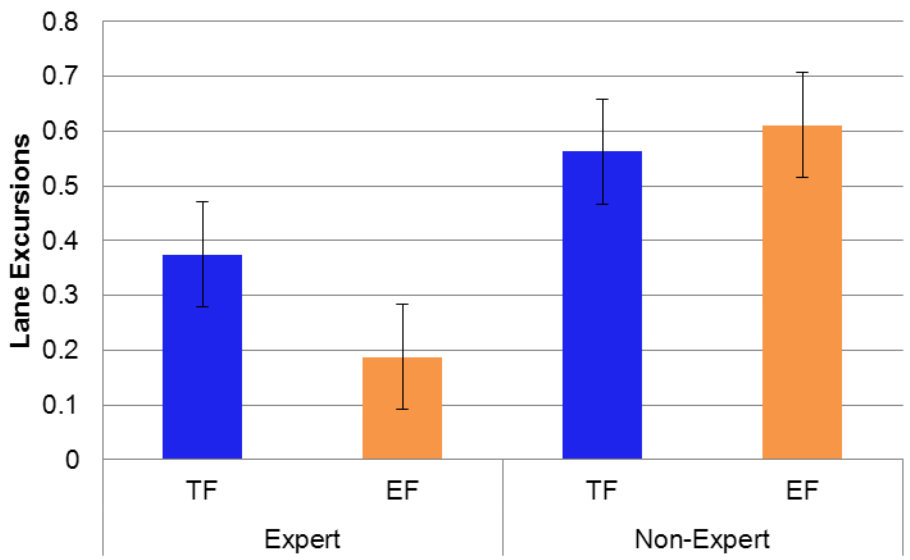

Figure 4-25. Lane excursions by predominant emotion regulation technique and level of expertise during the experimental session. Error bars are standard errors.

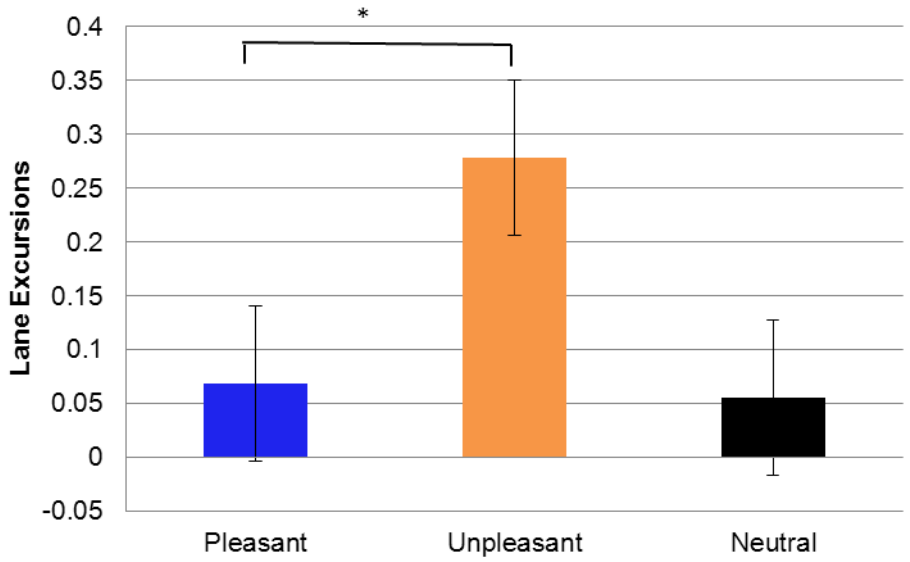

Figure 4-26. Lane excursions across emotional valences during the experimental drive. Error bars are standard errors.

Data also revealed a significant Valence x Expertise interaction (F = 4.502, *p* = .028). Experts and non-experts maintained their lane position similarly under pleasant and neutral conditions. However, non-experts swerve out of their lane significantly more than experts in reaction to unpleasant images (Figure 4-27).

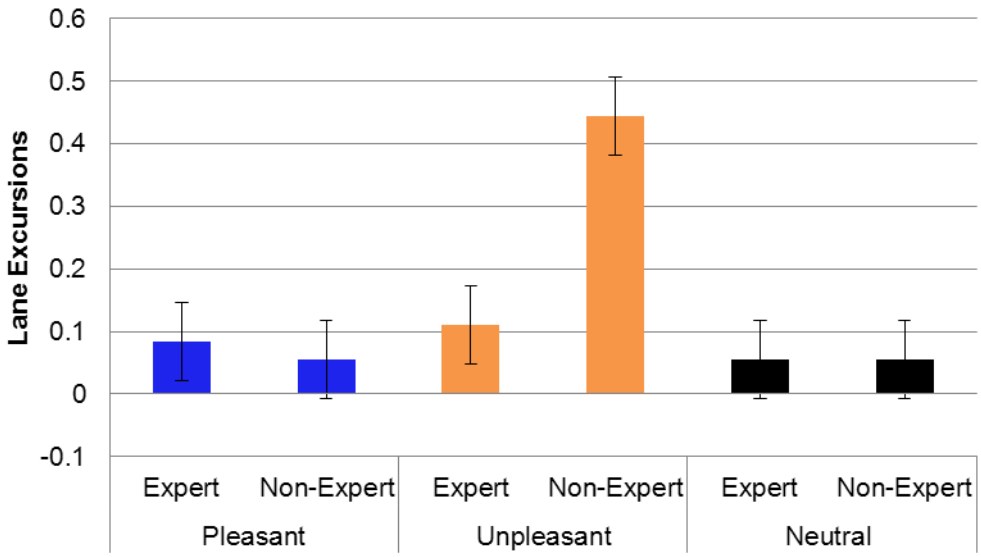

Figure 4-27. Expertise differences in lane excursions across emotional valences. Error bars are standard errors.

Domain-specific images

There was a significant main effect for emotional valence on lane excursions (F = 7.658, p = .002). As illustrated in Figure 4-28, pairwise comparisons showed that unpleasant scenes prompted significantly more lane excursions when compared to pleasant scenes (mean difference = .167, *p* = .005).

There was also a significant Valence x Expertise interaction (F = 6.838, *p* = .004). Under pleasant and neutral conditions, experts and non-experts maintained their lane positions similarly. However, when exposed to domain-specific unpleasant images, non-experts exhibited significantly more lane excursions than experts (Figure 4-29).

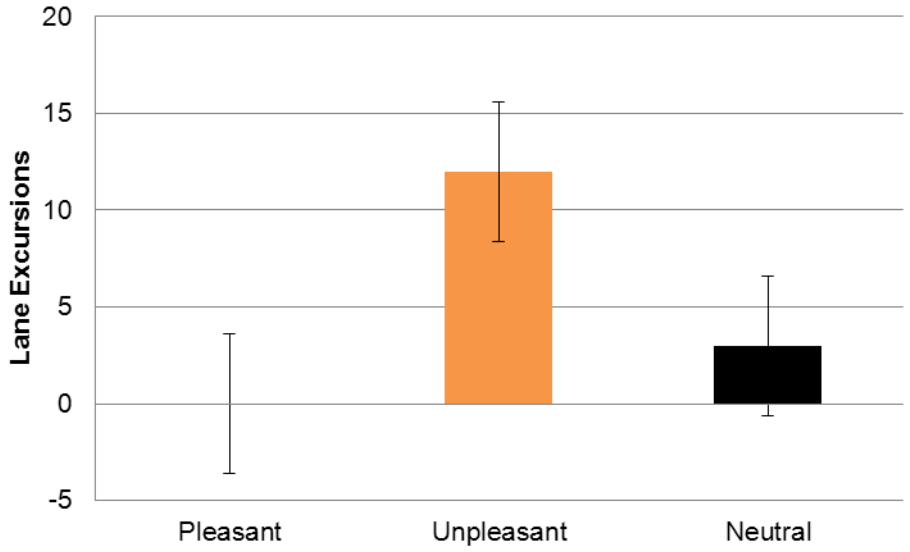

Figure 4-28. Lane excursions across emotional valences in response to domain-specific stimuli. Error bars are standard errors.

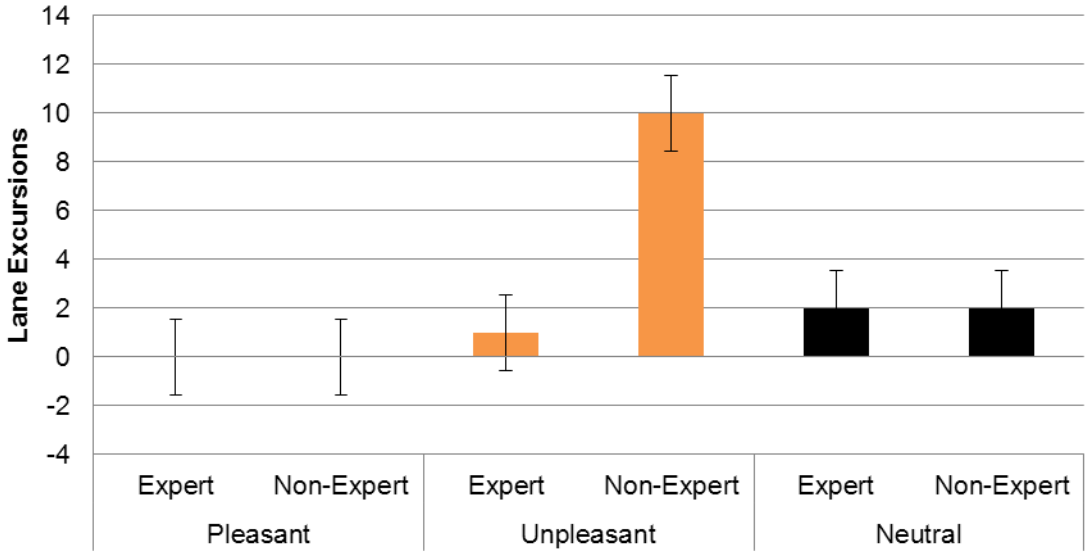

Figure 4-29. Valence x Expertise interaction on lane excursions during the experimental session. Error bars are standard errors.

Furthermore, there was a significant between-subjects effect of expertise on lane deviations in response to domain-specific images during the experimental session ($F = 4.301$, $p = .042$), where experts exhibited significantly fewer lane excursions than non-experts (Figure 4-30).

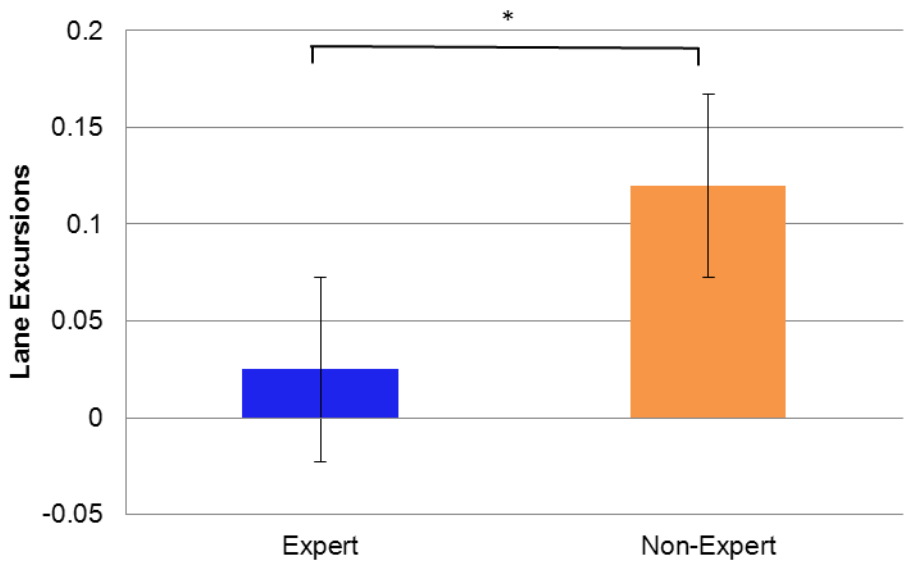

Figure 4-30. Effect of Expertise on lane excursions when exposed to domain-specific images. Error bars are standard errors.

Non domain-specific (IAPS) images.

There were no significant between or within subjects effects on lane excursions when participants saw IAPS images.

Image Ratings

Valence scores

Emotional valence scores for pleasant images (M = 6.7; SD = 0.93) were significantly higher (mean difference = 1.442, $p < .001$) and valence scores for unpleasant images (M = 2.6; SD = 1.2) were significantly lower (mean difference = 2.678, $p < .001$) compared to valence scores of neutral images (M = 5.3; SD = 0.55). Valence ratings for pleasant and unpleasant images were likewise significantly different (mean difference = 4.121, $p < .001$) as shown in Figure 4-31. There were no significant main between-subjects effects on emotional valence scores, indicating that all participants reacted to the images in the same fundamental manner.

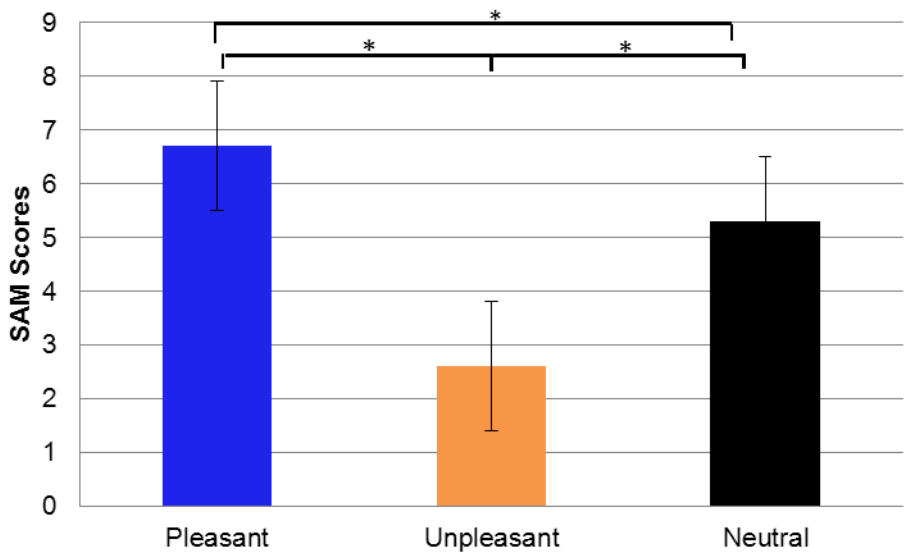

Figure 4-31. SAM scores for all emotional valences. Findings indicate that all valences were perceived as significantly different from the others. Error bars are standard errors.

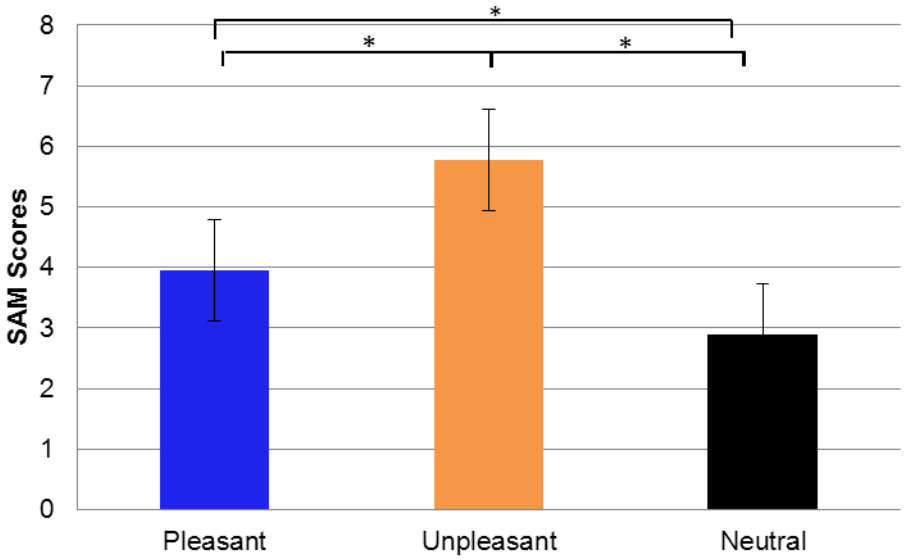

Figure 4-32. SAM arousal scores for all emotional valences. Findings indicate that all emotional valences were perceived as significantly different from the others in terms of arousal. Error bars are standard errors.

Arousal scores

There was a significant main within-subjects effect for Valence on arousal scores ($F = 84.844$, $p < .001$). Arousal scores for pleasant images ($M = 3.944$; $SD = 1.76$) were

significantly higher (mean difference = 1.047, $p < .001$) and arousal scores for unpleasant images (M = 5.771; SD = 1.87) were significantly higher (mean difference = 2.874, $p < .001$) compared to arousal scores of neutral images (M = 2.897; SD = 1.57). Arousal ratings for unpleasant images were likewise significantly higher than arousal scores for pleasant images (mean difference = 1.827, $p < .001$) as shown in Figure 4-32. There were no significant between-subjects effects on arousal scores; again, confirming that all participants were reacting the same way.

Anxiety Scores

Trait Anxiety

Expert and non-expert participants did not differ significantly in terms of trait anxiety (F = .289, $p = .593$), nor did males and females (F = .758, $p = .387$). Trait anxiety scores, however, did differ significantly between task-focused and emotion-focused drivers (F = 5.698, $p = .020$) as illustrated in Figure 4-33.

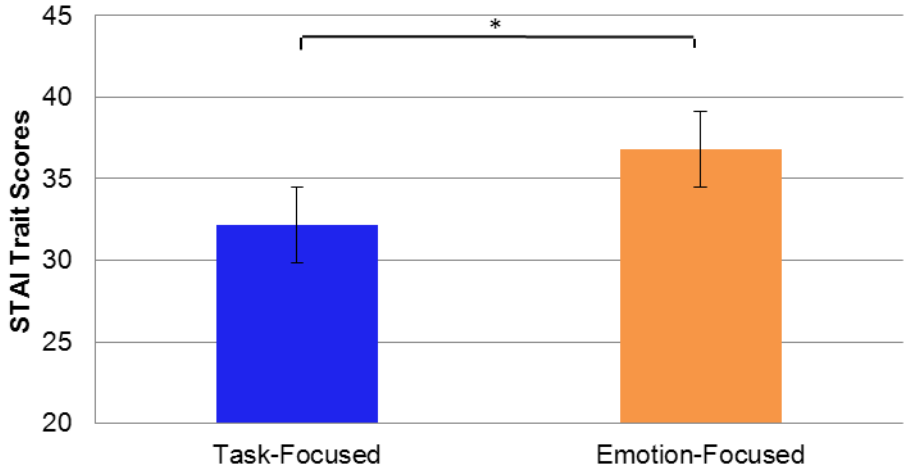

Figure 4-33. Task-focused and emotion-focused drivers' STAI trait anxiety scores.

State Anxiety: Before

Pre-drive state anxiety scores did not differ significantly between experts and non-experts (F = .096, *p* = .757), males and females (F = 1.359, *p* = .248), or task-focused and emotion-focused participants (F = .008, *p* = .931).

State Anxiety: After

Experts and non-experts did not differ significantly in terms of state anxiety after the experimental session (F = 1.764, *p* = .188). However, males and females did differ in terms of reported state anxiety post-drive (F = 8.029, *p* = .006) with females (M = 36.83) reporting a significantly higher level of state anxiety than males (M = 30.64) as illustrated in Figure 4-34. Additionally, there was a significant difference (F = 10.883, *p* = .002) in anxiety scores after the drive between task-focused and emotion-focused drivers, with emotion-focused participants (M = 37.28) reporting a significantly higher level of post-drive state anxiety than task-focused drivers (M = 30.19) as shown in Figure 4-35. Similar to the trait anxiety findings, emotion-focused individuals may have experienced higher levels of state anxiety after the stressful drive due to their maladaptive choice of emotion regulation style.

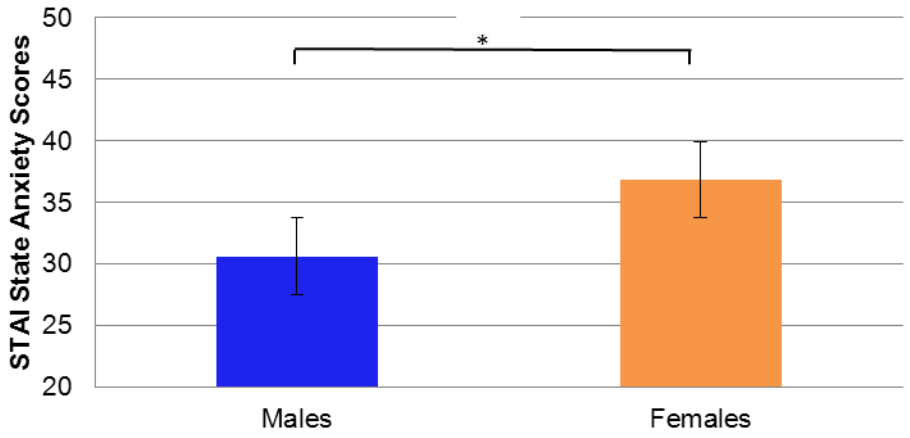

Figure 4-34. Sex differences in post-drive STAI state anxiety scores.

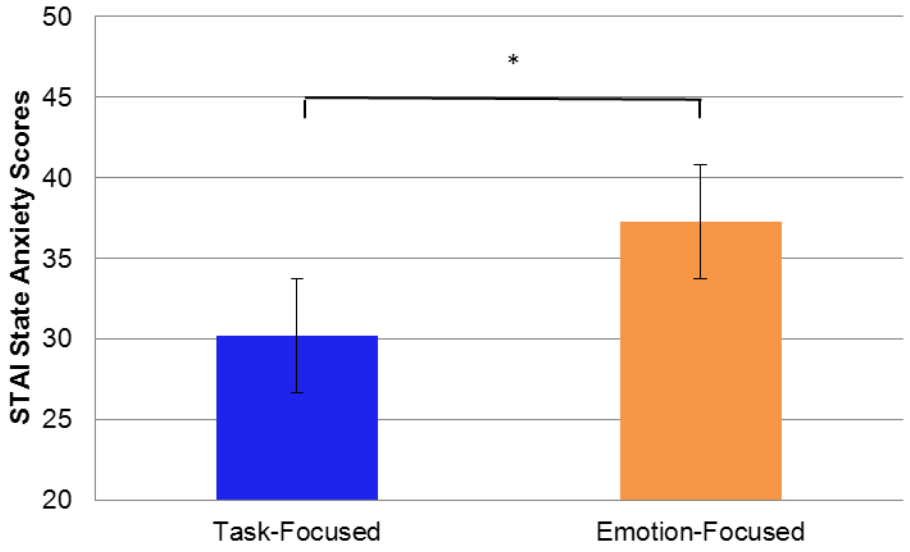

Figure 4-35. Task-focused and emotion-focused drivers' post-drive STAI state anxiety scores.

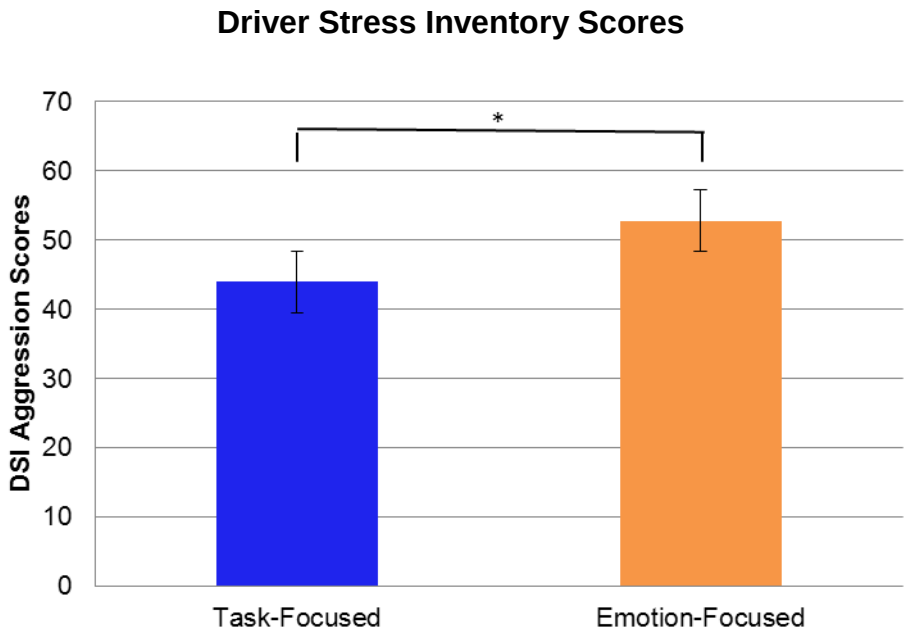

Figure 4-36. Task-focused versus emotion-focused drivers' aggression scores.

Aggression

Experts and non-experts did not differ significantly in terms of aggression (F = .734, *p* = .395), nor did males and females (F = .244, *p* = .623). There was, however, a significant main effect for PERT on aggression scores (Figure 4-36). Task-focused

drivers report significantly lower aggression scores than emotion-focused drivers (F = 8.227, *p* = .006).

Dislike of Driving

Experts' and non-experts' dislike of driving (DOD) scores did not differ significantly (F = .179, p = .674). However, there was a significant difference in the DOD scores of task-focused and emotion-focused drivers' (F = 4.866, *p* = .031), with task-focused participants reporting significantly lower DOD scores (Figure 4-37).

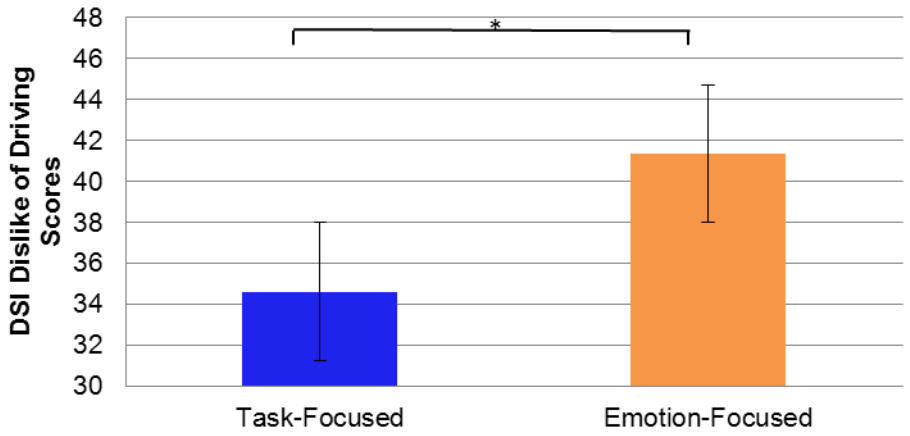

Figure 4-37. Task-focused versus emotion-focused driver's dislike of driving scores.

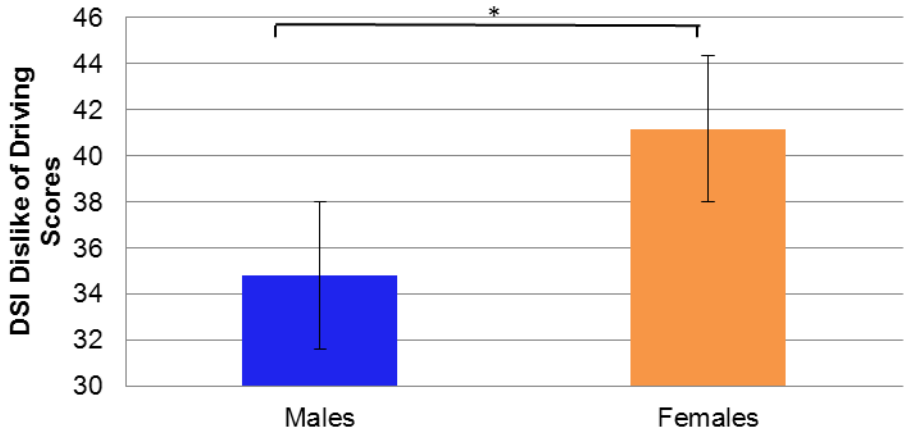

Figure 4-38. Sex differences in dislike of driving scores.

There was, likewise, a significant between-subjects effect for sex (F = 4.335, *p* = .041) on DOD scores with females reporting significantly higher DOD scores as seen in Figure 4-38. To my current knowledge, the differences in dislike of driving scores between sexes and predominant emotion regulation techniques seen here are novel.

Hazard Monitoring

There was a significant main effect for sex on hazard-monitoring scores; males scored significantly higher than females (F = 5.724, *p* = .020) as shown in Figure 4-39.

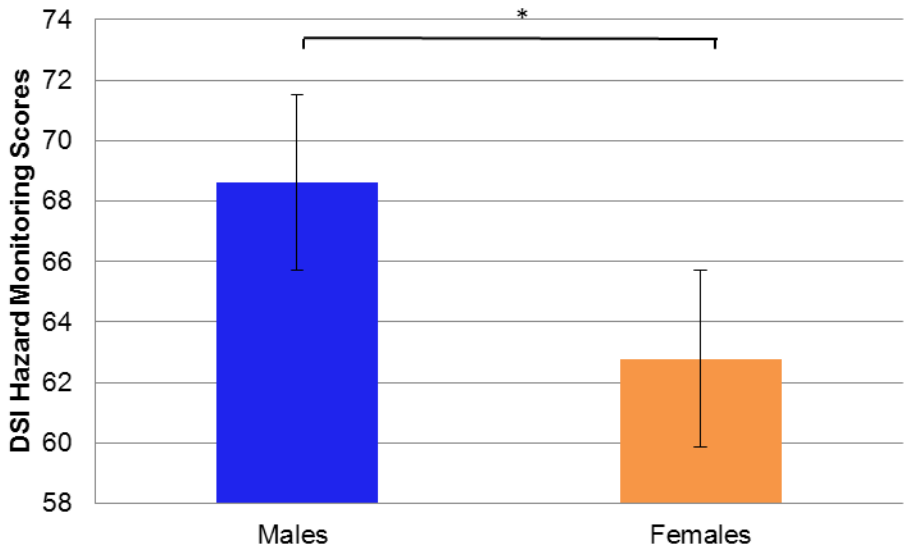

Figure 4-39. Sex differences in hazard monitoring scores.

There was no significant difference between experts' and non-experts' hazard monitoring scores (F = .508, p = .479). Task-focused and emotion-focused drivers similarly did not differ significantly (F = 3.526, p = .065).

Fatigue Proneness

Figure 4-40 illustrates the significant main effect for PERT on fatigue proneness scores, revealing emotion-focused drivers were significantly more prone to fatigue than task-focused drivers (F = 7.284, *p* = .009). Experts and non-experts did not differ

significantly in respect of fatigue proneness (F = 1.851, *p* = .178), nor did males and females (F = .679, *p* = .413).

Thrill Seeking

There were no significant differences in thrill seeking scores between levels of expertise (F = .454, *p* = .503), sexes (F = .755, *p* = .388), or predominant emotion regulation technique (F = .023, *p* = .879).

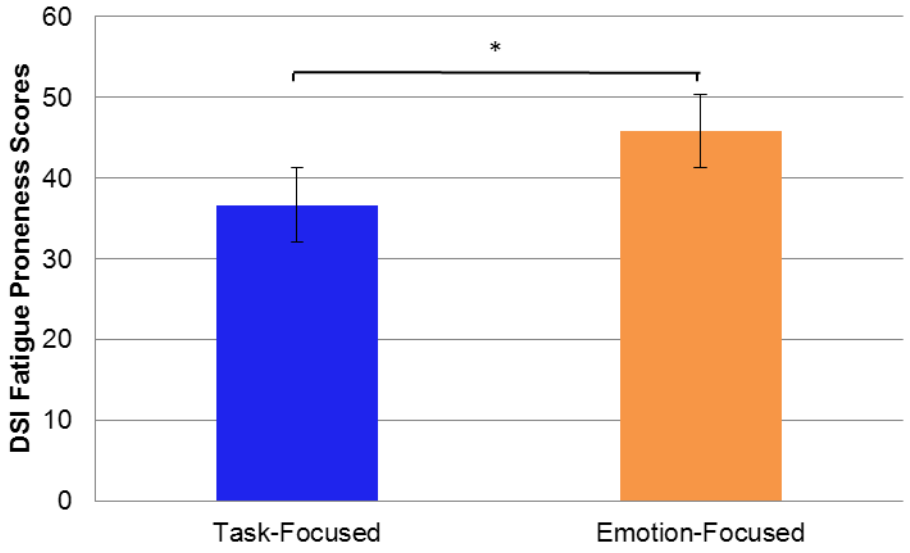

Figure 4-40. Task-focused versus emotion-focused drivers' fatigue proneness scores.

CHAPTER 5
DISCUSSION

Every year, tens of thousands of people lose their lives to traffic-related injuries (WISQARS, 2010). Additionally, hundreds of billions of dollars are spent as the result of traffic collisions (NHTSA, 2008). Accidents can be prevented by developing expertise as experts are characterized by safe and efficient behavior when engaged in the hazardous activity of driving. Stimuli which elicit emotion reactions are one aspect of the roadway environment which adds to the risk of driving. Several studies have investigated the effects of emotions on driving performance (Pêcher et al., 2009; Mesken et al., 2007; Groeger, 1997; Stephens & Groeger, 2006; Stephens & Groeger, 2009). Yet, no studies have addressed how emotions of different valence affect multiple necessary physiological systems during task performance, or how drivers' strategies to regulate their emotional reactions play into emotions' effects on physiological functioning or driving performance. There is, therefore, a clear need to understand differences between experts' and non-experts' functioning so as to design strategies by which to foster expertise more effectively and efficiently; particularly in a task which is engaged in so frequently and which entails life-or-death consequences. To better understand the complex interplay among factors contributing to safe driving performance, drivers' physiological reactions were recorded during a dual-task paradigm of simulated driving and processing of affective stimuli. Novel findings from this study reveal that emotions and drivers' choice of emotion regulation technique differentially impact the body's cardiovascular and motor systems; effects which in turn have significant influence over the safe operation of the vehicle. Specific physiological changes and their consequences on driving performance at both the expert and non-

expert levels are herein discussed. Limitations of the current study, practical applications of the findings, and potential directions for future research are also presented.

Effects on Physiological Systems

Heart Period

Exposure to valenced stimuli has been experimentally shown to produce a rapid, short-term slowing of cardiac output (Dunn et al., 2009). I therefore hypothesized that the presentation of affective images during the drive would lead to longer heart periods (i.e., heart rate deceleration) in all participants. In keeping with the hypothesis, drivers exhibited positive mean difference scores between phasic and baseline activity in response to affective stimuli (Figure 5-19). The dissimilar levels of somatic arousal across emotional valences support the hypothesis that emotions of dissimilar valence affect the same physiological system differently. Unpleasant images elicited the greatest reaction when compared to other emotional valences, which is in keeping with results of past research (Fairclough et al., 2006; Mesken et al., 2007). Intuitively, unpleasant depictions of aversive outcomes (i.e., dead bodies, car crashes, etc.) would affect drivers to the greatest extent as they portray the potentially lethal consequences underlying the task being performed. However, elevated physiological arousal as observed here, specifically in response to pleasant stimuli, contradicts previous research which saw no change in cardiac functioning when participants experienced pleasant emotions (Codispoti et al., 2001). Findings therefore suggest that pleasant emotions similarly excite autonomic functioning, yet to a lesser extent than unpleasantly emotional valenced stimuli.

Taken together, results suggest that 1) heart period is a measure sensitive to differential changes in somatic arousal caused by dissimilar emotions, 2) driver's predominant emotion regulation technique seems to exert little to no influence over cardiac function during dual-task driving and 3) both sexes experience the same level of arousal in the cardiac system in response to affective stimuli.

Co-contraction

According to Neuromotor Noise Theory, co-contraction of agonist and antagonist muscles occurs to a greater extent in affectively-charged environments abounding with external stressors (Van Galen & Van Huygevoort, 2000). Bloemsaat and colleagues (2005) reinforced this theory with experimental evidence when they observed higher levels of agonist/antagonist muscle co-contraction in response to higher levels of mental workload. Additionally, valenced stimuli have been shown to elicit muscular contractions of greater magnitude (Coombes, Cauraugh & Janelle, 2006; Coombes et al., 2008) and impede motor accuracy (Coombes, Janelle & Duley, 2005). Based on these empirical works, I hypothesized that all participants would experience an increase in co-contraction values after having seen affective versus neutral images. This hypothesis was partially supported. While the co-contraction ratio did increase relative to baseline (neutral detour signs) in response to driver stress of viewing the images (pleasant, unpleasant and neutral), the measure proved insufficiently sensitive to differentiate between emotional valences, as predicted.

EMG data indicate that males and females react differently to the same stimuli, supporting my hypothesis that female drivers are less reactive than male drivers given their propensity to use a greater quantity and variety of emotion regulation strategies (Martin & Dahlen, 2005). Males physiologically reacted more strongly and more variably

than females despite reporting significantly less anxiety and enjoying the driving task significantly more. Heightened reactivity on the part of males could be due to an attentional effect, given that males had significantly higher hazard-monitoring scores. Males higher rates of traffic-related aggression (Björklund, 2008), citations and injuries (Lonczak et al., 2007) may therefore be explained by the fact that they are physically responding more strongly to stimuli despite perceiving the images similarly to females and perceiving significantly less anxiety than females. Current sex differences therefore corroborate past findings that the sexes behave differently in response to affective stimuli (Björklund, 2008; Lonczak et al., 2007) yet perceive them similarly (Deffenbacher, 2008; Lonzak et al., 2007). Furthermore, females followed the same pattern of activation (regardless of emotional valence): task-focused females reacted to a greater extent than emotion-focused females. Males, on the other hand, varied in this respect based on emotional valence. In response to neutral pictures, males increased their co-contraction to the same extent regardless of their predominant emotion regulation technique. When responding to pleasant images, males similarly increased their co-contraction; yet, task-focused males increased these values to a greater degree. Finally, when exposed to unpleasant scenes, males experienced an increase in co-contraction if task-focused and a decrease if emotion-focused. Findings from this study support the idea that young male drivers could benefit from more and/or different training than females. Males could undergo training wherein they are exposed to driving-related stimuli and learn task-specific adaptive emotion regulation techniques to mitigate their heightened responses, thus fostering superior, adaptive driving behaviors.

The significance of predominant emotion regulation technique in this interaction lends empirical support for Matthews's (2002) transactional model which emphasizes the critical nature of cognitive stress processes (i.e., regulation style) as well as Johnson and colleagues (2006) supposition that coping strategies are an important consideration when acquiring expertise. Choice of predominant emotion regulation technique played a critical role in the efficient execution of the driving task. Adaptive (task-focused) drivers tended to drive more safely than maladaptive (emotion-focused) regulators. Higher trait-anxiety in maladaptive, emotion-focused copers may reflect these individuals' general inability to cope well with stress whether on or off the road. Additionally, males and females have been found to differ in the variety and quantity of techniques employed (Martin & Dahlen, 2005). Therefore, understanding how drivers choose which strategies they use, when they choose to use them and their efficacy will be crucial in fostering safe, superior performance.

Taken together, the co-contraction results indicate that 1) co-contraction is sensitive to increases in somatic arousal but is not able to distinguish emotional valence, 2) experts tended to experience greater muscular activity than non-experts in response to valenced stimuli when engaged in their domain-specific task, 3) adaptive emotion regulation techniques played a key, interactive role in muscular response to affective stimuli, by increasing co-contraction and thus improving fine-motor control of the steering wheel and 4) males consistently experience greater levels of muscular co-contraction relative to females.

Summary

The presence of valenced stimuli produced significant changes in both the cardiac and motor systems during driving. Heart period results were sensitive to different

emotional valences, indicating that the stimuli were processed and perceived differently (as confirmed by significant differences in valence and arousal scores). Muscular activity was likewise affected by the presence of emotional images. However, co-contraction values did not vary according to emotional valence, suggesting that despite the differential processing proposed by the changes in cardiac function, mental strategies (i.e., predominant emotion regulation techniques) regulated muscle control in the face of affective scenes to maintain a safe lane position, as indicated by the lack of a between-subjects effect for expertise on lane excursions during the experimental session. Such a position corroborates previous research indicating that physiological metrics are sensitive to stimulus-driven reactions and increases in attentional demand to a greater extent than driving measures alone (Lenneman & Backs, 2009).

Emotions' and Emotion Regulation's Impacts on Driving Performance

Emotions are known to significantly alter driving performance by prompting the operator to drive significantly faster or slower than the speed limit (Mesken et al., 2007; Pêcher et al., 2009), engage in more error-prone overtaking (Matthews et al., 1998), and decrease steering activity (Matthews, 2002). Such effects are not uniform, however. For instance, Pêcher and colleagues (2009) found that drivers who were primed to be happy drove significantly slower, while Mesken and colleagues (2007) found no performance differences when participants were in a pleasant mood. Researchers have likewise addressed how emotion regulation strategies affect large-scale driving behaviors. Drivers who regulate emotions adaptively (i.e., task-focused) have fewer errors, fewer violations and drive at slower speeds than maladaptive (i.e., emotion-focused) regulators (Matthews et al., 1996; Matthews, 2002). How expertise may affect these affective influences in driving remains unknown. Results from the present protocol

may therefore help to clarify the effects of different emotions and different emotion regulation strategies on driving measures at both the expert and non-expert levels. Differential emotional effects on the longitudinal (i.e., mean driving speeds) and lateral (i.e., lane excursions) control of the vehicle are discussed in reference to such issues.

Mean Driving Speeds

I predicted that experts would drive closer to the speed limit when compared to non-experts. The data supported my hypothesis. Additionally, I predicted that task-focused experts would drive closer to the speed limit than any other group; a hypothesis which was not supported by the data. These findings are in keeping with current theoretical and empirical knowledge of expert performance (Ericsson, 1998; 2006), particularly as it applies to the driving domain (Jamson et al., 2008). Additionally, when mean driving speeds were analyzed according to emotional valence, there was an effect for expertise only in response to domain-specific images; indicating that experts and non-experts responded similarly to IAPS images, yet experts drove better than non-experts when exposed to valenced images that depicted scenes relevant to their domain of expertise. Such performance differences only in response to domain-specific images corroborate past theory and research that expertise is domain-specific (Ericsson, 1998; 2006).

There was a significant effect for emotional valence on mean driving speeds in that participants drove slower in response to pleasant images when compared to unpleasant images. Results therefore substantiate the findings of Pêcher and colleagues (2009) which contend that pleasant emotions produce slower speeds and contest those which found no difference (Mesken et al., 2007). Based on mean driving

speed results, pleasant emotions have the capacity to affect performance as much as unpleasant emotions.

Further analysis revealed male and female regulators reacted dissimilarly. Males drove closer to the speed limit when emotion-focused as opposed to task-focused, and task-focused females drove closer to the speed limit than emotion-focused females. Moreover, no difference in mean driving speeds was observed between experts (whether task-focused or emotion-focused, male or female); however, between non-experts, emotion-focused males drove more closely to the speed limit as did task-focused females. As evident by the interactive influences of sex, expertise and emotion regulation style on driving performance, results again highlight the importance of considering these factors when designing driver training programs. Present programs designed to teach individuals how to drive include a standardized text (written exam) and driving around a course at the Department of Motor Vehicles (applied exam). Such methods are currently designed to be applied to all drivers and are extremely controlled for the safety of both driver and evaluator. Given the results of my study, drivers could be taught long-term, safe driving behaviors by enhancing these existing courses with systematic exposure to common, domain-specific stimuli and specific instruction fostering adaptive methods of coping with their reactions. Males can especially benefit from such a new approach given their propensities to react to a greater extent, to react more variably, and establish maladaptive coping strategies early in their development of expertise.

In sum, mean driving speed results indicate that 1) pleasant emotions do prove distracting to the driver (Pêcher et al., 2009), 2) experts drive more safely than non-

experts (Jamson et al., 2008), 3) expertise is domain-specific (Ericsson, 1998), and 4) emotion regulation plays a major interactive role in driving efficacy (Matthews, 2002).

Lane Excursions

As with mean driving speeds, I predicted that experts would prove to exercise superior lateral control over the vehicle when compared to non-experts (as reflected in less lane excursions). The data, however, only supported this hypothesis when in response to domain-specific images. As with the mean driving speed data, results promote the current understanding of the domain-specificity of expertise (Ericsson, 1998).

Exposure to unpleasant images resulted in more lane deviations as compared to neutral pictures. Results are inconsistent with Pêcher and colleagues (2009) who observed that pleasant emotions led to the greatest compromises in lateral control. According to my study, unpleasant scenes (particularly as they relate to driving) significantly affect drivers as they serve as an immediate reminder of the consequences of poor driving and can inform the driver that extra caution is needed in the present driving environment.

Lane excursions did not vary appreciably between experts and non-experts in response to pleasant and neutral images. However, non-experts violated the boundaries of their lane significantly more often than expert drivers after having seen unpleasant images. Data, therefore, once again highlight the domain-specificity of expertise (Ericsson, 1998). Moreover, results contest Pêcher and colleagues' (2009) findings concerning which emotional valence promotes the greatest deterioration in lateral vehicular control. The differential findings may be due to the fact that Pêcher and

colleagues primed moods with auditory stimuli over time, while my study had participants respond to immediate visual stimuli.

In sum, results indicate that 1) effective lateral control is compromised to the greatest extent after drivers witness unpleasant images, 2) experts, again, are safer drivers than non-experts (Jamson et al., 2008), and 3) expertise is domain-specific (Ericsson, 1998).

General Summary

Results from the present study demonstrate that emotions, whether of pleasant or unpleasant emotional valence, greatly affect driving performance. Pleasant emotions lead to a decline in participants' longitudinal control of the vehicle, producing the slower speeds seen in this study as well as by Pêcher and colleagues (2009). Unpleasant images depreciate drivers' capacity for effective lateral control, leading participants to cross the borders of their lane which subsequently increase the likelihood of an accident. Results concerning unpleasant pictures contradict Pêcher and colleagues' (2009) study which found increased instances of crossing the line of the shoulder when participants were primed with music to be in a pleasant mood.

No main or interactive effects for predominant emotional regulation technique were observed on either driving performance measure as type of regulation style played such a major interactive role in the motor control which leads to driving performance. Adaptive (task-focused) regulators seemed to consistently drive more safely when compared to maladaptive (emotion-focused) drivers, with the curious exception of non-expert males, indicating that adaptive regulation helped to produce more effective motor output which led to safer driving.

Limitations

A great limitation was the length of the time window under investigation. Participants were driving in the simulator for a total of 20 minutes, and while this duration may have been long enough to observe expertise differences, it may not be truly indicative of people's experiences over long-term drives. Similar, predominant emotion regulation technique differences may not have emerged from the data due to the fact that emotion-focused coping, while considered a maladaptive strategy to employ long-term, may prove effective over short intervals. The short length of the experimental session may have proven a significant limitation, yet it was necessary to minimize the time spent in the simulator to avoid comprising the physiological data with simulator sickness which tends to materialize after the individual has spent a long time in the simulator. Conversely, the 6 second time window from which EMG data were extracted may have been too long. Findings from Parlitz and colleagues (1998) reveal that experts' force is exerted and completed much more quickly than that of non-experts. Any large reactions may therefore be washed out by being averaged over such a long period of time combined with such a high sampling rate.

An additional limitation stems from the difficulty in separating emotional valence effects from attentional effects. Differences in functioning may not be due to the emotional valence itself, but rather to the driver's more distracted state as they devote more attentional resources away from the driving task. Expert drivers typically have more attentional resources to devote to the secondary task as they have automized their superior performance in driving (Fitts & Posner, 1967), yet they still need resources for the secondary task in which they are not experts (Lansdown, 2002).

Theoretical Implications

Findings from this study have important implications for motor control theory. Presently, empirical studies investigating the effects of affective stimuli on subsequent motor response or task performance neglect how individuals regulate their reactions to emotional circumstances. Yet, research has previously purported that people engage in emotion regulation everyday (Gross, Richards & John, 2006) and that they regularly and effectively engage in it at both the conscious and unconscious levels (Mauss, Bunge & Gross, 2007; Mauss, Cook & Gross, 2007; Hancock & Beatty, 2010). Results from the present study therefore serve to inform such theories by revealing the importance of accounting for an individual's principal emotion regulation style when investigating the effects of emotional valence on the effectiveness or efficiency of motor output.

Practical Implications and Directions for Future Research

Drivers' end goals are typically safety and efficiency. How well the driver performs, how they regulate their emotions and the type of stimuli they encounter seem to have significant bearing on their performance. Present findings may therefore influence future training requirements for licensure and certification. Drivers who are better able to manage their reactions and their subsequent control of the vehicle in the distracting roadway environment will help avoid the aversive and potentially fatal consequences of traffic accidents through better collision avoidance. Considering the present results, future research should take into account not only both pleasant and unpleasant valences when assessing emotional effects on cardiac functioning, but also the strategy individuals use to mitigate their reactions. As this study addressed the effects of visual stimuli, future research may include investigating how drivers' choice of emotion regulation technique may vary according to emotional stressors of different modalities

(i.e., auditory stressors, thermal stressors, etc.). Additionally, further studies should address how drivers' choice of emotion regulation strategy may vary over time as drivers become more fatigued (i.e., during longer drives). Finally, a better understanding of safe driving behavior may emerge by exploring how these modal and temporal variations may affect the physiological functioning of the driver when trying to safely and efficiently operate the vehicle.

Conclusions

The purpose of this project was two-fold: 1) to investigate how different emotions affect the cardiac and motor systems as experts and non-experts of both sexes perform the driving task and 2) how an individual's choice of emotion regulation technique can influence such emotional reactivity across different physiological systems. As hypothesized, emotions had significantly different effects on cardiac function, with unpleasant images causing significantly greater reactions. Contrary to hypothesis, however, muscular function did not vary by emotional valence. Taken together, these findings suggest that the body experiences differences in somatic arousal in the face of different valenced emotions, yet muscular control is maintained (through emotion regulation) in an effort to sustain safe performance. As predicted, experts drove significantly safer than non-experts with respect to both longitudinal and lateral control of the vehicle (both of which are equally compromised by the presence of affective stimuli). Improved driving performance can therefore be due to the use of adaptive emotion regulation strategies (i.e., task-focused coping) which played a critical interactive role in the muscular control underlying driving execution. The current study provides the first evidence that choice of emotion regulation strategy bears influence on task-specific motor output. Further empirical study may help shape the development of

individual training techniques that encourage the use of adaptive emotion regulation strategies to help all drivers adapt effectively and safely to a demanding and unpredictable environment so as to decrease the likelihood of traffic-related injuries and deaths.

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BIOGRAPHICAL SKETCH

Gabriella M. Hancock was born in California in 1986. She became fluent in French after attending Normandale French Immersion School in Edina, Minnesota and continues to relish any and all opportunities of conversing in such a beautiful language. As a child, she was educated on both sides of the Atlantic; having studied abroad at St. Catherine's Primary School in Chipping Campden, Gloucestershire, England. In 2005, Gabriella earned her high school diploma from Trinity Preparatory School in Winter Park, Florida. Three years later, she graduated from the University of Central Florida's Burnett Honors College with a B.Sc. in psychology. For the past three years, Gabriella has been a research and teaching assistant in the Performance Psychology Laboratory at the University of Florida where she completed her Master of Science degree in applied physiology and kinesiology with a concentration in biobehavioral science.