EFFECTS OF AFFECTIVE STATES ON DRIVER SITUATION AWARENESS AND ADAPTIVE MITIGATION INTERFACES: FOCUSED ON ANGER

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EFFECTS OF AFFECTIVE STATES ON DRIVER SITUATION AWARENESS AND ADAPTIVE MITIGATION INTERFACES: FOCUSED ON ANGER

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I dedicate this dissertation to my family, for their never-ending love and support within God's grace.

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TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

SUMMARY

Research has suggested that affective states have critical effects on various cognitive processes and performance. Evidence from driving studies has also emphasized the importance of driver situation awareness (Endsley, 1995b) for driving performance and safety. However, to date, no research has investigated the relationship between affective effects and driver situation awareness. Two studies examined the relationship between a driver's affective states and situation awareness. In Experiment 1, 30 undergraduates drove in a simulator after either anger or neutral affect induction. Results suggested that an induced angry state can degrade driver situation awareness and driving performance more than the neutral state. Interestingly, the angry state did not influence participants' perceived workload. Experiment 2 explored the possibilities of using an "attention deployment" emotion regulation strategy as an intervention for mitigating angry effects on driving, via an adaptive speech-based system. 60 undergraduates drove the same scenario as in Experiment 1 after affect induction with different intervention conditions: anger with no sound; anger with the ER system: directive/ command style emotion regulation messages; anger with the SA system: suggestive/ notification style situation awareness prompts; or neutral with no sound. Results showed that both speech-based systems can not only enhance driver situation awareness and driving performance, but also reduce the anger level and perceived workload. Participants rated the ER system as more effective, but they rated the SA system as less annoying and less authoritative than the ER system. Based on the results of Experiment 2, regression models were

constructed between a driver’s affective states and driving performance, being mediated by situation awareness (full mediation for speeding and partial mediation for collision).

These results allow researchers to construct a more detailed driver behavior model by showing how an affective state can influence driver situation awareness and performance. The practical implications of this research include the use of situation awareness prompts as a possible strategy for mitigating affective effects, for the design of an affect detection and mitigation system for drivers.

CHAPTER 1

INTRODUCTION

Emotions and affect shape our thoughts, motivations, and behaviors every day (Algoe & Fredrickson, 2011; Nass et al., 2005). Thus, emotions play a central role in personal evaluations of, or relationships with, artifacts and systems (Norman, 2005) and many tasks have an affective component, specifically under conditions of stress, workload, and multitasking (Lottridge, Chignell, & Jovicic, 2011). Driving, which is a very complex and indeterminate task, presents such a context in which emotions and affect can have enormous consequences. For instance, road rage (Chapter 5) is one of the most frequently reported examples of emotions impacting driving safety. This extreme case, however, is not alone in describing affect-related driving situations. Consider a driver who decides to take the long route to work to avoid the dense traffic that got him or her so agitated the last time he or she tried the “short” route. This mundane example demonstrates that emotions provide an omnipresent backdrop to our everyday experience (Algoe & Fredrickson, 2011).

Despite the importance and prevalence of affective states in everyday life, emotions and affect have not been a dominant topic of psychological science. During the first half of the twentieth century, most psychologists focused on studying observable behavior, whereas the cognitive revolution wielded strong influence over the rest of the century (Gazzaniga, Heatherton, & Halpern, 2010). Affect only started to be reintegrated into the mainstream of psychological science during the last two decades (Forgas, 1995). Emotions and affect have a similarly short history of being considered in human-machine system research, which used to be based on the tradition of the information processing approach and a focus on performance.

Picard's *Affective Computing* (Picard, 1997) opened a new era of an affective approach to human-machine system research, even though it led to roars of laughter at the first time (Picard, 2010). Affective elements allow for a *systems approach* and a more holistic view to understanding the human-machine system. For example, affective states have been known to play a major role in influencing all aspects of situation assessment and belief information, from cue identification and extraction to situation classification, and decision-selection (Hudlicka, 2003). Given that situation awareness (Endsley, 1995b) and peripheral awareness models (Buxton, 1995) have their origin in naturalistic decision making theory (Klein, 2008; Klein & Klinger, 1991), the inclusion of intrinsically necessary elements in natural situations, such as emotions and affect, is expected to enrich those human-machine system models. There is a growing realization that addressing the design challenges of complex sociotechnical systems may need to include affect in its description (Lee, 2006). This trend is reflected in recent journals, with the publications of special issues of *Ergonomics* (Helander & Tham, 2003) and the *International Journal of Human-Computer Studies* (Hudlicka, 2003), the birth of *IEEE Transactions on Affective Computing* (Picard, 2010), along with many popular books (e.g., Norman, 2005; Picard, 1997) and book chapters (e.g., Lee, 2006).

To date, a systematic approach to affect-related driving research has yet to be thoroughly developed. The majority of driving behavior models focus on the cognitive aspects of the drivers (e.g., Boer, Hildreth, & Goodrich, 1998; Liu & Salvucci, 2001). They do not include affective elements as *variables* to consider when modeling a driver.

Rather, such factors seem to be labeled as noise or errors in the model. Overall, affect has been treated peripherally and sporadically.

This dissertation attempts to examine roles and effects of affect on the well-known construct, *situation awareness* (SA) and driving behavior, with a focus on anger. First, the situation awareness model (Endsley, 1995b) is briefly reviewed in relation to driving behavior (Chapter 2). Based on the taxonomy of cognitive components of each level of SA, the relations between cognition and affect and their interaction mechanisms are discussed to demonstrate potential affective effects on SA and driving behavior (Chapter 3). This is followed by motivations for the current research and research questions (Chapter 4). Then, Experiment 1 on specific affective (i.e., anger) effects on driving performance and driver situation awareness is presented in Chapter 5. Chapter 6 describes Experiment 2, which evaluates adaptive user interface alternatives to mitigate anger effects on driving performance, along with other related variables. Finally, Chapter 7 presents planned and ongoing future works, as well as implications for theoretical and practical research.

CHAPTER 2

SITUATION AWARENESS AND DRIVING

Driving is a multitasking activity that requires a driver to simultaneously manage various undertakings including primary, secondary, and tertiary tasks (Geiser, 1985; Kern & Schmidt, 2009). Primary tasks include direct driving maneuvers, such as controlling the speed or checking the distance to other cars. Secondary tasks refer to functions that increase driving safety, such as activating turning signals or windshield wipers. Tertiary tasks include things such as the use of in-vehicle entertainment or information systems.

Most driving models have addressed primary tasks, and the majority of them have focused on lower-level control behaviors, such as lane keeping and curve negotiation (e.g., Boer, 1996; Boer & Hildreth, 1999; Donges, 1978; Hess & Modjtahedzadeh, 1990; McRuer, Allen, Weir, & Klein, 1977; Reid, Solowka, & Billing, 1981). Researchers have started to develop an integrated driver model that combines those lower-level models of control and higher-level models of cognitive processing (e.g., Levison & Cramer, 1995, Wierwille, 1998). The higher-level cognitive elements of such an integrated driver model involve maintaining situation awareness, determining strategies for navigation, deciding when to initiate and terminate maneuvers, and managing other secondary and tertiary tasks (Salvucci, Boer, & Liu, 2001).

This chapter investigates the situation awareness (SA) model (Endsley, 1995b), which is widely applied to an explanation of dynamic situations such as driving or aviation with a focus on linking sublevels of situation awareness with typical cognitive processes. Next, the discussion briefly outlines how researchers tried to connect the concept of situation awareness and driving behavior.

Situation Awareness Model

The situation awareness (SA) model (Endsley, 1995b) focuses on operator situation awareness, a widely accepted construct on which decision making and performance are dependent in complex, dynamic environments. Situation awareness is, in brief, an understanding of the state of the environment including relevant parameters of the system (Endsley, 1995a). Since its emergence, the SA model has been shown to be important in examining various contexts that human factors practitioners and theorists confront, ranging from aircraft, air traffic control (e.g., Durso, Hackworth, Truitt, Crutchfield, Nikolic, & Manning, 1999; Durso, Truitt, Hackworth, Crutchfield, & Manning, 1998), large-systems operations, tactical and strategic systems, to everyday activities such as operating heavy machinery or driving (e.g., with cruise control and a cell phone, (Ma & Kaber, 2005); with a navigation task, (Ma & Kaber, 2007); and with working memory tasks, (Johannsdottir & Herdman, 2010)). Endsley's (1995b) SA model illustrates three states of SA formation: *perception*, *comprehension*, and *projection*. The first level in achieving SA is to perceive the status, attributes, and dynamics of relevant elements in the environment. Therefore, this level involves the processes of *monitoring*, *cue detection*, and *simple recognition,* which lead to an awareness of multiple situational elements and their current states. For example, a driver needs to know where other vehicles and obstacles are, their dynamics, and the status and dynamics of his or her own vehicle. The second level is to synthesize each element of the perception level through the processes of *pattern recognition, interpretation,* and *evaluation*. Comprehension requires integrating this information to understand how it will have an impact on the individual's goals and objectives. For instance, a novice driver may be able to achieve the same level of perception as an experienced driver, but may fail to integrate various data elements along with related goals to fully comprehend the situation. The third level is to project the future actions of the elements in the environment. This level is achieved through knowledge of the status and dynamics of the elements, comprehension of the situation, and then extrapolating that information forward in time to determine how it will affect future states of the operational environment. Thus, this projection and *judgment* of future states are valuable for *decision making*.

Attention and *working memory* are treated as critical factors that limit operators from acquiring and interpreting information from the environment to form situation awareness. To overcome those limits, *mental models* and *goal-directed behavior* are hypothesized as important mechanisms. For the operator's affective state, *workload* and *stress* are partially addressed, but not integrated into the model. Because decision making and performance of action are separated from the situation awareness stage in Endsley's (1995b) model, good situation awareness can generally be a factor in predicting good performance, but it does not guarantee good performance. Several researchers have revealed positive associations between situation awareness and one or more dimensions of driving performance (Ma & Kaber, 2005, 2007) and developed their own driver situation awareness model (e.g., Gugerty, in press; Ma & Kaber, 2005; Matthews, Bryant, Webb, & Harbluk, 2001). However, there is no standard situation awareness model in driving so far.

Table 1. Relations between situation awareness components in Endsley's (1995b) model and typical cognitive processes that are addressed in affect literature.

Level of Situation Awareness	**Sub-components of Each Level SA**	**Typical Cognitive Processes**
Level 1 SA Perception	The processes of monitoring, cue detection, and simple recognition	Attention & Perception
Level 2 SA Comprehension	The processes of pattern recognition, interpretation, and evaluation	Interpretation & Judgment
Level 3 SA Projection	Comprehension of the situation, and then extrapolating that information forward in time to determine how it will affect future states of the operational environment	Judgment & Decision Making

Table 1 describes the relations between the level of the situation awareness model and typical cognitive processes. Level 1 SA perception can be described in relation with attention and perception in traditional affect research. Of course, attention may influence all three levels of SA, but it can be accounted for by similar mechanisms to perception and overall processing style in affect literature. Level 2 SA comprehension can be described in relation with interpretation and judgment. Level 3 SA projection can also be described by judgment and decision making. Decision making is differentiated from SA process in the narrow sense in Endsley's model. Nonetheless, judgment and decision making literature are too intermingled with each other to be separated. Because decision making is included in the overall SA model, I believe that the inclusion of decision making is appropriate for discussion in this dissertation.

The next chapter summarizes empirical evidence of affective effects on situation awareness and driving performance mostly based on psychological affect research with a focus on these cognitive processes.

Situation Awareness and Driving

Given that poor SA is a greater cause of accidents than improper speed or improper driving technique (Gugerty, 1997), there have been attempts to try to conceptualize driver SA. For example, Matthews, Bryant, Webb, and Harbluk (2001) have tried to propose a model for driver situation awareness that can be used as a basis for understanding the possible impact of the intelligent transportation systems on driving performance.

From a driving perspective, SA includes spatial awareness (i.e., an appreciation of the location of all relevant features of the environment), identity awareness (i.e., knowledge of salient items), temporal awareness (i.e., knowledge of the changing spatial picture over time), goal awareness (i.e., the highest goal may be the navigation plan to the destination; at a lower level, the maintenance of speed and direction to conform to the navigation plan; and at a still lower level, the need to maneuver and place the vehicle in an appropriate manner within the surrounding traffic stream), and system awareness (i.e., relevant information within the larger driving environment as a system). These aspects of SA have been integrated into a goal-oriented model of driver behavior that encompasses strategic, tactical, and operational goals of driving (Matthews et al., 2001; Ward, 2000). For instance, operational driving tasks (e.g., steering and braking responses) require level 1 SA. Tactical driving tasks require levels 1 and 2 SA to facilitate safe maneuvering of a vehicle in traffic by judging and comparing lane positions. Strategic tasks require level 3 SA for near-term projection of changes in the driving course and traffic patterns or for formulation of navigation plans.

On the other hand, Gugerty (in press) discussed situation awareness in driving with a focus on managing attention. His model involves three cognitive processes to update and maintain SA as knowledge: (1) automatic, preattentive processes that occur unconsciously and place almost no demands on cognitive resources; (2) recognition-primed decision processes that may be conscious for brief periods (< 1 second) and place few demands on cognitive resources; and (3) conscious, controlled processes that place heavy demands on cognitive resources. His model is conceptually different from Endsley's model. However, in practice, it compromises with Endsley's in that perceiving the elements of a situation (level 1 SA) is probably highly automated in most situations, whereas comprehension and projection (levels 2 and 3 SA) are more likely to use recognition-primed and controlled processes.

In addition to these conceptualizations, there have been several empirical studies that try to engage SA in driving context. Walker and colleagues (Walker, Stanton, & Young, 2006) evaluated the effects of different forms of non-visual vehicle feedback on driver SA using a probe-recall method. The findings confirm that the vehicle feedback (particularly auditory feedback) plays a key role in coupling the driver to the dynamics of their environment. An interesting result is that drivers demonstrated little awareness of diminished SA despite the large changes in vehicle feedback.

Other studies identified positive associations between SA and one or more dimensions of driving performance using various secondary tasks (Johannsdottir & Herdman, 2010; Ma & Kaber, 2005, 2007). For example, Ma and Kaber (2005) examined driver situation awareness involving an adaptive cruise control (ACC) system while calling on a cell phone. Results showed that use of the ACC system improved overall driver SA under typical driving conditions, and reduced driver mental workload. However, the cell phone conversation degenerated driver SA (especially, levels 2 and 3

SA) and increased driver mental workload. The stage of perception (level 1 SA) may place relatively lower demands on human mental resources, as compared to comprehension (level 2 SA) and projection (level 3 SA), and consequently drivers may be able to address such demands even when resource competition occurs (Ma & Kaber, 2005). In a subsequent study, Ma and Kaber (2007) assessed the effects of in-vehicle navigation aids and reliability on driver SA and performance in a simulated navigation task. Results revealed that perfect navigation information generally improved driver SA and performance compared to unreliable navigation information and task-irrelevant information. They concluded that the in-vehicle automation appears to mediate the relationship of driver SA to performance in terms of operational and strategic behaviors.

Johannsdottir and Herdman (2010) examined the roles of working memory subsystems in supporting driver SA. Participants in their experiment drove a simulated vehicle and monitored surrounding traffic while concurrently performing either visuospatial- or phonological-load tasks. From two experiments, they showed that a visuospatial task interfered with drivers' ability to recall the positions of traffic located in front of vehicle. In contrast, a phonological task interfered with drivers' ability to recall the positions of traffic located behind their vehicle. However, they proposed that driver SA for surrounding traffic must involve other components such as an episodic buffer (Baddeley, 2000) that is assumed to bind and store information from working memory and long-term memory into a unified episodic representation. They suggested that the episodic buffer would presumably be a core mechanism for supporting level 2 (and possibly, level 3) SA.

CHAPTER 3

AFFECTIVE EFFECTS ON SITUATION AWARENESS AND DRIVING

In this chapter, a few specific effects of affect on cognition are deeply examined with a special focus on mechanisms of the effects. Empirical evidence of effects on various cognitive processes will shed light on potential roles of affect in driver situation awareness and performance. Based on the previous chapter, cognitive processes that are deeply related to situation awareness including attention and perception, interpretation, judgment, and decision making are mainly investigated. Before starting a detailed review on those, the definition and taxonomies of affective constructs and general relations between affect and cognition are briefly presented for clearer understanding of this area.

Affect: Definition and Taxonomy

Affect describes several relevant constructs that are distinct, but frequently treated as interchangeable, including emotions, feelings, and moods. Specifying them based on previous research would be helpful to proceed with the discussion here. *Emotions* generally refer to the physiological response of the brain and body, whereas *feelings* are the mental representation of that response (Damasio, 2001). Feelings are known to follow emotions evolutionarily and experientially. While emotions represent an autonomic adaptive response that prepares organisms to respond to threats and opportunities, feelings represent the conscious perception and interpretation of that bodily response. (Damasio, 1994). Emotions have a salient cause, occur and diminish quickly and thus, are relatively intense and clear cognitive contents (e.g., anger or fear). In contrast, *moods* are less intense, more diffuse, and more enduring and thus, unclear to the person experiencing them (e.g., just like feeling good or feeling bad) (Bodenhausen, Sheppard, & Kramer, 1994; Forgas, 1995). Although moods are more subtle, they often exert a more enduring effect on behavior (Forgas, 2002).

Affect is sometimes referred to as a “faint whisper” of emotions (Slovic, Finucane, Peters, & MacGregor, 2004) or as something weaker than emotions. However, affect is often used as a generic label including any other related terms (Forgas, 1995; Hudlicka, 2003; Mayer, 1986). Based on this notion, for the present dissertation, affect or affective states will widely embrace reactions with straightforward oppositional values, such as like and dislike, boredom and excitement, or approach and avoid; basic emotions such as happiness, sadness, anger, and fear; complex emotions such as shame, guilt, and jealousy; even some moods and other dynamic affective states such as fatigue, stress, and confusion. Here, the focus is always on affective states, which can be dynamically changeable depending on situations, rather than unchangeable personality traits or long-term moods. In the current dissertation, ‘affect’ is used as the most inclusive term as compared to other terms. Where appropriate, the traditional usage of terms in the specific research domain is followed.

Sometimes, emotions can be categorized as background emotions, basic emotions (e.g., Ekman’s emotion set, 1992), and social emotions (Damasio, 1999). Also, depending on the relation between the source of the affect and the task requiring a response, integral affect (related to the task) and incidental affect (not related to the task) are differentiated (Bodenhausen, 1993). This distinction between integral and incidental affect is also important in driving contexts (Jeon & Walker, 2011a). One of the most common approaches to understanding the experience of emotions is the circumplex model, in which emotions are arranged in a circle around the intersections of two core dimensions of affect (Russell, 1980). The circumplex model maps emotions according to their *valence*, indicating how negative or positive they are, and their *activation*, indicating how arousing they are. This model has been useful as a basic taxonomy, or classification system of mood states (Barrett, Mesquita, Ochsner, & Gross, 2007). However, empirical research has shown the importance and reasons researchers need to go beyond the simple valence and arousal dimensions to administer more accurate affect research (e.g., Jeon, Yim, & Walker, 2011).

Relations between Affect and Cognition

Traditionally, psychological sciences have suggested various theories on the relations among emotion, physiological arousal, and cognition (e.g., the James-Lange theory (James, 1884), the Cannon-Bard theory (Cannon, 1927), and the Two-Factor theory (Schacter & Singer, 1962)). One of the unresolved issues is whether affective processes should be considered as a part of the cognitive representational system or as an entirely separate mental faculty (Fiedler, 1988; Hilgard, 1980; Salovey & Mayer, 1990). Zajonc (1984) showed with empirical findings that affect can be aroused without the participation of cognitive processes and thus, can function independently. Other theorists also underlined the possibility that affect is external to, and may independently inform, cognitive outcomes (Clore, Schwarz, & Conway, 1994; Niedenthal, 1990; Schwarz & Clore, 1988; Strack, Martin, & Stepper, 1988). Therefore, regardless of the order between them, it is important to assume that cognition and affect are distinct and dynamically interact with each other (Forgas, 1995).

Affect has enormous effects on cognition ranging from selective influences on each stage of information processing to overall influences on information processing style, such as the relative weight given to top-down and bottom-up processing (Lee, 2006). For example, affect influences the perception and organization of memory (Bower, 1981); categorization and preference (Zajonc, 1984); goal generation, evaluation, and decision-making (Damasio, 1994); strategic planning (Ledoux, 1992); focus and attention (Derryberry & Tucker, 1992); motivation and performance (Colquitt, LePine, & Noe, 2000); intention (Frijda, 1986); communication (Birdwhistle, 1970; Ekman & Friesen, 1975; Chovil, 1991); and learning (Goleman, 1995). For a recent review of influences of affect on higher level cognition such as interpretation, judgment, decision making, and reasoning, see Blanchette and Richards (2010).

Approach and Scope

Understanding of the relationship between affect and cognition is crucial to a complete understanding of human behavior in complex, dynamic environments such as driving or aviation. Full examination of the relationship between affect and cognition is beyond the scope of the present dissertation. Hence, I focus on the relationship between affect and the selected cognitive constructs that appeared in the previous section as important sub-components in situation awareness model: attention and perception, interpretation, judgment, and decision making. The attention section largely includes contents related to perception and overall processing, which share similar mechanisms with attention. Judgment literature intrinsically overlaps with a considerable amount of memory and decision making literature. Thus, in each section, I try to introduce more mechanisms to explain multifarious affective effects, and remove overlapped components.

This approach is expected to begin to bridge the considerable gap between traditional affect research and the situation awareness model in driving research. This chapter will provide sufficient evidence that affect is a vital element of driver situation awareness and needs to be integrated in a generic driving behavior model and research program.

Affective Effects on Attention and Perception

Definition

Attention is the means by which we actively process a limited amount of perception, thought, and behavior from the enormous amount of information available through our senses, our stored memories, and our other cognitive processes (De Weerd, 2003; Rao, 2003). Attention is generally acknowledged to depend on inhibitory control with respect to limited resource or capacity (Hasher, Lustig, & Zacks, 2007; Shiffrin, 1988). Because attention, perception, and processing styles have been intertwined in affect literature, they are treated with together in this section.

Empirical Effects of Affect on Attention and Perception

With respect to the relations between affect and attention and perception, there have been numerous studies that show positive moods promote a greater focus on global processing and negative moods promote a greater focus on local processing. For example, negative states, particularly in high arousal (e.g., anxiety, fear) narrowed the scope of attention (Easterbrook, 1959). On the other hand, positive states (e.g., elation, mania) showed the complementary effect of broadening the scope of attention (Derryberry &

Tucker, 1994). Evidence originally stemming from clinical research on manic cognition showed that manic people such as creative artists use over-inclusive categories (Andreason & Powers, 1975; Richards & Kinney, 1990). Studies with nonclinical positive states have also used global-local visual processing paradigms to evaluate biases in attentional focus (Basso, Schefft, Ris, & Dember, 1996; Derryberry & Reed, 1998; Fredrickson & Branigan, 2005; Gasper & Clore, 2002). To illustrate, Gasper and Clore (2002) employed two image-based tasks to test the hypothesis. Their first experiment showed that individuals in sad moods were less likely to use an accessible global concept to guide attempts to reproduce a drawing from memory than those in happy moods. The second experiment also showed that people in sad moods were less likely to classify figures on the basis of global features than those in happy moods.

Research also demonstrated that performance on attention-demanding tasks improved when participants were in a positive mood (Derryberry & Tucker, 1994; Olivers & Nieuwenhuis, 2006). For example, positive emotion films (amusement and contentment) increased participants' thought-action repertoires by increasing their urges to be active and outdoors (Fredrickson & Branigan, 2005). In contrast, negative emotion films (anger and anxiety) shrunk participants' thought-action repertoires by decreasing their urges to consume, contemplate, and work. Moreover, during positive mood, individuals with the greatest breadth in semantic access (i.e., indexed by number of remote associates accessed) showed the most pronounced visuospatial attentional breadth (i.e., indexed by increased flanker incompatibility effect, (Rowe, Hirsh, & Anderson, 2007). The result of this altered capacity for attentional selection engenders a broad exploratory processing mode rather than narrow a vigilant processing mode. This reflects a relaxation of inhibitory control, and thereby reduces the tendency to narrowly focus attention across disparate information domains. Similarly, researchers found that experimentally manipulated failure feedback produced a local bias, whereas success feedback produced a global bias (Brandt, Derryberry, & Reed, 1992), cited in (Derryberry & Tucker, 1994).

Mechanisms

Many theorists have suggested that positive affect leads to reduced cognitive processing. This *capacity explanation* assumes that happy moods activate a larger network of associations than sad moods, thereby reducing the resources available for effortful processing (Mackie & Worth, 1989; Worth & Mackie, 1987). On the other hand, a *motivational explanation* assumes that participants avoid expending effort on tasks that are not enjoyable in order to maintain their current happy state (Isen, 1987; Wegener, Petty, & Smith, 1995). An alternative explanation is that the information provided by positive affect may signal that one's goal has already been achieved (Martin, Ward, Achee, & Wyer, 1993) or that further processing is unnecessary (Clore et al., 1994). However, in (Gasper & Clore, 2002), there was no evidence that sadness elicited more extensive processing than the positive affect did. In fact, participants in sadder moods did not show superior recall of the picture, produce more complex drawings, nor demonstrate better overall performance than those in happier moods. Also, these reduced processing interpretations cannot explain why participants with a positive emotion generated more action urges in thought-action repertories than those in a negative emotion (Fredrickson & Branigan, 2005).

The *affect-as-information approach* can provide an alternative explanation (Schwarz & Clore, 1983, 1988, 1996) in which affective feelings are considered as consciously accessible information from ongoing, non-conscious appraisals. Recently, this approach also proposed the *levels-of-focus hypothesis* which states that in task situations, cues from happy and sad moods may be experienced as information that promotes attention to global and local information (Clore & Gasper, 2000; Clore et al., 2001; Wyer, Clore, & Isbell, 1999). However, differences between positive and neutral states in global processing are not accounted for by this affect-as-information approach because people generally tend to be in positive moods and a global bias is considered normative.

The *broaden-and-build theory* may be an alternative mechanism (Fredrickson, 1998, 2001), which predicts that the cognitive consequences of positive states are distinct from those evident in neutral states. According to the broaden-and-build theory, (1) positive emotions may broaden the scopes of attention, cognition, and action, widening the array of percepts, thoughts, and actions and (2) people can build a variety of personal resources from positive emotional states including physical, social, intellectual, and psychological resources. However, for the mechanism of the build hypothesis, more research is needed for longitudinal, empirical evidence.

In conclusion, positive affect may not decrease effort or primary task engagement. When it comes to a definition at the outset, it seems that the easing of inhibitory control alters the quality of attention, resulting in a shift from a narrow focused state to a broader and more diffuse attentional focus. Positive states, by loosening the reins on inhibitory control, may result in a fundamental change in the breadth of attentional allocation to both external visual and internal representational spaces (Rowe et al., 2007). Nevertheless, there has not been an underlying mechanism beyond those conceptual discussions, such as the neurological underpinnings of those effects.

Plausible Specific Effects

The positive effects of positive moods on attention-demanding tasks do not always work in the same way. Jefferies, Smilek, Eich, and Enns (2008) investigated the relationship between visual attention and the self-reported mood of participants using two axes: valence (negative vs. positive) and arousal (low vs. high). The results were complex: Sadness (low arousal with negative affect) produced the highest levels of performance, and anxiety (high arousal with negative affect) led to the lowest levels of performance. Calm and happy states (low and high arousal combined with positive affect) were associated with intermediate performance. Therefore, it is difficult to conclude that a positive mood yields better performance.

This finding of a valence-arousal interaction highlights the possibility that the control of attention may not directly be linked to the core emotional dimensions of valence and arousal. Researchers may need to specify connections between attention and each emotional state, going beyond valence-arousal dimensions. Various studies have shown more specified effects. For example, anger may facilitate attentional circuits best suited for combat (Blanchard & Blanchard, 1988), fear may enable circuits best suited for evaluating danger and flight (Lang, Davis, & Ohman, 2000), disgust may be linked to circuits involved in expelling harmful bodily substances (Berridge, 2003), and joy and surprise may be linked to processing information in a global and fluent manner (Fredrickson, 2003).

Potential Influences on Driving Performance and Safety

Attention is inevitably important in driving because driver inattention is one of the major factors in traffic accidents. The US National Highway Traffic Safety Administration (2006) estimated that driver inattention within three seconds occurred before 80% of crashes and 65% of near-crashes. Further, Rowe and colleagues (2007) demonstrated that positive mood positively influenced not only visual attention but also semantic access. Based on this finding, one may assume that a driver in a positive mood can integrate all of the diverse information effectively and does not focus on a particular element, which seems to be a desirable state in such a complex environment. Conversely, others may argue that a driver in a positive mood can be more easily distracted by various environmental elements. In the same line, a driver in a negative mood may be expected to drive better with a more narrow attention focused on driving than a driver in a positive mood. Those contradictory arguments need to be resolved with a variety of empirical studies with specified affective states.

Affective Effects on Interpretation

Definition

Interpretation can be usually defined as an assignment of meanings to symbols or object (Sternberg & Sternberg, 2009). Regarding the topic of the present dissertation, interpretation can be best defined as the resolution of ambiguous information (Blanchette & Richards, 2010).

Empirical Effects of Affect on Interpretation

Because the ability to correctly interpret ambiguous signs that could predict harm is obviously crucial for adaptive functioning, much research on interpretation has focused on threat and anxiety (Blanchette & Richards, 2010). In an early study (Butler & Mathews, 1983) self-reported anxious people made more negative interpretations of threat/neutral ambiguous scenarios and saw themselves as being at greater risk than other people. They also perceived that the negative event would occur for them more frequently than for another person. Similarly, socially anxious individuals generated more negative interpretations of ambiguous social scenarios in comparison with control and other anxiety-disordered individuals (e.g., Amir, Beard, & Bower, 2005; Huppert, Pasupuleti, Foa, & Mathews, 2007).

Much research has been examined on affective effects on interpretation with respect to verbal and facial ambiguity. For verbal ambiguity, robust findings have been attained using a homophone-spelling task (e.g., brews/bruise) where a series of threat/neutral homophones together with filler words are auditorily presented ostensibly as a standard spelling test. Both high-trait anxious (Byrne & Eysenck, 1993; Eysenck, MacLeod, & Mathews, 1987; Hadwin, Frost, French, & Richards, 1997) and clinically anxious (Mathews, Richards, & Eysenck, 1989) participants yielded more threat-related spellings than the control participants. Likewise, mood-congruent interpretive bias has been shown in a recognition paradigm for ambiguous sentences (Eysenck, Mogg, May, Richards, & Mathews, 1991), reading times for different interpretations (Calvo, Eysenck, & Castillo, 1997; MacLeod & Cohen, 1993), and naming ambiguous targets (Calvo et al., 1997).

For facial ambiguity, researchers created ambiguous facial expressions by morphing two emotions together in varying proportions along a continuum (e.g., Young, Rowland, Calder, & Etcoff, 1997). For example, Sprengelmeyer et al. (1997) found that clinically anxious participants identified fear and anger better and showed a tendency for sadness compared to control participants. In a similar vein, non-clinical, high anxious participants were more sensitive to fear than the low anxious participants (Richards et al., 2002). Overall, the typical finding across all of the different methods is that anxious individuals resolve the ambiguity in line with the more threatening interpretation in comparison with control participants.

Mechanisms

An important question in understanding how anxiety influences interpretation is when exactly emotion has an impact on ambiguity resolution (Blanchette & Richards, 2010). In other words, researchers asked whether anxiety influences interpretive process or merely influences the response that participants choose to report. To examine this, Richards and French (as cited in Blanchette & Richards, 2010, p. 566) used a lexical decision task, controlling for a response bias effect. High-anxious participants and low-anxious participants saw threat/neutral homograph primes followed by targets that were related or unrelated, and threatening or neutral associates of the targets. Across participants, a threat-related associate for one participant was a threat-unrelated associate for another. Therefore, any observed priming effect must have been due to the facilitatory effect of the prime rather than any response bias, which would facilitate processing of unrelated threat associates. The researchers found evidence for a threat-related priming effect in anxiety and this could not be accounted for by a response-bias explanation. This is also shown in (Mathews et al., 1989), which adopted skin conductance responses for the homophone-spelling test. Results showed that there was no evidence for a response bias. Therefore, it seems that anxiety is genuinely affecting interpretation, not simply response selection. Additionally, subsequent studies using ambiguous target information with primes and manipulated Stimulus Onset Asynchrony (SOA) (Richards, French, Johnson, Naparstek, & Williams, 1992) and a Rapid Serial Visual Presentation (RSVP) technique (Calvo et al., 1997) confirmed that anxiety is more likely influencing selection of one meaning rather than initial generation of possible interpretations.

It is interesting that the same cognitive mechanisms have been proposed for attentional and interpretive biases in anxiety. According to them (Mathews & Mackintosh, 1998), selective attention to threat and an interpretive bias for threat are the results of competition between preattentive threat evaluation mechanisms and top-down attentional control mechanisms. Research found that all participants showed an increase in amygdala activity in response to fearful expression when attention was directed to the expressions, but only the high-anxious individuals showed this increased amygdala activity when the fearful expressions were unattended (Bishop, Duncan, & Lawrence, 2004). This increased amygdala activity may be coupled with a decrease in the recruitment of prefrontal control mechanisms. That is, anxiety seems to modulate the balance between preattentive threat-detection mechanisms and top-down control processes.

Plausible Specific Effects

The relation between interpretive bias and anxiety has been shown robust, but for other affective states, the evidence is still not clear. On the one hand, participants induced to feel disgusted may show the same interpretive biases as anxious participants. For example, in a study that manipulated mood and examined the resolution of ambiguity using threat/neutral homophones, participants in the disgust manipulation condition showed comparable negative biases for threat-related interpretation to those observed in anxiety (Davey, Bickerstaffe, & MacDonald, 2006). On the other hand, some early studies (e.g., Butler & Mathews, 1983; Cane & Gotlib, 1985) using self-report methods showed negative interpretive biases in depressed individuals. However, in more recent studies (Bisson & Sears, 2007; Mogg, Bradbury, & Bradley, 2006) where there was minimal opportunity for a response bias to be observed, there was no depression-related interpretive bias. Davey, Menzies, and Gallardo (1997) found that agoraphobia and acrophobia were associated with a tendency to interpret ambiguous bodily sensation as threatening. Individuals with high social anxiety also tend to interpret neutral facial expressions in a threatening manner (Richards et al., 2002; Yoon & Zinbarg, 2008) and have consistently been shown to interpret ambiguous social scenarios in a negative direction (e.g., Amir et al., 2005; Hertel, Mathews, Peterson, & Kintner, 2003; Wenzel, Finstrom, Jordan, & Brndle, 2005).

However, many of these studies on different types of anxiety have relied on self-report measures, and thus, there might be an influence of response bias. More work is needed to investigate the effects of other affective states on interpretation, such as anger or positive emotions.

Potential Influences on Driving Performance and Safety

Anxiety is one of the most prevalent affective states during crisis situations and its affective influences on cognition have been extensively studied (Hudlicka & McNeese, 2002). We can look at overall anxiety-effects on attention and interpretation regarding driving contexts. As discussed in attention and perception section, the generic effects of anxiety on attention encompass a narrowing of attentional focus, difficulty focusing attention, and increased attention to threatening stimuli (Mineka & Sutton, 1992;

Williams, Watts, MacLeod, & Mathews, 1997). This narrowing of attention may also lead to neglect of other critical tasks, and a failure to detect other related cues. Also, anxiety predisposes one towards interpretation of ambiguous stimuli as threatening (Williams et al., 1997). Based on these principles, Hudlicka and McNeese (2002) identified plausible influences of the anxious state on pilot behavior: anxiety-induced narrowing of attention (e.g., focusing on signals representing unknowns or threats) and anxiety-induced perceptual bias (e.g., misinterpreting ambiguous radar returns as threats). Likewise, in driving situations, an anxious driver (e.g., a novice driver) is likely to focus only on the part, instead of the entire task and neglect other crucial parts. Moreover, the anxious individual may interpret ambiguous stimuli (i.e., other cars around) as more threatening and feel more stress.

Affective Effects on Judgment

Definition

Judgment is a process by which people cope with the ambiguity inherent in estimating the future events (Blanchette & Richards, 2010). Thus, the outcome of this process, the estimate, is a key component of decision making.

Empirical Effects of Affect on Judgment

Considerable research has examined whether affect influences risk perception or how people estimate the likelihood of future negative events. In one of the classic risk perception studies (Johnson & Tversky, 1983), participants were asked to read positive or negative news clips about different forms of death. The news clips had anecdotal information about death but did not include the probability of its occurrence. When participants evaluated the likelihood of death resulting from a variety of causes, those who received the negative-mood induction showed increased risk estimates for all causes of death than those who received the positive-mood induction. This increase was independent of semantic distance of the topics between the mood induction and judgment. Subsequent studies (Constans & Mathews, 1993; Mayer, Gascke, Braverman, & Evans, 1992) measured participants' estimates of likelihood for future events based on induced moods. They generally showed the mood-congruent effects in judgment: participants in positive moods estimated positive events as more likely than participants in negative moods and vice versa. However, the mood-congruent effects do not always occur in every situation as shown in the following paragraph.

Forgas (1995) in his Affect Infusion Model (AIM), identified relations between four judgmental strategies and the degree of affect infusion into judgments. According to AIM, affect is unlikely to influence judgments in a mood-congruent direction during the first two *reconstructive* strategies: *direct access processing* and *motivated processing*. Direct access processing is used when the target is either highly familiar or typical, a relevant past judgment can be directly accessed in memory, and there is little internal or external demand for reprocessing. For example, affect had little impact on judgments about familiar consumer products, but had more impact on judgments about highly unfamiliar items, showing the well-known mood-congruent effects (Srull, 1984).

Similarly, when highly targeted motivated processing is used, the mood-congruent effects are not likely to occur. Because people are active mood regulators (Erber & Erber, 1994), sometimes they intentionally control negativity in judgments as a result of relevant social norms and values (Brown, 1965), thereby research often yields the mood-*incongruent* results (Sedikides, 1994).

In contrast, affect is likely to influence judgments in a mood-congruent direction during the other two *constructive* strategies: *heuristic processing* and *substantive processing*. Heuristic processing is used when the target is simple or highly typical, the personal relevance of the judgment is low, there are no specific motivational objectives, the judge has limited cognitive capacity, and the situation does not demand accuracy or detailed consideration. In terms of lack of adequate processing resources (e.g., time and cognitive resources), heuristic processing seems to frequently occur in driving situations and thus, the mood-congruent effects are likely to occur. The AIM predicts that affect infusion directly influences heuristic processing through the affect-as-information mechanism. A number of studies showed significant mood-congruent effects in heuristic judgment strategies, such as consumer goods (Isen, 1984), other people (Clore & Byrne, 1974), and social issues (Forgas & Bower, 1987).

Likewise, when substantive processing is used, the mood-congruent effects are likely to occur through its selective impact on the information used in computing a judgment (Bower, 1991; Forgas, 1992). Substantive processing is used when the target is complex or atypical; the judge has no specific motivation, has adequate cognitive capacity, and is motivated to be accurate. In substantive processing, the judge is required to select, learn, and interpret novel information about a target and relate this information to preexisting knowledge structures. Various social judgments (e.g., job applicant judgment (Baron, 1987), health-related judgment (Croyle & Uretsky, 1987)) reliably demonstrated the mood-congruent effects in the substantive processing strategy. If a driver is an inexperienced driver or drives an unfamiliar route, substantive processing may occur and entail the mood-congruent effects.

Mechanisms

There are a couple of hypothetical mechanisms to explain the affective effects on judgment. The *availability heuristic* (Tversky & Kahneman, 1973, 1974) denotes the process by which participants form estimates of likelihood based on how easily they can retrieve instances from memory. MacLeod and Campbell (1992) validated the availability heuristic, showing that the magnitude of observed changes in judgment can be statistically determined by the magnitude of observed changes in memory accessibility. In their experiment, they found that their mood induction facilitated memory accessibility for events that were emotionally congruent with the induced mood. They also reported a negative correlation between recall latency for past events and the perceived future probability of similar events.

Similar to the availability heuristic, the *affect-priming model* also suggests that affect can *indirectly* inform judgments by facilitating access to related cognitive categories (Bower, 1981; Forgas, 1995, 2006; Isen, 1987). A number of studies supported this hypothesis based on mood-congruent memory facilitation (Derry & Kuiper, 1981; Greenberg & Beck, 1989). If temporary (incidental) affective states prime mood-congruent exemplars and make those exemplars more accessible, this leads to inflated estimates of likelihood. Also, it does not necessarily depend on actual probability. The affect-priming model can predict various cognitive results based on activations derived from an affective node: (1) selective attention: Mood-congruent details tend to receive greater attention than do mood-incongruent ones due to the selective activation of a mood-related association (Bower, 1981). (2) selective encoding: People will spend more time reading and encoding affect-congruent details into a richer network of primed associations and use basis of judgment (Bower, 1981; Forgas & Bower, 1987). (3) selective retrieval: Affectively congruent information has a greater likelihood of being retrieved than do other details (Bower, 1991). (4) associations and interpretations: Affect can prime the associations elicited by a stimulus and thus, influence its subsequent top-down, constructive interpretation (Bower, 1981, 1991). Forgas (1995) pointed out that the affect-priming model works better on constructive, substantive tasks such as social judgments rather than mere information retrieval. However, this model is notoriously difficult to falsify compared to the affect-as-information model in which only unattributed moods may have judgmental consequences.

The affect-as-information hypothesis also accounts for the mood-congruent judgment. Clore and Huntsinger (2007) proposed that participants use the information delivered by affective states strategically during the judgment process. As described in the AIM, a *direct* link between affect and evaluative judgment has been emphasized (Forgas, 1995). In some sense, this also relates somewhat to research on judgmental heuristics because affect functions as a judgment-simplifying heuristic device as participants consult their mood to infer a judgment (Schwarz & Clore, 1988). However, the affect-as-information model shows limited effects depending on the circumstances. For example, in a study, the mood influenced *global* judgments about overall life satisfaction (i.e., *heuristic processing*), but had no effect on judgments about *specific* life domains (i.e., *direct access processing*) (Schwarz, Strack, Kommer, & Wagner, 1987). Presumably, this is because in the domain-specific case, prior evaluations were more *directly* accessed. When it comes to memory, the affect-as-information model shows another issue. The affect-as-information model predicts mood effects at the retrieval stage only, whereas memory-based models can account for encoding, learning, and attention effects (Forgas & Bower, 1987). Therefore, the affect-as-information model alone cannot explain every case. Rather, it seems to predict the mood-congruent effects in quick, simple, and heuristic judgment.

Plausible Specific Effects

Although Johnson and Tversky (1983) showed general affective effects on risk perception (e.g., negative affect increases estimates of likelihood for negative events), generalization of the effects needs to be cautious. For example, students with increased anxiety for a statistics exam showed an increase in risk perception for the exam but not for other tasks (Constans, 2001). Even within the same valence, different affective states specifically influence judgments. A study found that happy participants made faster lexical decisions to happiness-related words but not to other positive words (Niedenthal & Setterlund, 1994). Research also found that fear increased risk estimates, but anger reduced risk estimates (Keltner, Ellsworth, & Edwards, 1993; Lerner & Keltner, 2000). It can be accounted for based on different cognitive appraisal mechanisms. Whereas anger is related to certainty and individual control, fear is related to uncertainty and situational control. Likewise, previous research indicates that sadness and anger influence causal attribution in highly distinct ways (Bodenhausen, 1994). This is also because sadness is characterized by attributions of situational control in the cognitive appraisal dimension, whereas anger is characterized by attributions of individual control.

Potential Influences on Driving Performance and Safety

Driving tasks inherently require a driver to make a judgment and decision. Consider the situation where one is late for an appointment and a traffic signal changes to yellow when his or her car approaches the intersection, or where one is in the leftmost lane and needs to make the next turn left, but there is no break in the oncoming traffic flow. Even a simple lane change in a heavy traffic situation requires multiple judgment calls. If a driver errs in judgment, successive decision making and action can tremendously be influenced, thereby leading to an accident.

Traditionally, researchers have believed that a happy driver is a better driver (Eyben et al., 2010; Grimm et al., 2007; Jones & Jonsson, 2005). However, from the perspective of the affect-priming model, this may not be necessarily true. A driver in a happy state is likely to think that happy events will occur and thus, can easily loosen up and be relieved. On the contrary, a driver in an unhappy state is likely to think that unhappy events may occur and thus, can drive more defensively. This plausibility can be called a typical '*sadder but wiser phenomenon*' (Alloy & Abramson, 1979). Moreover, according to the availability heuristic, an individual may not speed up on the same road where he or she has received a speeding ticket even though he or she is late for the meeting. There does not seem to be an overarching mechanism for relations between affect and judgment. It may depend on each situation and should be validated with empirical research.

Affective Effects on Decision Making

Definition

While research on judgment examines how people estimate and evaluate the likelihood of different outcomes, research on decision making investigates how people actually select among different options (Blanchette & Richards, 2010). However, because studies on judgment and decision making are intermingled with each other, a clear distinction in literature may not be easy. Just as in judgment, the key in decision making has also been to identify whether affective states have an impact on the tendency towards risk and a considerable amount of studies have supported this notion. Therefore, regarding decision making research, I concentrate more on specific affective effects that go beyond the mood-congruent effects and effects of integral affect on decision making that have not been covered in the judgment section.

Plausible Specific Effects on Decision Making

As is the case in judgment, most research on affective influences on decision making has depended on comparison of different valences (i.e., positive and negative) (Arkes, Herren, & Isen, 1988; Conway & Giannopoulos, 1993; Isen & Geva, 1987; Wright & Bower, 1992). However, research has shown that the information conveyed by affective states may not be fully explained by a sheer positive and negative dimension. For instance, Gallagher and Clore (1985) asked angry and fearful participants to make judgments about whether a person deserved to be blamed and about the likelihood of negative life events. Whereas angry participants reported higher assessments of blame and lower assessment of risk, fearful participants reported the reverse. In a conceptually similar study, Raghunathan and Pham (1999), conducted three experiments using gambling decisions (Experiments 1 and 3) and job options (Experiment 2). Results consistently showed that sad individuals were biased in favor of high risk/high-reward options, whereas anxious individuals were biased in favor of low-risk/low-reward options. Anxiety has generally shown robust risk-averse effects. This effect has been shown even for induced anxiety as well as trait anxiety (Vastfjall, Peters, & Slovic, 2008). Similarly, positive moods also led to a risk aversion. In an experiment with a roulette game, participants in a positive mood were more risk averse than participants in a control group (Isen & Geva, 1987). Interestingly, participants in a positive mood might be risk seeking in low-risk situations, whereas they became more risk averse than the control group as the risk level increased (Isen, Nygren, & Ashby, 1988). Unlike the plausible prediction based on the valence dimension, while anxiety and positive states increased risk aversion, sadness increased risk seeking.

Mechanisms

Several explanations that were examined in the judgment section may not fully account for those specific effects on decision making. First, the mood-congruent effects cannot explain specific affective effects on decision making. Even though both angry and fearful or anxious and sad participants were in a negative mood, each condition yielded different outcomes. For instance, if anxious participants perceive negative events as being more likely to happen, this should increase risk aversion and this is consistent with the empirical result. In contrast, if participants in positive moods perceive positive events as being more likely, this should increase risk taking, which is the opposite of the empirical result. For the similar reason, reduced processing capacity by anxiety and sadness (e.g., Conway & Giannopoulos, 1993; Eysenck, 1982) cannot explain those specific effects. Also, difference in arousal does not provide an adequate explanation. Anxiety is generally associated with high arousal, whereas sadness is associated with low arousal (Russell, 1980). Although high arousal should increase risk seeking (Mano, 1994), anxious participants were more risk averse than sad participants (Raghunathan & Pham, 1999).

The effects of positive moods on decision making (i.e., risk aversion) also seem to be related to the *perceived utility* (Blanchette & Richards, 2010). According to the perceived utility, decision making is based not only on estimates of the likelihood that something will happen, but also on estimates of the value of that outcome. For example, although the likelihood that a fatal car accident will occur may be relatively low, the consequences of this happening are so high that it is worth wearing a seatbelt. According to Isen et al. (1988), positive moods might influence the perceived utility of negative outcomes. In other words, happy participants might perceive losses even more negatively than control participants.

The mood-repair hypothesis (Schaller & Cialdini, 1990; Zillmann, 1988) may provide a relatively consistent explanation to those phenomena. Participants in each negative condition may have favored one option because it would make them answer the question "What would I feel better about…?" This is also associated with the affect-as-information theory I already discussed. More specifically, this pattern can be related to the cognitive appraisal mechanism again. It may be because anxiety and sadness convey distinct types of information to the decision-maker and prime different goals. For instance, anxiety primes an implicit goal of uncertainty reduction, whereas sadness primes an implicit goal of reward replacement. In conclusion, research on affect and decision making shows that specific affect has distinct effects on risk taking and risk aversion.

Effects of Integral Affect on Decision Making (Somatic Markers)

Research on attention, judgment, and decision making has focused on *incidental* affect which is mostly an induced one and not related to the contents or tasks of those cognitive processes. On the other hand, there has been extensive research regarding effects of *integral* affect on decision making, called *somatic markers*. Damasio (1994) proposed the somatic marker theory, which posits that most self-regulatory actions and decisions are affected by bodily reactions called somatic markers. When one contemplates an action, one can experience an emotional reaction based partly on one's expectation of the action's outcome, an expectation influenced by one's history of performing either that action or similar actions. For example, if in the past driving fast has led to speeding tickets, which makes drivers feel bad, in the future, they may be more likely to choose to slow down when they see a speed limit sign.

In somatic markers research, investigators often use the Iowa gambling task (Damasio, 1994), a decision making task where participants have to choose from different decks of cards, which include immediate (large or small) rewards and unpredictable (large or small) losses. In general, participants quickly learn to avoid the risky decks that result in a total loss due to unpredictable bigger losses. Their strategy is reflected in skin conductance responses (SCRs), showing that participants produce SCRs when the outcome turns out a loss. Moreover, participants also develop anticipatory SCRs. In other words, SCRs occur before the loss is revealed, when the risky option is being considered. This physiological response occurs before participants can verbalize an explicit appreciation of the likelihood of winning for each of the decks. In subsequent research (Bechara, 2004; Bechara, Damasio, & Damasio, 2000), Damasio and his colleagues found that people with damage to the frontal lobes (ventromedial prefrontal cortex (VMPFC)) tend not to use past outcomes to regulate future behaviors. In a study using the same gambling task (Bechara et al., 2000), patients who had damage to their frontal lobes continued to follow a risky strategy and typically did not develop anticipatory SCRs: They selected a card from a stack that gave bigger rewards, but led to a total loss. Therefore, Damasio and his colleagues hypothesized that peripheral physiological reactions are used in the decision making process and help individuals to avoid risky options by evoking a negative feeling at the time these options are considered. There has also been some criticism of somatic markers, such as the interpretation of the physiological data (Tomb, Hauser, Deldin, & Caramazza, 2002) or the extent of independence of physiological responses from explicit knowledge (Maia & McClelland, 2004).

There is an effective application of the somatic markers to risk perception processing systems. Some researchers have proposed that people apprehend reality and risk by two interactive, parallel processing systems: the analytic system and the experiential system (Epstein, 1994; Slovic et al., 2004). The *analytic system* is a deliberative, analytical system that functions by way of established rules of logic and evidence such as probability calculus. The *experiential system* is intuitive, fast, mostly automatic, and not very accessible to conscious awareness. It depends on images, metaphors, and narratives to which affective feelings have become attached. In this view, rational decision making requires proper integration of both modes of thought. Given that affect is the essence of the experiential system, affect becomes a crucial component to influence risk perception and decision making. This is in line with Norman's (1993) experiential and reactive cognition. According to him, experiential cognition is associated with reactive behaviors with expertise and skills, whereas reflective cognition is slow and planned, reconsidered behaviors.

Under those models, affect sometimes comes prior to, and directs, cognitive processes, much as Zajonc (1984) suggested. With respect to the presence of two separate systems, I can find some plausible neural mechanisms. The evolutionarily older part of the brain, such as brainstem and cerebellum and a newer part, cerebral cortex are separated by the *limbic system*. The brain structures in the limbic system are especially important for controlling basic motivations, such as eating and drinking, and emotions (Gazzaniga et al., 2010). Of the limbic system, the *amygdala* has an important role in emotion-related processing. Information reaches the amygdala along two separate pathways. The first path is a "quick and dirty" system that processes sensory information nearly instantaneously. Sensory information travels quickly through the *thalamus* to the amygdala for priority processing. The second pathway is somewhat slower, but it leads to more deliberate and thorough evaluations. Sensory material travels from the thalamus to the *sensory cortex*, where the information is scrutinized in greater depth before it is passed along to the amygdala. In brief, the fast system prepares animals to respond and the slower system confirms the threat. The first path can be seen as a basis of *risk as feelings* in the experiential system. The second path seems to function in the analytic system.

This notion is associated with various cognitive processes including risk perception, judgment, and decision making. One distinction is that this depicts a separate, independent affective process rather than the effects of incidental affect on cognition, which I have described earlier in this chapter.

Potential Influences on Driving Performance and Safety

As discussed, somatic markers may directly account for affective effects on decision making in driving environments. A driver's covert memory on bad experience related to speeding tickets may enable the driver to slow down when he or she encounters a police car on the road even though he or she cannot remember the past experience overtly. If one route irritated the driver before, he or she might select a detour even if that alternative route would take more time to get to the destination.

More specifically, pertaining to the two different risk perception systems, Kelly, Kinnear, Thomson, and Stradling (2010) demonstrated that there may also be two distinct ways in which drivers appraise risk. They measured inexperienced and experienced drivers' physiological responses to the development of driving hazards using skin conductance response (SCR). Results showed that experienced drivers produced a significantly greater SCR to developing hazards than inexperienced drivers. Nevertheless, the results of cognitive rating of risk were not significantly different from each other. The difference between cognitive and physiological responses supports the theory that distinguishes between different forms of the risk appraisal system. Also, this result indicates that experts in driving may develop an unconscious affective strategy (i.e., it may be called "somatic markers") to rapidly cope with risk rather than a conscious cognitive strategy (because cognitive ratings of risk were not significantly different). This seems to be deeply related to the automation of experts' behavior. However, there has been a debate on automation of the drivers' behavior. Horswill and McKenna (2004) reviewed studies demonstrating that experienced drivers used more cognitive resources for hazard perception than less experienced drivers, suggesting that hazard perception does not become automated with extensive experienced, but instead remains a controlled process. Lee (2006) discussed plausible effects of affect on automation in more details, but to date, empirical research on the affect and automation topic has been rare. See (Merritt, 2011) for a fairly recent empirical work on affective influences on automation reliance.

Summary and Conclusion

This review is restricted to those studies that have conceptualized diverse mechanisms that can account for the affective effects on each level of situation awareness. Some of them can explain multiple effects, but there seems to be no overarching mechanism that can explain all the cases because phenomena are too diverse. However, based on this review, it becomes clear that a driver's various affective states may influence all levels of situation awareness and driving performance.

Just as in other research, it would be desirable for affect-related driving research to be deeply rooted in generic theories. As described in this chapter, affect researchers have proposed considerable theories and hypotheses to identify the mechanisms of the relations between affect and other psychological constructs. Those can be good theoretical ingredients that affect-related driving research can use and develop further for its own purpose. For example, if happy drivers are the best drivers (as is usually suggested), then the broaden-and-bulid theory can serve as a good mechanism to explain this trend. If different affective states have different effects on driving performance and safety even though they belong to the same negative valence, the cognitive appraisal mechanism may give an appropriate explanation. The somatic markers hypothesis can provide a proper account for affect induced from the driving tasks (i.e., integral affect). With respect to driver risk perception and automated reactions, the experiential and analytic systems may function as a good taxonomy. By attempting to actively apply existing theories and search for a new theory, this embryonic research field may be able to attain a suitable framework for potentially fruitful new avenues of research. However, these potentials have to be empirically validated. This dissertation tries to identify specific effects of an angry state on driver situation awareness, perceived workload, subjective judgment on general driving behavior, and driving performance compared to a neutral state. Moreover, the current disseration includes a new attemtp to use the concept, situation awareness, as an active way to enhance driving performance by mitigating affective effects (Experiment 2), as well as a passive construct that predicts and accounts for driving performance (Experiments 1 and 2).

CHAPTER 4

MOTIVATIONS FOR THE CURRENT RESEARCH AND RESEARCH QUESTIONS

Recent empirical research (Jeon, Yim, & Walker, 2011; Jeon, Yim, & Walker, unpublished) has shown that different emotions might have different effects on driving even though they belong to the same valence or arousal dimension. In their experiment on a driving simulator, participants with induced angry or happy states showed more degenerated driving performance than those with induced fear or neutral states. Interestingly, these performance differences were not directly reflected on subjective risk perception or perceived workload. This subtlety has motivated researchers to investigate the relations between affect and driving in a more sophisticated way. In the current research, I attempt to examine affective effects on driving in relation to the situation awareness model. This approach is expected to identify the roles and mechanisms of affective effects in a dynamic context in a more systematic way. To test plausible specific effects, I focus on 'anger', one of the most important affective states in driving (e.g., Jeon & Walker, 2011d). Once more knowledge on the roles and mechanisms of the affective effects is accumulated, methods on how to mitigate the affective effects on driving performance and safety could be determined. In fact, there have been a few studies (Harris, 2011; Harris & Nass, 2011) that attempt to regulate drivers' affective states using various emotion regulation techniques such as cognitive reappraisal and suppression strategies. However, there has been no research to investigate the possibility of the *attention deployment* (Gross, 2002) strategy. Moreover, there has been some research on offline situation awareness training (e.g., Moertl, Canning, Gronlund, Dougherty, Johansson, & Mills, 2002; O'Brien & O'Hare, 2007), but there has been no research on the use of online (real-time) situation awareness prompts for the improvement of operator situation awareness. This possibility was explored by integrating situation awareness prompts into the attention deployment strategy in order to mitigate the impact of affect on driving performance and safety in addition to the use of emotion regulation prompts.

Research Questions

In this dissertation, I try to attain a deeper understanding of the effects of affective states on driver situation awareness and adaptive mitigation interfaces. More specifically, I am interested in the following two research questions:

1) What are the specific effects of an angry state on driver situation awareness and driving performance? (Experiment 1)
2) How do adaptive speech-based systems based on the attention deployment strategy effectively mitigate the impact of an angry state on driver situation awareness and driving performance? (Experiment 2)

In addition to these research questions, I pose the question of whether subjective workload or risk perception is independent of a driver's affective states and situation awareness. It is also of interest whether an induced angry level will become lower in the two types of speech-based system conditions compared to the no intervention condition. Further, I hope to contribute to designing optimal speech-based affect mitigation interfaces in terms of the message style (i.e., suggestive/ notification style vs.

directive/command style) (Lee, Gore, & Campbell, 1999) and users' assessment about system politeness (Nass, 2004) and other characteristics.

To answer these research questions, two empirical experiments were conducted. In Experiment 1, young drivers (college students) drove in a simulator after affect induction to examine whether the induced angry state influences driver situation awareness and driving performance as well as perceived workload and subjective judgment regarding their general driving. Half of the participants drove the same route with the induced neutral state. In addition to collecting various driving performance variables, the data on situation awareness were collected during driving (implicit performance) and in the end of the session (offline questionnaire) (Durso et al., 1999). In Experiment 2, young drivers drove in a simulator after anger induction with either of two types of speech-based systems or with no such system to see whether speech-based systems can increase driver situation awareness and driving performance compared to the no intervention condition. Additionally, all of these data were compared to a neutral state without such a speech-based system as a baseline. Details on methods and results for each experiment are included in the following chapters (Chapter 5 and Chapter 6).

CHAPTER 5

EXPERIMENT 1: AFFECTIVE EFFECTS ON DRIVER SITUATION AWARENESS AND PERFORMANCE

This chapter presents an empirical study about effects of an angry state on driver situation awareness and driving performance. This approach is supported by the evidence provided in Chapters 2 and 3. As discussed, affective states have a considerable amount of impact on various cognitive states and these effects should be reflected on each level of the SA model, thereby the overall SA. To this end, I used the offline situation awareness assessment adapted from the SAGAT (Endsley, 1995a, 2000) in addition to implicit performance measure which was defined as the coping level with predicted hazard events. Before the details of Experiment 1, the current chapter outlines some findings on empirical effects of anger on driving performance and its relation with young drivers, followed by situation awareness measurement.

Road Rage and Aggressive Driving

Research has shown that anger negatively influences various driving performance and risky behaviors such as infractions, lane deviations, speed, and collisions (Deffenbacher, Deffenbacher, Lynch, & Richards, 2003; Jeon et al., 2011b; Underwood, Chapman, Wright, & Crundall, 1999). One of the undeniable examples of angry effects on driving performance and safety is road rage and aggressive driving (Galovski & Blanchard, 2004). Road rage has become one of the nation’s top three highway threats, along with drunk driving and failure to use a seat belt (Bowles & Overberg, 1998).

According to research by the American Automobile Association (AAA), aggressive drivers are even more threatening to motorists than drunk drivers: 40% of respondents reported that aggressive drivers endanger traffic safety the most (Joint, 1995; Mizell, Joint, & Connell, 1997).

In its broadest sense, road rage can refer to any display of aggression by a driver (Joint, 1995). However, given that road rage involves a large range of behaviors, from mild forms such as yelling or honking to extreme forms such as physical attacks or cutting off other drivers, there remain inconsistencies regarding an accurate definition of road rage and its frequency (Burns & Katovich, 2003). For example, in one research, 56% of respondents admitted to driving aggressively at least part of the time (Young, 1998). In the same year, another study showed that only 6% of respondents admitted to engaging in such aggressive behavior (Jouzaitis, 1998). However, in that report, 90% of motorists said they encountered road rage over the course of a year. In fact, an average of at least 1,500 people are injured or killed each year in the United States as a result of "aggressive driving" (Mizell et al., 1997). Road rage is extremely influential in driving behavior, and increases the risk of causing an accident (Wells-Parker et al., 2002). Even mild aggressiveness precludes the driver from concentrating on the traffic, increasing the risk of an accident (Deffenbacher, Oetting, & Lynch, 1994).

Generally, there has not been much research on the cause of road rage. One exception to note is the attempt of Burns and Katovich (2003) to reveal the various causes of road rage and aggressive driving through a newspaper analysis from 1985 through 1999. They categorized the causes of road rage into two sections: those related to human behavior or actions and those related to the structure of the environment. Human factors seemed more dominant than environmental factors. While 71.9% (*N* = 368) of the noted causes of road rage found in newspaper articles were related to human factors, 28.1% (*N* = 144) of the causes were related to environmental factors. For example, driver behavior (*N* = 185), specifically related to driving an automobile (e.g., weaving in and out of lanes, tailgating, flashing one's headlights, speeding, bumping another's car, etc) accounted for more than half (50.3%) of the total number of human factors and 36.1% of all noted causes of road rage. On the other hand, aggressive driver actions (*N* = 50) (e.g., obscene gestures, verbal assaults, aiming a weapon, shaking one's head, etc) accounted for 13.6% of all noted human-related causes and 9.8% of all causes of road rage. Other affective causes included time constraints (*N* = 23), tardiness (*N* = 5), frustration (*N* = 10), stress (*N* = 9), pain/discomfort (*N* = 2), and worry (*N* = 1). In light of this analysis, it seems that researchers need to understand when and how these diverse affective states turn into road rage or aggressive driving in order to prevent it. Environmental factors that accounted for road rage included traffic/congestion (*N* = 58), more people driving/people in general (*N* = 12), poor engineering/road design (N = 11), followed by road construction (*N* = 8), weather (*N* = 8), and traffic signals (*N* = 6).

Although the preferred approach to dealing with aggressive drivers largely involves punitive sanctions, researchers have given a skeptical response to the effectiveness of the punitive reactions to control or reform human behavior (Currie, 1985; Kappeler, Blumberg, & Potter, 2000). An alternative *preventative* approach is to detect various drivers' affective states and to provide drivers with affect-regulating aids.

A great amount of research has supported that diverse affective states influence cognitive processes (Chapter 3) and studied the various effects of each specific affect on driving. It has been shown that there are some populations who are especially vulnerable to issues regarding driving, affect, and affect regulation, such as drivers with traumatic brain injury, young or older drivers, and novice drivers (Jeon, Roberts, Raman, Yim, & Walker, 2011). Accordingly, for those populations affect-related driving research becomes more important than for others. Here, I focus on young drivers.

Young Drivers and Aggressive Driving

Research has found that young drivers are overrepresented in crashes involving excessive speeds, curves, alcohol, fatigue, distraction, and passengers (Ferguson, 2003; Williams, 2003). Specifically, young drivers are more likely to engage in distracting activities while driving (e.g., Gras et al., 2007; Lam, 2002; Poysti, Rajalin, & Summala, 2005). To illustrate, up to 58% of young drivers have used text messaging on their cell phone while driving (Tesla, 2004). What makes it worse is the fact that young drivers are more biased to their assessment of their skill level (Holland, 1993; Matthews & Moran, 1986; Sivak, Soler, & Trankle, 1989). Consequently, young drivers overestimate their ability to drive and drive with greater risks of distraction-related crashes (Lam, 2002). Moreover, young drivers (e.g., aged 17 to 30) are more likely to exhibit aggressive driving behaviors compared to older drivers (Mathews et al., 1998). For example, young drivers low in emotional adjustment and high in sensation seeking showed high levels of aggressive driving and speeding in competition with others and consequently, showed poor performance in a simulated driving task (Deery & Fildes, 1999). Such results indicate that young drivers belong to a highly vulnerable group in terms of aggressive driving.

Situation Awareness Measurement

Situation awareness is a complex process that requires assessment by a variety of online (during driving) and offline (post-driving) measures (Gugerty, in press). Endsley (1995a) reviewed methodologies for the measurement of situation awareness in dynamic systems. As discussed above, performance and SA showed positive correlation, but performance measure suffers from diagnosticity and sensitivity. Subjective techniques such as SART (Situation Awareness Rating Technique) (Taylor, 1990) is an alternative way. However, research showed that subjective ratings were not likely to predict correct SA (Durso et al., 1999; Walker et al., 2006). There have been some methodologies using a freeze technique including the SAGAT (Situation Awareness Global Assessment Technique) (Endsley, 1995a, 2000) and the SPAM (Situation-Present Assessment Method) (Durso et al., 1999; Durso et al., 1995). The SAGAT is an online query technique that taps an individual's recent memory of the situation. In the SAGAT, driving information on the display is removed and randomly selected questions are presented to the operator. The more queries correctly answered, the better is the operator's SA. In the SPAM, SAGAT-like queries are given to the operator, but information remains in view and response latency is used as the primary dependent measure. In these freeze techniques, SA queries have been frequently given during the task. Even though these techniques are widely used, frequent queries may not be appropriate for the current study: First, providing queries may disrupt driving and influence the other measures as well. Second, frequent queries may enable drivers to concentrate more on driving behavior and even to memorize contextual information, which is not the case in an actual affective state. The presence of an assessment technique during driving is likely to distract participants from the affective source and lead to deterioration of the meaning of the current experiment. Therefore, in the current experiment, SA was assessed with two types of techniques, one during driving and the other at the end of the driving.

The first SA measure was implicit performance measure (e.g., Durso et al., 1999) which is operationally defined as the coping level with hazard events. Hazard perception has been considered to be situation awareness for dangerous situations in the traffic environment (Horswill & McKenna, 2004). Whereas empirical research has shown counterintuitive results stating that driving skill is not an important discriminatory variable for road safety (e.g., Williams & O'Neill, 1974), only drivers’ hazard perception has been found to correlate with drivers’ accident records. Researchers have widely used filmed traffic situations for a hazard perception test and asked participants to actively respond whenever they detect a traffic hazard, using a lever (e.g., Pelz & Krupat, 1974), button (e.g., McKenna & Crick, 1991), or touch screen (e.g., Hull & Christie, 1992). However, requiring such an active response from participants is different from the natural driving environment and in the current experiment it might distract participants from their affective source. Therefore, I used implicit performance measure instead of obtaining explicit real-time response. The driving scenario has ten events (see Table 2) that require a driver’s special care and each event can be recognizable 3-5 seconds before it happens so participants can predict the event in advance and behave appropriately. If the participants have good situation awareness in that moment, they are expected to cope with the situation in a good manner.

Another measure is an offline questionnaire using an adaptation (see Appendix A, Ma & Kaber, 2007) of the SAGAT. Endsley (1995a) once suggested that this type of post-test questionnaire would reliably capture the subject's SA at the end of the trial. My offline query includes three different parts: (1) questions about the last driving scene, which means SA; (2) questions about the whole driving, which means driving-relevant long-term memory; and (3) driving-irrelevant questions as a basis. The recall-based queries (2) may be biased by participants' subjective recall ability and be arguable. However, in the same paper (Endsley), the empirical results showed that the SA information is obtainable from long-term memory stores if schemata or other mechanisms are used to organize SA information. Thus, the SA information which was clearly processed with respect to driving may be able to remain longer (i.e., deep processing) than other irrelevant information (i.e., shallow processing).

Hypotheses

Hypothesis 1a

Anger will degrade driving performance more than neutral affect.

Hypothesis 1b

Anger will degrade driver situation awareness in terms of both implicit performance and the offline questionnaire.

Hypothesis 1c

Driving performance results will be positively correlated with situation awareness levels.

Hypothesis 1d

Subjective judgment on general driving behavior in the angry state will be different from that in the neutral state: (1) based on the mood congruent effects or affect priming: risk perception in the angry state will be higher than that of the neutral state. (2)

based on the cognitive appraisal mechanism: driving confidence in the angry state will be higher than that of the neutral state.

Hypothesis 1e

Perceived workload of the angry state will not be different from that of the neutral state (based on Jeon et al., 2011a, 2011b).

Method

Participants

Among 35 undergraduate students who registered for the study, five (14%) participants showed symptoms of simulation sickness in the screening test, so they were excused from the remaining experimental procedure. Thus, 30 participants (14 female, 16 male; mean age = 20.9, *SD* = 2.9; 15 anger, mean years of driving = 4.5, *SD* = 1.9; 15 neutral, mean years of driving = 5.2, *SD* = 3.3) completed the experiment for partial credit in psychology courses. They reported normal or corrected-to-normal vision and hearing, and provided informed consent and demographic details about age, gender, and years of driving. All participants were required to have a driver's license and more than two years of driving experience to control for the effects of novice drivers' variable driving. Therefore, all of the participants could be categorized as an "advanced apprentice/junior journeyman" group in driving experience level (Durso & Dattel, 2006).

Apparatus

Figure 1 shows the GT Driving Simulator, a mid-fidelity National Advanced Driving Simulator (NADS) MiniSim version 1.8.3.3. The simulation software runs on a single computer, running Microsoft Windows 7 Pro on an Intel Core i7 processor, 3.07

GHz and 12 GB of RAM, and relays sound through a 2.1 audio system. Three Panasonic TH-42PH2014 42" plasma displays with a 1280x800 resolution each allow for a 130 degree field of view in front of the seated participant. The center monitor is 28 inches from the center of the steering wheel and the left and right monitors are 37 inches from the center of the steering wheel. The MiniSim also includes a real steering wheel, adjustable car seat, gear-shift, and gas and brake pedals, as well as a Toshiba Ltd. WXGA TFT LCD monitor with a 1280x800 resolution to display the speedometer, etc. Environmental sound effects are also played through two embedded speakers. These sounds included engine noise, brake screech, turn indicators, collisions, etc. In the present experiment, all participants experienced the same pre-defined route and properties for the driving task.

Figure 1. View of driving in a simulator. Each participant drove the same pre-defined route.

Driving Scenario

A driving scenario was created using the iSAT software, which comes with the NADS MiniSim. The scenario included an urban road (with speed limit 40 mph) and a highway (with speed limit 50-65 mph). Also, it contained various road signs and vehicles, traffic signals, and pedestrians commonly seen in an actual driving environment. Ten different hazard events (see Table 2) were created in the scenario to measure driver situation awareness. Those events occurred approximately every minute, beginning a minute after the start of the drive.

Table 2. Hazard events in the driving scenario.

Predictable Hazard Events
Event 1. Swerving car
Event 2. Swerving motorcycle
Event 3. Traffic signal suddenly changed into yellow in the intersection
Event 4. Suddenly u-turning car in front of the participant
Event 5. Running boy from behind the parked car
Event 6. Suddenly pulling out car
Event 7. Suddenly appearing truck in highway entrance
Event 8. Construction and lane merge
Event 9. Crossing two deer
Event 10. Cutting off car

Design and Procedure

Before inducing an affective state, participants were asked to rate their current affective states using seven-point Likert-type scales (1: not feel at all ~ 7: strongly feel) (see Appendix D). The affective states included nine discrete adjectives that were reported as important affective states in driving contexts: fearful, happy, angry, depressed, confused, embarrassed, urgent, bored, and relieved (Jeon & Walker, 2011d). Then, participants went through the GT Simulator Sickness Screening Test: (1) Rating their current physical feelings on 17 categories using eleven-point Likert-type scales (0: not feel at all ~ 10: strongly feel) (see Appendix B); (2) Drive a 2 minute city driving scenario in the simulator (different from the scenario used in the actual experiment); (3) Rate their physical feelings again on the same questionnaire. If the participants felt any symptoms of simulator sickness (e.g., light headed, dizzy, or other adverse reaction) at any time during the drive, the simulation was stopped and they were excused from testing. They were also excused from testing if their scores show signs of simulator sickness (i.e., if any Likert scale value was 5 or higher than the pre-drive rating, or if any three of the ratings were 3 points above the pre-drive survey, adapted from Gianaros, Muth, Mordkoff, Levine, & Stern, 2001).

Participants who had not shown evidence of simulator sickness on the Simulator Sickness Screening Test completed the experimental task. Participants were randomly assigned to each affect condition. Participants had 12 minutes to write a description of their past emotional experience (anger) which is a frequently-used affect induction methodology (e.g., Bodenhausen et al., 1994; Ellsworth & Smith, 1988). An experimenter instructed them to remember the memory as clearly as possible and to emotionally revisit the experience again. Participants were urged to refer to two sample paragraphs (Bodenhausen et al., 1994; Jeon et al., 2011a) in the instruction sheet to help them write their own paragraphs (Appendix C). One of these was related to driving as shown in the following:

"…it was already late for the meeting when I woke up. I nimbly packed all resources I organized last night and drove my car in a hurry. But after a while, a huge truck blocked the road and series of cars were waiting for that truck to make a U-turn. I saw there was not enough space for the truck and all cars had to back their car one by one to make more space during the already hectic morning hours. It was a disaster!" (Anger)

If there were more than one experience, participants could choose to write about all of them within the time provided. Participants in the neutral affect condition wrote a description of the mundane events of the previous day (Bodenhausen et al., 1994; Jeon et al., 2011a).

After describing the experiences, participants completed ratings on their present affective states and subjective judgment questions on driving competence and risk perception (e.g., Dorn & Matthews, 1995) using three seven-point Likert-type scales: (1) How do you feel about your confidence level for driving? (2) How much do you feel accident risk in your driving? (3) Do you think your driving is safer than other drivers who are your same age and gender?

After these questionnaires, participants drove the predefined scenario, which lasted approximately 13 minutes. They were instructed to drive as they would drive in the real world, following any traffic and safety rules. Through the driving course, they drove straight except for one left turn, which the experimenter announced in advance. Right after the drive, the participant was asked to answer the offline SA assessment questionnaire. After filling out the SA questionnaire, participants completed the third affective state rating and short questionnaire for demographic information. Finally, they filled out the electronic version of NASA TLX (Hart, 2006) to provide measurements of perceived workload for the overall driving task while under an induced affective state, and provided comments regarding the study. All the participants were debriefed on the study and plausible affective effects on their actual driving at the end of the experiment.

Dependent Variables for Driving Performance

Driving performance data were collected (1) manually by a real-time judge who was present at all times and (2) by system logging.

(1) Manual log: During the drive, a trained experimenter recorded the number of all driving errors, as well as the coping level with the ten hazard events, as an implicit performance measure for driver SA. The coping level for each event was scored as 0: smooth management; 1: near accident with brake screech sound; or 2: crash with objects (thus, their overall implicit performance scores across ten events could range from 0: best to 20: worst). Manually counted number of errors included four general driving performance categories which anger has negatively influenced (e.g., Deffenbacher et al., 2003; Dula, Martin, Fox, & Leonard, 2011; Jeon et al., 2011a; Jeon et al., 2011b; Underwood et al., 1999). Crossing the center line and sideline were combined into “Lane Deviation” (LD). Infractions of red lights and failure to use turn signals were categorized under “Traffic Rules” (TR). Violations of the speed limit were named “Over Speed” (OS), and collisions were named “Collision” (CO). Specifically these variables were chosen because anger easily leads to aggressive behaviors and these aggressive behaviors in driving situations highly account for road rage (Burns and Katovich, 2003).

(2) System log: Additional driving performance data were automatically logged in the driving simulator. Automatically logged data included five driving performance

categories: Lane Deviation (deviated feet from the center of the road), Speed, Steering Wheel Angle, Brake Pedal Force, and Collision. The first four variables contained various data such as average, standard deviation, maximum, and minimum. Lane Deviation also included the number of lane crossing.

Other driving performance measures such as the lane-change-test (Mattes, 2003) or headway distance measures (e.g., Ma and Kaber, 2005) were not used in this study because participants might concentrate more on those tasks, being distracted from their affective source.

Results

Manipulation Checks

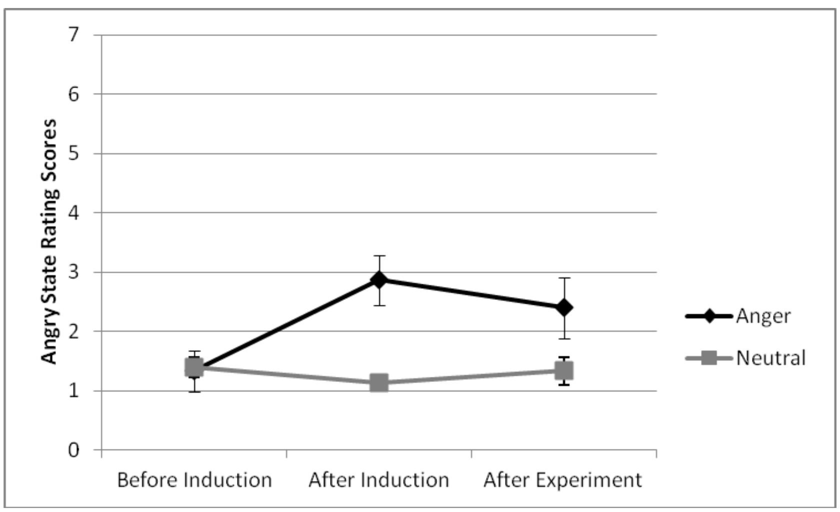


Figure 2. Angry state rating scores across rating timings. In the angry condition, the angry-score after induction was higher than the score before induction. Also, the score after the experiment was higher than the score before induction. For the neutral condition, there was no significant change in the angry rating scores. Error bars indicate standard error of the mean.

Writings about angry experiences seem to fit into expectations based on the cognitive appraisal model (Ellsworth & Smith, 1988; Smith & Ellsworth, 1985). Overall, participants in the angry state tended to describe events related to 'other-responsibility' and 'individual control', including conflict with colleagues (4), frustration at parents (1), failed tasks or bad jobs (5), lost chances or personal belongings (3), and road rage (2). For the neutral condition, participants described just daily activities such as driving or walking (6), getting ready in the morning/for bed (2), grocery shopping (1), and other routine (6), which is in accordance with previous research (Jeon et al., 2011a).

Figure 2 shows the overall mean rating of angry states at the three times. Results were analyzed with a separate repeated measures analysis of variance (ANOVA) for each affective condition. An ANOVA result revealed a statistically significant difference among the three timings for anger, $F(2, 28) = 4.41$, $p < .05$, $\eta_p^2 = .24$. For the multiple comparisons among the three timings for anger, paired samples t-tests were conducted. The angry-score after induction ($M = 2.87$, $SD = 1.6$) was higher than before induction ($M = 1.33$, $SD = 1.3$), $t(14) = -2.88$, $p < .05$. The angry-score after the experiment ($M = 2.40$, $SD = 1.9$) became slightly but not significantly lower than after induction, $t(14) = 1.10$, $p > .05$. It was not significantly but numerically higher than before induction, $t(14) = -1.74$, $p = .10$. For the neutral condition, the change of participants' angry state was also analyzed. Participants in the neutral showed no significant change among the three timings for anger.

For the angry participants, there were also significant changes in happy rating, $F(2, 28) = 3.49$, $p < .05$, $\eta_p^2 = .21$ and embarrassed rating, $F(2, 28) = 3.70$, $p < .05$, $\eta_p^2 = .21$ across the three timings. The happy-score before induction ($M = 4.93$, $SD = 1.6$)

significantly decreased after anger induction (*M* = 3.93, *SD* = 1.6), *t*(14) = 2.19, $p < .05$, and slightly increased after the experiment (*M* = 4.07, *SD* = 1.2), *t*(14) = -0.52, $p > .05$ to the level before induction. The embarrassed-score before induction (*M* = 0.93, *SD* = 0.3) marginally increased after anger induction (*M* = 1.64, *SD* = 1.2), *t*(14) = 2.19, $p = .065$, and even increased further after the experiment (*M* = 1.79, *SD* = 1.2), which led to the significantly higher score than before induction, *t*(14) = -2.48, $p < .05$.

For the neutral participants, there were also significant changes in fearful, $F(2, 28) = 5.29$, $p < .05$, $\eta_p^2 = .27$, and happy states, $F(2, 28) = 4.41$, $p < .05$, $\eta_p^2 = .24$, across the three timings. The fearful-score before induction (*M* = 1.73, *SD* = 1.1) significantly decreased after induction (*M* = 0.93, *SD* = 0.3), *t*(14) = 2.86, $p < .05$, but significantly increased after the experiment (*M* = 1.73, *SD* = 1.0), *t*(14) = 2.86, $p < .05$, to the level before induction. The happy-score before induction (*M* = 4.60, *SD* = 1.2) was similar to the score after neutral induction (*M* = 4.27, *SD* = 1.1), but significantly decreased after the experiment (*M* = 3.67, *SD* = 1.1), *t*(14) = 2.20, $p < .05$.

In short, the intended angry level increased after the induction procedure and decreased while driving. Even after the experimental procedure (around 15-20 minutes), induced anger seemed to still remain. There were a couple of accompanied changes in other affective states. After neutral induction, the fearful-score decreased, but the happy-score decreased only after the experiment. With anger induction, the happy-score decreased, whereas embarrassed-score increased.

Subjective Judgment

For the subjective judgment rating scores across the affective states, results were analyzed with independent samples t-tests for each question. Overall, no comparison led to statistically significant results on subjective judgment ratings. Participants in the angry state (M = 5.79, SD = 1.3) showed a numerically higher confidence level than in the neutral state (M = 5.36, SD = 1.3). Simultaneously, participants in the angry state showed a slightly higher accident risk level (M = 3.71, SD = 2.0) than in the neutral state (M = 2.93, SD = 1.6) and a lower safety level (M = 5.64, SD = 1.2) than in the neutral state (M = 5.92, SD = 0.8).

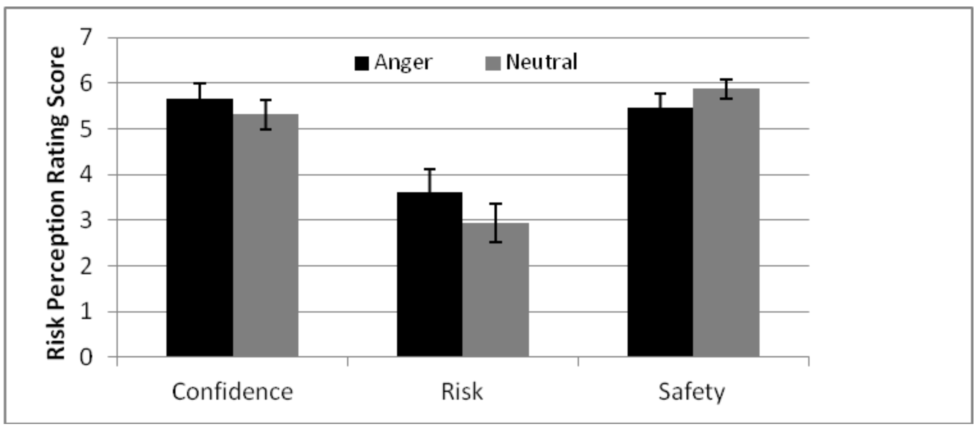


Figure 3. Subjective judgment rating scores. Overall, there was no significant result on the subjective judgment rating. Error bars indicate standard error of the mean.

Driving Performance

As reported, driving performance data were collected in two ways: manual log and system log and both of them showed significant differences between the two conditions.

(1) Manual log: Figure 4 shows overall driving performance aggregated across four categories in both affective states. Anger (M = 9.53, SD = 3.6) led to significantly more errors than neutral (M = 5.67, SD = 3.0), $t(28) = 3.19$, $p < .01$. Figure 5 shows the

number of driving errors according to error type in both affective states, which indicates that participants in the angry condition consistently made more errors in the neutral condition except for the number of collisions. For each type of driving errors, independent samples t-tests revealed that the participants in the angry state (*M* = 2.13, *SD* = 1.4) made significantly more lane deviation times than in the neutral state (*M* = 1.00, *SD* = 0.8), *t*(28) = 2.75, *p* = .01. Additionally, the participants in the angry state (*M* = 6.80, *SD* = 1.8) made significantly higher number of overspeed errors than in the neutral state (*M* = 4.27, *SD* = 2.9), *t*(28) = 2.87, *p* < .001.

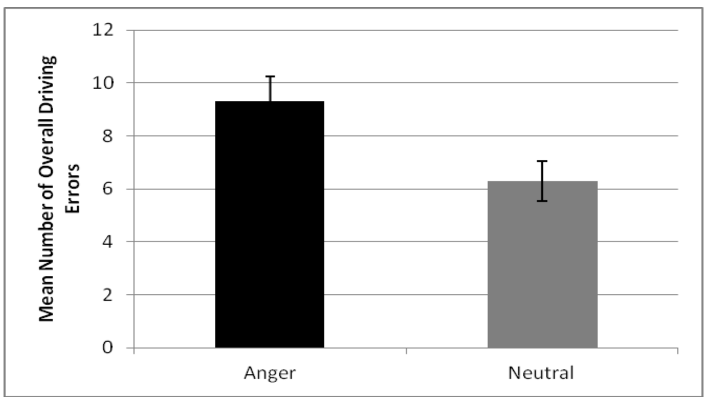


Figure 4. Number of overall errors in both affective states (manual log). Anger led to significantly more errors than neutral. Error bars indicate standard error of the mean.

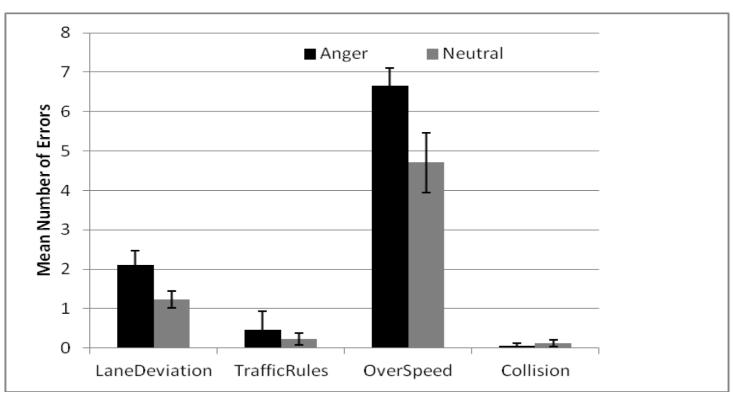


Figure 5. Number of errors according to error type in both affective states (manual log). Error bars indicate standard error of the mean.

(2) System log: Figure 6 shows the mean maximum speed in both affective states. Anger (M = 74.11, SD = 6.0) led to significantly higher maximum speed than neutral (M = 70.05, SD = 2.3), $t(28) = 2.44$, $p < .05$. Figure 7 shows the mean number of lane deviation times. Again, anger (M = 18.4, SD = 7.0) led to significantly higher number of lane deviation times than neutral (M = 13.3, SD = 4.1), $t(28) = 2.45$, $p < .05$. There was no other variable to show a significant difference between the two conditions.

These consistent results were confirmed by highly positive correlations between the manual log data and the system log data (lane deviation with lane deviation times, $R^2 = .53$, $p = .002$, with average lane deviation, $R^2 = .46$, $p < .05$, with std of lane deviation, $R^2 = .62$, $p < .001$; over speed with average speed, $R^2 = .68$, $p < .001$, with maximum speed, $R^2 = .57$, $p = .001$; collisions with collisions, $R^2 = .32$, $p = .092$). To ensure that no other variables influenced the performance results, the results for gender and driving experience were also analyzed. For gender, there was no significantly different number of errors between females (N = 14) (M = 6.43, SD = 2.7) and males (N = 16) (M = 8.86, SD = 4.4). For driving experience, years of driving did not show significant correlation with the number of driving errors. However, years of driving showed significantly negative correlation with the maximum speed ($R^2 = -.41$, $p < .05$) and the brake pedal force standard deviation ($R^2 = -.45$, $p < .05$). In other words, more experienced drivers were not likely to drive with higher speed and showed more reliable brake pedal force, which looks intuitive. Moreover, there was no significant difference in years of driving between the angry condition (M = 4.46, SD = 1.9) and the neutral condition (M = 5.23, SD = 3.3).

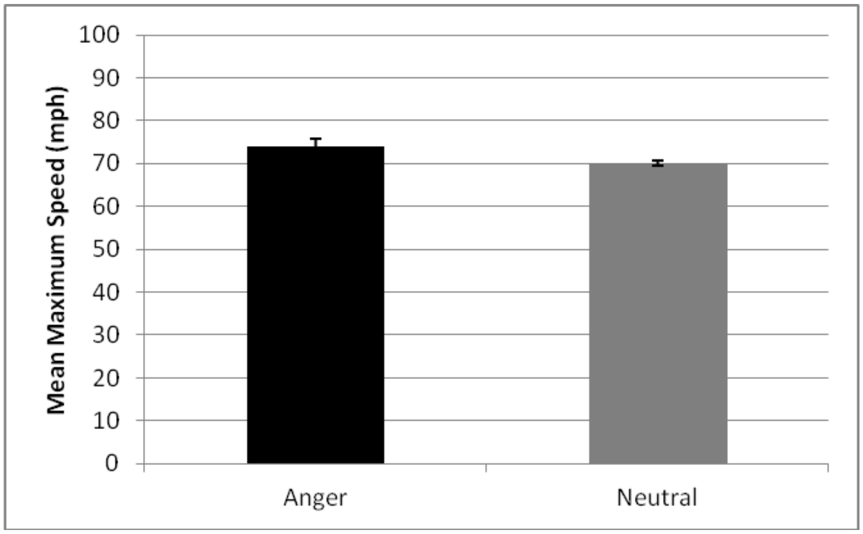


Figure 6. Maximum speed in both affective states (system log). Error bars indicate standard error of the mean.

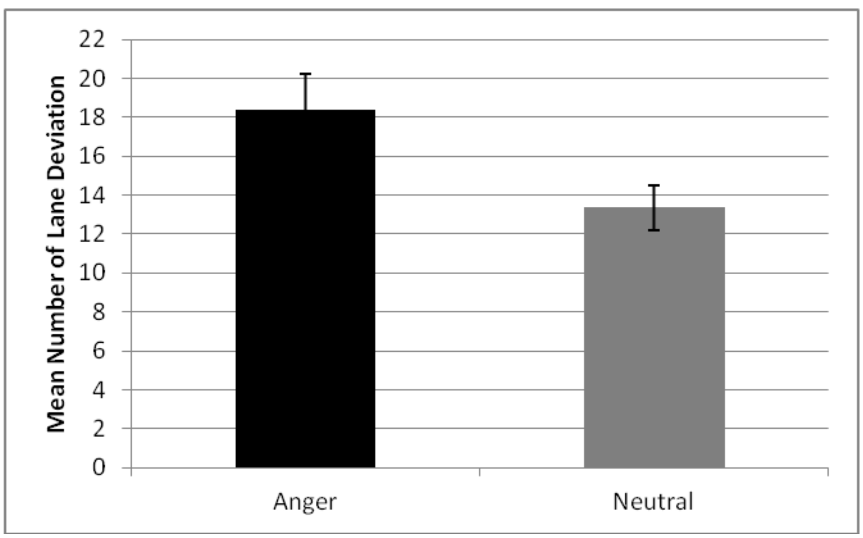


Figure 7. Number of lane deviation times in both affective states (system log). Error bars indicate standard error of the mean.

Situation Awareness

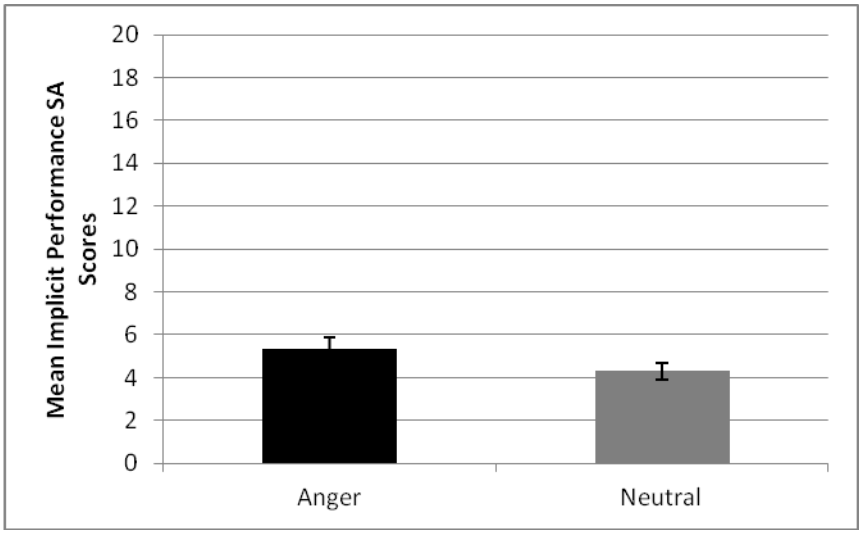


Figure 8. Implicit performance SA scores in both affective states. In the angry condition, the score was higher than in the neutral condition, which means anger degrades driver situation awareness more. Error bars indicate standard error of the mean.

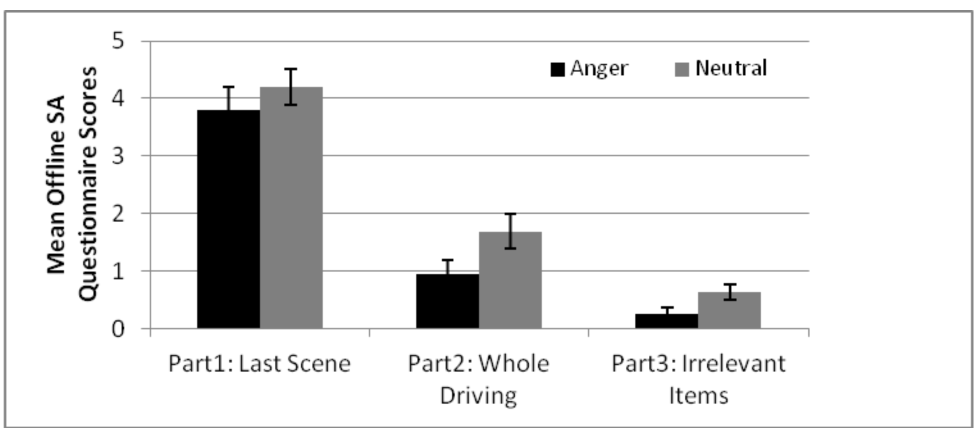


Figure 9. Offline SA questionnaire scores in both affective states. In the angry condition, the scores were lower than in the neutral condition, which means anger degrades driver situation awareness more. Error bars indicate standard error of the mean.

For the SA scores, results were analyzed using independent samples t-tests for both implicit performance and offline questionnaire scores. Note that a higher score in the implicit performance measure means worse situation awareness, whereas a higher score in the offline questionnaire means better situation awareness. Figure 8 shows the mean implicit performance scores in both affective states. Anger (M = 5.4, SD = 2.0) led to significantly higher scores than neutral (M = 4.0, SD = 1.6), $t(28) = 2.12$, $p < .05$, which means that participants in the angry state had lower driver situation awareness than in the neutral state. Figure 9 shows the mean offline questionnaire scores. Overall, in all three parts of the questionnaire, participants in the angry condition gained lower scores than participants in the neutral condition, which means lower situation awareness. In questions about (1) the last driving scene (operationally defined as SA, here), anger (M = 3.8, SD = 1.5) led to lower scores than neutral (M = 4.2, SD = 1.2), but it was not statistically reliable, $t(28) = -.798$, $p > .05$. In questions about (2) the whole driving, anger (M = 0.9, SD = 0.9) led to marginally lower scores than neutral (M = 1.7, SD = 1.2), $t(28) = -1.90$, $p = .068$. In questions about (3) driving-irrelevant items, anger (M = 0.3, SD = 0.4) led to significantly lower scores than neutral (M = 0.6, SD = 0.5), $t(28) = -2.21$, $p < .05$.

Implicit performance SA scores significantly positively correlated with the number of errors in the manual log ($R^2 = .37$, $p < .05$). There was no significantly different implicit performance SA scores between females (M = 4.29, SD = 1.9) and males (M = 5.13, SD = 2.1). Also, years of driving did not show a significant correlation with situation awareness scores. There was no correlation between the amount of increased angry state and situation awareness or performance. In other words, overall, angry drivers show worse situation awareness and more errors on average, but the change in the self-rating score cannot predict driver situation awareness or driving performance.

Perceived Workload

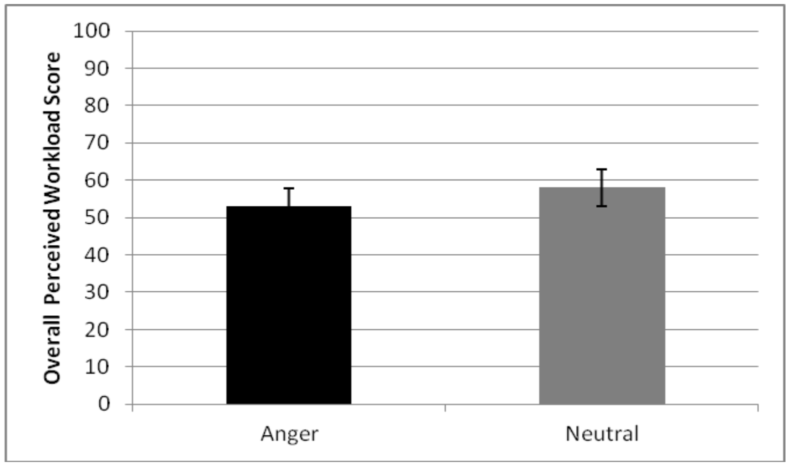


Figure 10. Overall perceived workload scores. In the angry condition, the score was numerically lower than in the neutral condition, but was not statistically reliable. Error bars indicate standard error of the mean.

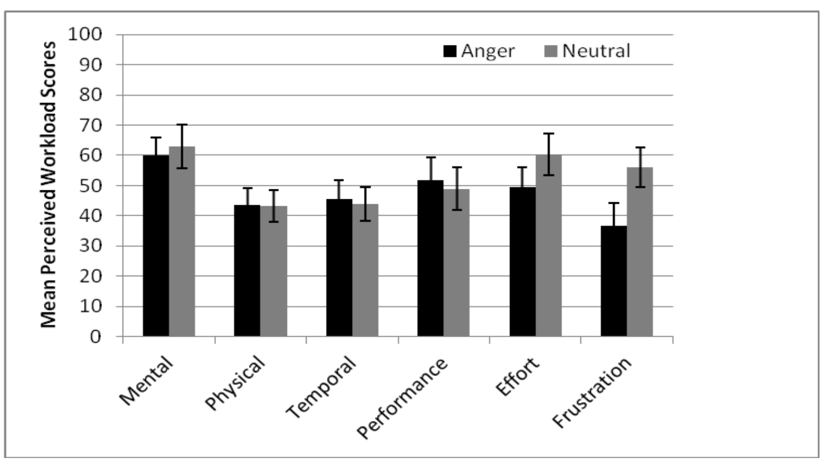


Figure 11. Subcomponent scores of perceived workload. In the angry condition, the frustration score was numerically but not statistically lower than in the neutral condition. Error bars indicate standard error of the mean.

For overall perceived workload scores (Figure 10), independent samples t-tests showed no difference in both affective states, which means there is no significantly different perceived workload resulting from an angry state. However, an interesting result was found when comparing subcomponents of NASA TLX measures (Figure 11); anger (M = 36.6, SD = 29.7) showed numerically but not statistically lower *frustration* than neutral (M = 56.1, SD = 24.5) (p = .067).

Discussion of Experiment 1

Experiment 1 compared diverse variables including subjective judgment, driving performance, situation awareness, and perceived workload in the induced angry state with those in the neutral state. The overall results demonstrated that the induced anger can degenerate driver situation awareness and driving performance. However, it did not significantly influence either the subjective judgment or the overall perceived workload.

Affect Induction

First of all, one of the important successes of the current experiment is the effective induction of the angry state. It was found that the induced anger decreased as the driving experiment went on, but a certain amount of affect still remained after the experiment, which accounts for the source of different outcomes between the two affect conditions. The common change between the affective conditions was that the happy level decreased after either angry or neutral induction. However, a closer look reveals that the happy state significantly decreased after induction in the angry condition, whereas the happy state significantly decreased after the experiment in the neutral condition. In other words, in the angry condition, the decrease of the happy state was due to anger induction, but in the neutral condition, the decrease of the happy state was due to the demanding driving task.

The current experimental protocol, which has been recently developed, has already consistently been an effective application of the traditional affect induction methodology to driving research (Jeon et al., 2011a; Jeon et al., 2011b). In traditional psychological lab studies, affect researchers have not measured the *third affect* level because most of them only have participants answer a few questions right after the affect induction. Thus, they did not need long-lasting affective states for their research purpose. Additionally, traditional affect research typically conducted the manipulation check only for the intended affective state. In contrast, the current study protocol has checked various important affective states together and thus provided a more holistic view of a driver's overall affective state changes. In traditional studies, psychologists have used diverse induction methodologies with a focus on incidental affect, such as watching photos (Lang, Bradley, & Cuthbert) or film clips (e.g., Fredrickson & Branigan, 2005), reading scenarios or stories (e.g., Johnson & Tversky, 1983; Raghunathan & Pham, 1999), listening to music (e.g., Jefferies, et al., 2008; Rowe, et al., 2007), or writing down their past experience (e.g., Gasper & Clore, 2002). On the other hand, driving researchers have tried to devise some hazard events so that drivers got frustrated (i.e., integral affect) in those scenarios (e.g., Harris & Nass, 2011; Lee, 2012). However, they just assumed drivers' emotional state, but did not conduct the necessary manipulation checks.

In the present dissertation, 'writing personal experiences' was used as *incidental* affect induction, specifically because anger needs a clear opponent or source of affect. In this aspect, watching photos or film clips might not be sufficient to induce anger.

Moreover, because driving is a much more complicated and longer-lasting task than a simple social judgment or decision making task, the strength and duration of induced affective states are expected to be more important and have a greater influence on driving performance. Therefore, this experiment also included some hazard events in the scenario as a source of *integral* affect. The results support that the multiple induction procedure and manipulation checking strategies used in the current experiment work well for this type of driving study.

An important further research question includes "how to guarantee that the induced affective states in a driving simulation are equivalent to affective states in actual driving?" Affective states induced from real driving situations or other life contexts might have a bigger impact on driving performance than the affective states induced from hazard events in simulated driving or writing past experiences.

Another challenge to be tackled is plausible combinations of several affective states or other tasks. To illustrate, any feelings before driving (incidental affect) can worsen with emotional events while driving (integral affect), in addition to, for example, difficulty in finding a destination on the navigation device (secondary task). The effects of secondary tasks on driving can be evaluated along with various affective effects. The amount of incremental effect can also be analyzed compared to each of the single cases. Given the absence of a clear-cut answer so far, a great deal of case study and explorative research is needed regarding multiple affective effects or the combination of affective effects and other tasks.

Subjective Judgment

Even though it did not lead to statistically reliable results, anger numerically led to a higher risk perception level and a lower safety level, which is consistent with previous research (Jeon et al., 2011a) as well as the mood congruent effects or affect priming. Participants in the angry state might rate their safety level lower based on their negative affect or socio-cultural stereotype that might have been formed by pervasive road rage and aggressive driving phenomena. This is plausible because anger is known to encourage a stereotypic thought process (Bodenhausen, 1993; Bodenhausen et al., 1994).

The interesting result is that even though angry participants seemed to expect their lower safety and higher risk level, they did not compensate for the expected performance decrease. This might be because participants in the angry condition felt more confident with their driving than participants in the neutral condition. Based on the cognitive appraisal mechanism, anger is deeply related to 'certainty' and 'individual control' (Ellsworth & Smith, 1988; Smith & Ellsworth, 1985). This is a big difference between secondary task effects and affective effects in driving. Research has shown that participants who were asked to do dual tasks while driving intuitively adopt an adaptive behavior in order to perform the secondary task (Chen & Lin, 2003; Gugerty, Rando, Rakauskas, Brooks, & Olson, 2003; Tchankue, Wesson, & Vogts, 2011). For example, Chen and Lin (2003) showed that participants compensated for a need for increased reaction time by increasing the headway distance to the lead car and decreasing speed during the dual-task scenario (driving and talking) using hands-free cell phone. However, in the present experiment, participants did not show such a tendency to make up for their degenerated performance, which seems more dangerous even than doing a secondary task. So, driving while angry may be even more problematic than driving while talking on the phone.

Driving Performance

Angry participants consistently showed more errors than neutral participants in most error types. From this experiment, specific angry effects on driving variables were clearly confirmed including over-speed, more lane deviations, and more infractions of traffic rules. All of these components make their driving more risky and are likely to lead to fatal outcomes when integrated with other situations in real driving.

This low performance in the angry state corresponds to the expectation based on the cognitive appraisal mechanism as well as from previous research (Jeon et al., 2011a; Jeon et al., 2011b). From the results of the subjective judgment task conducted before driving, angry drivers might be aware of their lower safety level, but they could not avoid lower driving performance. As mentioned, lack of compensation due to their controllability and over-confidence might contribute to their worse performance, in addition to lower situation awareness.

Manually checked driving performance measures and driving simulator log data played complementary roles for each other. On the one hand, the simulator had some limitations of data logging. For instance, the scenario had two different speed limit zones, but the simulator did not differentiate the two different behavior patterns. Moreover, the system did not detect whether the participant turned on the indicator before changing lanes or turning, which can be counted by the experimenter. On the other hand, the experimenter's measurement might also not be perfect. Therefore, measuring and integrating both of them successfully provided a more precise picture of what happened during participants' drive.

Situation Awareness

As expected, driver situation awareness was degenerated by induced anger, especially when measured using implicit performance. Offline questionnaire results showed a similar pattern, but did not lead to a statistically significant difference in part 1, which was intended to measure driver SA. It seems that a one time survey may not be sufficient to obtain enough statistical power. As discussed earlier, the SAGAT or the SPAM frequently asks participants about SA questions to get sufficient data. One interesting result is that the participants in the angry condition also showed lower scores than in the neutral condition in part 3, questions of which were not related to a primary driving task, such as restaurant names and signs. It was originally hypothesized that participants in both groups would be similarly bad at answering those task-irrelevant items. Due to this unexpected different result in part 3, however, it became less clear whether better results of the neutral participants in part 1 and part 2 came from different processing levels and memory, or came from just different response attitudes toward any questions based on their affective states.

Situation awareness scores were positively correlated with some of the driving performance scores as hypothesized. Therefore, one can infer that the induced angry state might decrease driver situation awareness, which degenerates driving performance in turn. However, in order to identify a clear cause and effect relationship, such as a mediation model between affect, SA, and performance, further research is required with more participants (see Experiment 2). It can be challenging to show such a cause and effect relationship between the two (c.f., Durso et al., 1999), because situation awareness is a critical element of performance, but does not necessarily guarantee performance.

Based on the present results, it is difficult to say that the coping level of hazard events corresponds to driving techniques or experience. First of all, years of driving did not show a significant correlation with situation awareness scores, nor with driving performance. In addition, driving literature has usually reported that nine to ten years of difference is needed to make significantly different performance levels between participants (e.g., Durso & Dattel, 2006). There was no difference in years of driving between the two conditions in the current experiment.

For the original purpose of this dissertation, the relationship between cognitive processes and situation awareness and its effects on driving performance can be further disentangled in terms of more theoretical aspects. Endsley and her colleagues (Endsley, Bolte, & Jones, 2003) classified SA demons – the enemies of situation awareness as follows: attention tunneling, requisite memory trap, workload, anxiety, fatigue, and other stressors (WAFOS), data overload, misplaced salience, complexity creep, errant mental models, and out-of-loop syndrome. Based on the identical results between two conditions, *workload* can be eliminated from the current discussion. Among the remaining others, it seems reasonable to focus on delineating "*attentional tunneling*" here as the affective effects on situation awareness with respect to Experiment 2 as well as Experiment 1.

Constant juggling of different aspects of the environment is a key factor for successful SA. Unfortunately, people can often get trapped in a phenomenon called attentional tunneling (Baddeley, 1972; Broadbent, 1954), in which people lock in on certain aspects or features of the environment they are trying to process, and will either intentionally or inadvertently drop their scanning behavior. Even though drivers can consistently scan their environment, it does not necessarily mean that the information at that location is processed. Such instances resulting from a failure of divided attention has also been called "*inattentional blindness*" and widely explored in laboratory studies (Simons & Chabris, 1999). In either case, drivers cannot maintain good SA. These types of attentional issues can arise from affective sources, which are assumed to happen in the current experiment. *Rumination* is one of the cognitive demands or resource misallocations created by affective sources (Beal, Weiss, Barros, & MacDermid, 2005). It is defined as "a class of conscious thoughts that revolve around a common instrumental theme and that recur in the absence of immediate environmental demands requiring the thoughts" (p.7). According to Berkowitz (1989), goal blockage that is common to *ruminative* thought frequently precedes an affective response such as frustration, anger, or anxiety. Moreover, if the cause of the affective state is unrelated to the current performance episode (i.e., incidental affect, which is also the case in the current experiment), continued ruminative thought should serve as an additional cognitive demand that interferes with task performance (Beal et al.). In summary, induced anger yielded rumination, which led to attentional tunneling or inattentional blindness so that drivers did not develop complete and accurate knowledge of driving environments and vehicle states (SA), and thereby driving performance was degenerated.

Perceived Workload

It is an important finding that there was no significant difference in perceived workload between the two conditions. If it means that affective effects are independent of perceived workload, it might imply that affect research needs a different approach or framework from the workload research tradition. If performance degeneration in the angry state is not because of workload, there should be other mechanisms that need to be identified further.

Interestingly, participants in the angry state showed an even lower frustration score (Anger: 37) than in the neutral state (Neutral: 56). If a general neutral state can be considered as a slightly positive state (e.g., Gasper & Clore, 2002) (in fact, before affect induction, happy score was 4.6 in the neutral state and 4.9 in the angry state), this could be partly explained based on a motivational explanation (Isen, 1987), which suggests that people in the positive state generally want to maintain their positive state. According to that notion, if maintaining happiness is prevented, happy people are likely to perceive more loss. In the current experiment, neutral (i.e., slightly happy) participants were asked to complete a new and demanding task (driving in a simulator for the first time). Moreover, they were subjected to unintended or unexpected errors while coping with various hazard events. Taken together, participants in the neutral state might feel more frustration than those in the angry state because of these obstacles to maintaining their positive feelings. In contrast, participants in the negative state (i.e., anger) might feel less frustration while driving than in the neutral state because they started their new task with a negative state, which they would be generally less motivated to maintain.

CHAPTER 6

EXPERIMENT 2: ADAPTIVE MITIGATION INTERFACES FOR ANGRY STATES

This chapter presents an empirical study investigating speech-based mitigation interfaces for angry drivers. So far, the concept of situation awareness has been used as an assessment tool to predict a driver's performance. The second experiment uses situation awareness prompts to distract or *awake* drivers from an angry state, and make them concentrate on the driving environment.

This approach is based on *attention deployment* methods, which is one of the strategies in the most widely accepted emotion regulation model (Gross, 1998b). This experiment compared the suggestive/ notification style situation awareness (SA) prompt condition with the directive/ command style emotion regulation (ER) message condition as attention deployment strategies. There was also a no-sound condition with anger induction and a neutral condition as baseline conditions.

Before the details of Experiment 2, the current chapter outlines research on speech-based in-vehicle systems, the emotion regulation model, and affect regulation research for in-vehicle contexts.

Speech-Based In-Vehicle Systems

One of the main research interests of in-vehicle technologies includes the natural, intuitive interaction between a driver and a car (Eyben et al., 2010). Indeed, the concept of driving has evolved from an independent task of the driver to a collaborative work with a passenger (e.g., Forlizzi, Barley, & Seder, 2010) or an intelligent agent (e.g., Jeon, 2010). An obviously natural way to communicate with an in-vehicle system is using speech, just as with a human co-driver. Several studies have attempted to identify design considerations for speech-based in-vehicle systems. Some of them tested basic characteristics of the in-vehicle voice. For example, using a *young* adult voice for the in-vehicle information system made older drivers feel more confident while driving, need less time to complete the driving course, and have fewer accidents than using an *old* adult voice (Jonsson, Zajicek, Harris, & Nass, 2005). Subsequent research (Jonsson, 2009) showed that using a *familiar* voice (famous TV and radio presenters) yielded better performance (avoiding accidents, following traffic rules and lane keeping) for angry drivers than using an *unfamiliar* voice. Moreover, with the *familiar* voice drivers perceived the in-vehicle system to have a more positive influence and rated themselves as more attentive while driving than with the *unfamiliar* voice.

Others investigated more dynamic aspects of the speech-based in-vehicle systems. For instance, Nass et al. (2005) showed that when the in-vehicle voice emotion matched the driver's emotional state (e.g., energetic to happy and subdued to upset), drivers had fewer accidents and attended more to the road (actual and perceived), and even spoke more with the car. That result is especially interesting in that it is contradictory to a general expectation that a happy system voice would always be felt as positive (Grimm et al., 2007). Follow-up studies may be of interest to validate that surprising finding. In another study (Jonsson et al., 2004), drivers were given interspersed warnings about the drivers' performance while they were driving with three conditions: driver blame, driver and car blame, and environment blame. According to the results, with warnings associated with the environment, drivers felt most at-ease, liked the system, rated the quality of the car higher, and attended to the road better than with the other conditions.

Emotion Regulation Model

The most well-accepted emotion regulation model in psychology is a '*process model*' (Gross, 1998a, 1998b, 2002; Gross & Thompson, 2006), in which emotions and affect may be regulated at five points in the emotion generative process: situation selection, situation modification, attention deployment, cognitive change, and response modulation. For example, based on this model, drivers can select low-traffic routes instead of high-traffic routes (situation selection) or try to minimize its affective impact (situation modification). However, driving is a complicated, interactive situation so that drivers are often not able to control every variable.

Attention deployment includes not only distracting an individual from an affective source (Gross, 2002) but also concentrating intensely on a particular topic or task (Csikszentmihalyi, 1975). Accordingly, an effective strategy would allow the adaptive in-vehicle system to distract a driver from an affective source and enable the driver to concentrate on the driving environment.

Diverse empirical evidence has supported that cognitive change (e.g., reappraisal-down) is cognitively and socially more effective than suppression, which is a response modulation at the final regulation point (Gross, 2002). Additionally, recent studies have found that engaging in cognitive reappraisal even changes the activity of brain regions involved in the experience of emotion (Ochsner, Bunge, Gross, & Gabrieli, 2002).

Further issues include how to develop an affect regulation model *fitting for drivers* and its variations for specific populations, such as young drivers, older drivers, or drivers with Traumatic Brain Injury who are specifically vulnerable to affective issues in driving contexts (Jeon, Roberts, Raman, Yim, & Walker, 2011; Jeon & Walker, 2011a).

Affect Regulation Research for In-Vehicle Contexts

There are several suggestions for a driver's affect regulation, from the road rage literature (e.g., Mizell et al., 1997): consider altering your schedule; improve the comfort of your vehicle; while in traffic, concentrate on being relaxed; and don't drive when you are angry. These, however, look more like general advice on *static* preparation for driving and not for providing sophisticated strategies for *dynamic* driving environments.

With respect to real-time emotion regulation for drivers, there are at least four opportunities for interventions to tackle a driver's affective issues. First, if the mechanisms are clearly known for the affective effects, direct mitigation of the affective states may be possible: change the induced affective state into a positive affective state using affect regulation techniques and adaptive user interfaces, or change the induced affective state into a neutral state. However, it is not clear which direction is better. So far, there is no empirical validation of those possibilities. Moreover, the mechanisms for affective effects are intertwined with each other and there is no overarching mechanism as shown in Chapter 3.

Second, cognitive reappraisal is a plausible strategy to adopt. Harris and Nass (2011) showed that drivers in a reappraisal-down speech condition (e.g., "heavy traffic results from limited routes, not the behavior of other drivers") had better driving behavior and reported less negative emotions than participants in a reappraisal-up speech condition (e.g., "the behavior of overly aggressive and inconsiderate drivers leads to traffic congestion") or a silent condition. However, there are several downsides to using the cognitive reappraisal strategy: (1) The system must be able to exactly know and interpret the driving situation; otherwise, inappropriate comments can yield worse results. (2) The use of cognitive reappraisal is limited to integral affect, which is coming from the driving task itself and cannot be applied to incidental affect, such as a driver's anger before driving. (3) It tries to change a driver's affective state itself – depending on a driver's state or characteristics, he or she might be able to accept the system's reappraisal and regulate his or her state, whereas in some serious cases, it might be impossible to change his or her state at all. (4) Reappraisal might require a driver's cognitive efforts even if the cues are given by the speech-based system, which might cause additional workload. In Harris' (2011) subsequent studies, there was no measure of drivers' workload with respect to the cognitive reappraisal strategy.

Third, the system can probably be designed to increase performance regardless of the regulation of the affective state itself. For high workload and stressful situations, the intelligent system can temporarily prevent incoming calls or email notifications. Making visual fonts larger (Hudlicka & McNeese, 2002), or adding auditory displays for a specific task may help improve driving and other related-task performance and reduce drivers' perceived workload (Jeon, Park, Heo, & Yun, 2009). This strategy might work well for new drivers or old drivers who are overwhelmed with too much information in the car (Jeon et al., 2011). However, it seems to be hard to apply this method to angry drivers.

Finally, attention deployment, which is one of the five steps in the process model for emotion regulation, can be used. For example, calling one's own name can sometimes break through to conscious awareness (Moray, 1959). This processing occurs preattentively, similar to low-level stimuli that produce the pop-out effect in auditory tasks (e.g., cocktail party effects, Pollack & Pickett, 1957) or in visual search tasks (Treisman & Gormican, 1988). Thus, it can directly have impact on driving performance and safety. It may work well for making a driver distracted from an affective source, but how the system can make a driver concentrate on the driving environment is another question to answer. In order to identify user needs in the in-vehicle emotion regulation interfaces, Jeon and his colleagues (Jeon et al., 2011) conducted interviews and focus groups with drivers with Traumatic Brain Injury (TBI), driving rehab specialists, and young drivers. Results showed that a system might need to have user-specific specifications depending on target user populations. For example, driving rehab specialists (who are not trained in social psychology) wondered about using short, direct commands for drivers with TBI such as "focus on your driving" or "relax your grip on the wheel." However, researchers found that telling young drivers about driving or their affective states is likely to make them feel that a system is a back-seat driver.

The second experiment tries to apply attention deployment using situation awareness prompts. To date, situation awareness queries have been used as an assessment tool to predict a driver's performance. However, situation awareness itself has never been used as a dynamic cue to improve driving performance and safety. This is a more unobtrusive and indirect way to mitigate affective effects on driving performance. In addition to trying regulate or control a driver' affective state (e.g., "Take it easy", "Relax your grip on the wheel"), there is a condition that enhances driver situation awareness (e.g., "If you see any restaurant, let me know"), and thereby improves driving performance and safety.

In addition to the contents of the message, there has been some research on the message style. For example, Lee et al. (Lee et al., 1999) carried out a driving simulator experiment with either command messages (e.g., "Slow down") or notification messages (e.g., "Icy road ahead"). Command messages promoted greater compliance than notification messages, but might reduce safety. That result requires further research because in a driving context, safety usually has a priority over a driver's compliance to the in-vehicle system. Moreover, it is still of interest whether the command style messages would yield greater compliance for any classes of drivers in a certain affective state, because traditional literature reports that suggestive styles have been found to lead to greater compliance than directive styles (Crockenberg & Litman, 1990; Lytton, 1977; Rocissano, Slade, & Lynch, 1987). Based on these backgrounds, the hypotheses for Experiment 2 are as follows.

Hypotheses

Hypothesis 2a: Situation awareness

Driver situation awareness will be improved more in the two speech-based system conditions (ER and SA) using the attention deployment strategy than in the no-sound condition. Situation awareness in the two speech-based system conditions will not be different from that in the neutral condition. Situation awareness in the suggestive/ notification style situation awareness (SA) prompt condition will be more improved compared to the directive/ command style emotion regulation (ER) message condition.

Hypothesis 2b: Driving performance

Driving performance in the no-sound condition will be worse than in the neutral condition. Driving performance will be better in the two speech-based system conditions (ER and SA) than in the no-sound condition.

Hypothesis 2c: Subjective judgment

Risk perception in all three angry states will be higher than in the neutral state and driving confidence in all three angry states will be higher than in the neutral state.

Hypothesis 2d: Perceived workload

There will be no difference between the no-sound condition and the neutral condition in perceived workload. The use of speech-based systems will not add more perceived workload to drivers compared to the neutral or the no-sound conditions.

Hypothesis 2e: Angry state

The angry state rating score after the experiment will become higher or at least, stay in a similar level in the ER condition, whereas the angry state rating score will become lower in the SA condition.

Hypothesis 2f: System assessment

The speech-based system assessment scores will favor the SA condition over the ER condition. Also, participants will respond more to the speech-based system in the SA condition than in the ER condition.

Method

Participants

Among 73 undergraduate students who registered for the study for partial credit in psychology courses, seven participants (9.5%) showed symptoms of simulation sickness in the GT SSST so they were excused from the remaining experiment. Additionally, five participants could not complete the experiment because of a software error leading to system lag (4) and an experimenter instruction error (1). One extreme outlier data set was also taken out in the analysis (over 7 standard deviations in driving errors). The remaining 60 participants (26 female, 34 male; mean age = 20.2, *SD* = 1.2; anger 15 participants, mean years of driving = 4.5, *SD* = 1.5; neutral 15, mean years of driving = 4.2, *SD* = 1.5; ER 15, mean years of driving = 4.3, *SD* = 1.1; SA 15, mean years of driving = 4.2, *SD* = 1.6) completed the experiment and their data were further analyzed. They reported normal or corrected-to-normal vision and hearing, signed informed consent forms, and provided demographic details about age, gender, and years of driving. All participants had a driving license and more than two years of driving experience. None had participated in Experiment 1.

Apparatus

The apparatus, including the NADS MiniSim driving simulator, was identical to Experiment 1.

Driving Scenario

The same driving scenario was used as in Experiment 1, except that speech audio clips were added in the ER and the SA conditions.

Speech Sounds

For each of the ER and the SA conditions, eleven TTS (text-to-speech) files (.wav) were generated for all of the intervention speech clips using the AT&T Labs TTS Demo program with the female voice Crystal-US-English (http://www.research.att.com/~ttsweb/tts/demo.php) (see Table 3). Speech clips in the two conditions simply consisted of a TTS phrase that played for each situation (2-3 seconds before or after the situation) as the participant approached the trigger zone. For both conditions, the timing of spoken speech was exactly same. On average, the speech clips in the ER condition lasted 2.4 seconds and the SA condition lasted 2.5 seconds.

Table 3. Speech-based system script used in the ER and the SA conditions.

	the directive/ command style emotion regulation (ER) prompt	**the suggestive/notification style situation awareness (SA) prompt**
01After getting started engine	Forget your angry feelings. You are driving now.	If you see any restaurant, let me know.
02After Event1. Swerving Car	Calm down. Don’t be angry at others’ behavior.	Oh, we may need to have a wild driver detector
03After Event 2. Motorcycle	That’s OK. Forget it.	Yes, we need to buy a wild driver detector.
04Before Event 3. Traffic Signal	Be careful when approaching the intersection.	There is a dangerous intersection ahead.
05After Event 4. U-turn	Check mirrors before a u-turn.	Can you still see the blue car in your mirrors?
06After Event 5. Running Boy	Take a deep breath.	Were we speeding?
07After Event 6. Pulling out Car	Relax your grip on the wheel	This type of car sometimes blocks your view.
08Before Event 7. Truck in HWY Entrance	Be cautious when getting on the highway.	Getting on the highway is always challenging.
09Before Event 8. Construction & Lane Merge	Slow down when you see a construction sign.	Road signs are sometimes hard to read.
10After Event 9. Two Deer	Everything’s OK. You are in control.	Vehicles are not the only things on the road.
11After Event 10. Cutting off Car	Never mind. Focus on your driving.	Vehicles entering the highway often cause hazards.

Both sets of speech clips were created based on the attention deployment strategy and they were cautiously made different from the cognitive reappraisal (Harris, 2011) mechanism. The ER speech clips mainly came from driving rehab specialists' suggestions (Jeon et al., 2011). As intended, the ER speech focused more on emotion regulation message (7 times), but also had direct commands about *specific situations* (4 times: # 04, 05, 08, 09) in order to balance the amount of information provided in the two conditions. In contrast, the SA condition focused more on the facilitation of situation awareness using suggestive/ notification messages about *specific situations* (8 times) and also had refreshing messages just to distract drivers from their affective source (3 times: # 01, 02, 03). Through several pilots considering the overall duration and understandability of both sets of speech clips, refined speech clips were designed so that researchers or practitioners in either side of philosophy (ER or SA) would be able to practically adopt them in their system.

Design and Procedure

The overall procedure was similar to that of Experiment 1, except that participants heard 11 speech-clips over the course of the drive, and could respond to the speech-based system while driving. Participants filled out the speech-based system assessment questionnaire after the drive.

Before inducing an affective state, participants were asked to rate their current affective states. Then, participants went through the GT Simulator Sickness Screening Test. Only participants who had not experienced simulator sickness completed the actual experimental task. Next, participants had 12 minutes to write a description of their past emotional experience(s), associated with either anger (no-sound, ER, and SA conditions) or neutral affect (neutral condition). Participants were randomly assigned to each affect condition. After describing the experiences, participants completed ratings on their second affective states and the same subjective judgment questions on driving competence and risk perception. After completing these questionnaires, participants drove the predefined scenario for around 13 minutes. They were instructed to drive as they would drive in the real world, following any traffic and safety rules. Also, participants were told that as they drove, they would hear a speech-based systems' comments on various events 10 times (Harris, 2011) in addition to one at the start of the drive. They were not required to speak or respond in any way, but they could if they wanted (Jones & Jonsson, 2005). Right after the drive, participants were asked to fill out the offline SA assessment questionnaire and the electronic version of NASA TLX (Hart, 2006) to provide measurements of perceived workload for the overall task (driving while interacting with the speech-based system, under an induced affective state). After filling out the two questionnaires, participants were asked to answer the speech-based system assessment questionnaire. They also evaluated the other system that they had not experienced, by reading the written script in each situation. Then, participants filled out a short questionnaire for demographic information and provided comments regarding the study. All participants were debriefed by the experimenter about the study and plausible affective effects on their actual driving.

While driving, a trained experimenter recorded the number of errors of all the driving performance measures, as well as a measure of how the drivers coped with hazard events, as implicit measures of driver SA. In addition, the experimenter counted the number of participants' interactions or responses to the speech-based system. Meanwhile, driving performance data were also logged in the driving simulator.

Results

Manipulation Checks

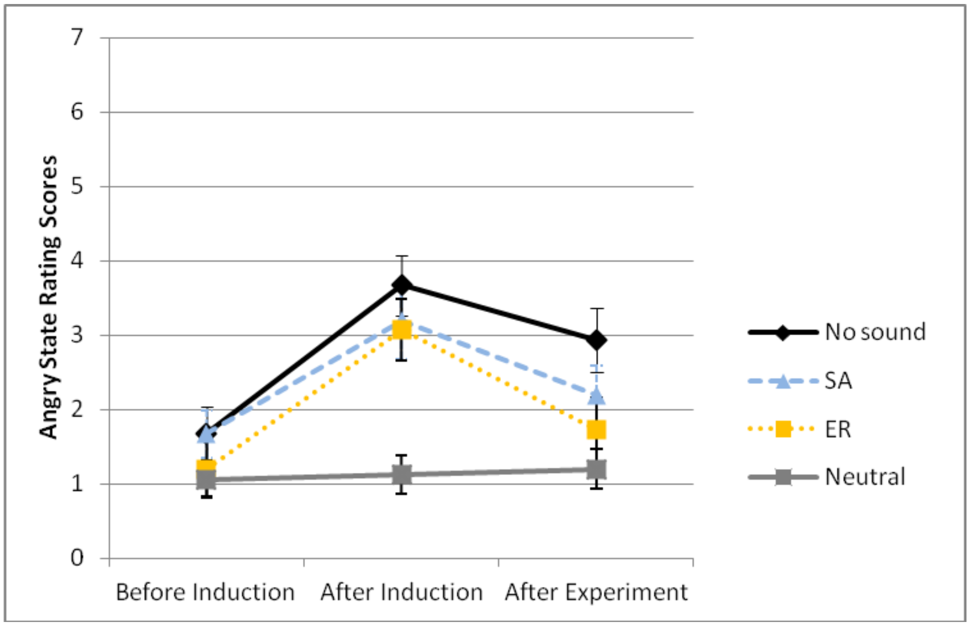


Figure 12. Angry state rating scores across rating timings. In the three anger conditions (no-sound, ER, SA), the anger scores increased after induction. Only in the ER and SA conditions, anger significantly decreased after the experiment. Error bars indicate standard error of the mean.

Again, the participants' writings about past angry experiences can be examined based on the cognitive appraisal model (Ellsworth & Smith, 1988; Smith & Ellsworth, 1985) and were similar to those in Experiment 1. Angry experiences included conflict with colleagues, family, or boy/girl friends (23), feeling unfair/ insulted/ ignored/ rude

(7), failed tasks or bad grades (11), slow/heavy traffic (2), and speeding ticket and court process (4). For the neutral condition, participants described just daily activities such as driving or walking (6), getting ready in the morning/for bed (3), grocery shopping (2), and other routine activities (watching TV, laundry, etc) (4).

Figure 12 shows the overall mean rating scores of the angry state at the three times. Results were analyzed with a separate repeated measures analysis of variance (ANOVA) for each affective condition. There was a statistically significant difference among the three timings for the no-sound condition, $F(2, 28) = 11.13$, $p < .001$, $\eta_p^2 = .44$. For the multiple comparisons among the three timings for the no-sound condition, paired samples t-tests were conducted. The angry-score after induction ($M = 3.66$, $SD = 1.6$) was higher than before induction ($M = 1.67$, $SD = 1.4$), $t(14) = -4.70$, $p < .001$. The angry-score after the experiment ($M = 2.93$, $SD = 1.7$) numerically decreased, $t(14) = 1.62$, $p > .05$, but was still significantly higher than before induction, $t(14) = -3.11$, $p < .01$.

There was a statistically significant difference among the three timings for the ER condition, $F(2, 28) = 12.03$, $p < .001$, $\eta_p^2 = .46$. For the multiple comparisons, paired samples t-tests were conducted. The angry-score after induction ($M = 3.07$, $SD = 1.5$) was higher than before induction ($M = 1.20$, $SD = 0.5$), $t(14) = -4.53$, $p < .001$. The angry-score after the experiment ($M = 1.73$, $SD = 1.1$) significantly decreased compared to after induction, $t(14) = 2.87$, $p < .05$ and returned to the same level as before induction, $t(14) = -1.95$, $p > .05$.

There was also a statistically significant difference among the three timings for the SA condition, $F(2, 28) = 7.83$, $p < .01$, $\eta_p^2 = .36$. Again, for the multiple comparisons, paired samples t-tests were conducted. The angry-score after induction ($M = 3.20$, $SD =$

2.0) was higher than before induction (*M* = 1.67, *SD* = 1.2), *t*(14) = -3.62, $p < .01$. The angry-score after the experiment (*M* = 2.20, *SD* = 1.5) significantly decreased compared to after induction, *t*(14) = 2.19, $p < .05$ and also returned to the same level as before induction, *t*(14) = -1.95, $p > .05$. Participants in the neutral (control) condition showed no significant change among the three timings for the angry state.

There were also changes in other affective states. For the no-sound group, there were also significant changes in happy, *F*(2, 28) = 15.21, $p < .001$, $\eta_p^2 = .52$, embarrassed, *F*(2, 28) = 5.04, $p < .05$, $\eta_p^2 = .27$, and relieved states, *F*(2, 28) = 5.87, $p < .01$, $\eta_p^2 = .30$ across the three timings. The happy-score before induction (*M* = 4.27, *SD* = 1.2) significantly decreased after anger induction (*M* = 2.73, *SD* = 1.5), *t*(14) = 5.28, $p < .001$, and slightly increased after the experiment (*M* = 3.00, *SD* = 1.5), but it was still significantly lower than before induction, *t*(14) = 4.01, $p = .001$. The embarrassed-score before induction (*M* = 1.40, *SD* = 1.1) slightly increased after anger induction (*M* = 1.60, *SD* = 1.5) and significantly increased further after the experiment (*M* = 2.27, *SD* = 1.8), *t*(14) = -2.20, $p < .05$. The relieved-score before induction (*M* = 3.07, *SD* = 1.8) significantly decreased after anger induction (*M* = 1.80, *SD* = 1.6), *t*(14) = 2.87, $p < .05$, but significantly increased after the experiment (*M* = 3.20, *SD* = 2.0) to the level before induction.

For the ER group, there were also significant changes in the happy state, *F*(2, 28) = 3.69, $p < .05$, $\eta_p^2 = .21$ across the three timings. The happy-score before induction (*M* = 5.27, *SD* = 1.6) marginally decreased after anger induction (*M* = 4.40, *SD* = 1.9), *t*(14) = 1.99, $p = .066$, and stayed at the same level as after the experiment (*M* = 4.40, *SD* = 1.6), which was significantly lower than before induction, *t*(14) = 2.23, $p < .05$.

For the SA group, there were also significant changes in happy, $F(2, 28) = 14.51$, $p < .001$, $\eta_p^2 = .51$ and confused states, $F(2, 28) = 5.22$, $p < .05$, $\eta_p^2 = .27$ across the three timings. The happy-score before induction ($M = 4.60$, $SD = 0.0$) significantly decreased after anger induction ($M = 3.47$, $SD = 1.1$), $t(14) = 5.26$, $p < .001$, and increased after the experiment ($M = 3.80$, $SD = 1.1$), $t(14) = -1.58$, $p > .05$. However, this was still significantly lower than the level before induction, $t(14) = 3.60$, $p < .01$. The confused-score before induction ($M = 1.73$, $SD = 1.3$) significantly decreased after anger induction ($M = 1.27$, $SD = 0.8$), $t(14) = 2.43$, $p < .05$, and even decreased further after the experiment ($M = 1.20$, $SD = 0.9$).

For the neutral participants, there were also significant changes in happy, $F(2, 28) = 9.02$, $p = .001$, $\eta_p^2 = .39$ and relieved states, $F(2, 28) = 5.84$, $p < .01$, $\eta_p^2 = .29$ across the three timings. The happy-score before induction ($M = 4.93$, $SD = 1.1$) significantly decreased after neutral induction ($M = 3.93$, $SD = 1.5$), $t(14) = 2.96$, $p = .01$, and slightly decreased further after the experiment ($M = 3.87$, $SD = 1.2$). The relieved-score before induction ($M = 2.80$, $SD = 1.8$) marginally decreased after neutral induction ($M = 2.07$, $SD = 1.8$), but significantly increased after the experiment ($M = 3.47$, $SD = 2.2$), $t(14) = -3.40$, $p < .01$.

In short, the intended angry level increased after the induction procedure and decreased while driving. However, after driving with the ER and SA systems, the angry state returned to the same level as before induction. As in Experiment 1, there were some accompanying changes in other affective states. After either neutral or anger induction, the happy-score decreased and did not return to the level before induction. Also, in the no-sound and the neutral conditions, the relieved-score decreased after induction, but increased again after the experiment.

Subjective Judgment

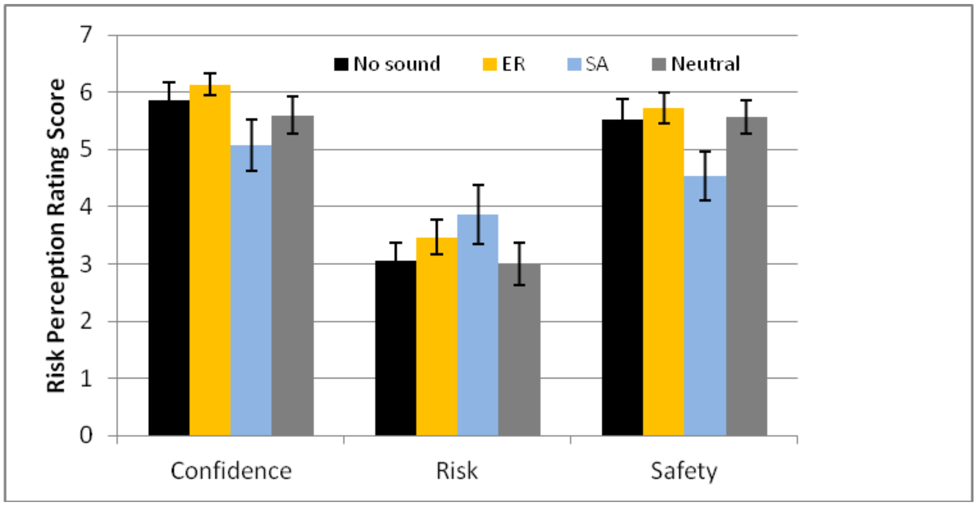


Figure 13. Subjective judgment rating results. Overall, there was no significant result on the subjective judgment rating. Error bars indicate standard error of the mean.

Overall, ANOVA results showed no significant result on subjective judgment ratings across all the conditions (Figure 13). The subjective judgment ratings were conducted before the start of the drive and any intervention. Therefore, the focus of analysis was in the comparison between the induced anger conditions (no-sound, ER, SA) and the neutral condition. When the neutral state was compared with the mean of the three angry conditions, the results showed similar *patterns* to those in Experiment 1: the confidence level was slightly higher in the angry conditions (M = 5.7) than in the neutral (M = 5.6); the accident risk was slightly higher in the angry conditions (M = 3.5) than in the neutral (M = 3); the driving safety was slightly lower in the angry conditions (M =

5.3) than in the neutral (*M* = 5.6). However, even though all of these differences were repetitively shown both in Experiments 1 and 2, they did not reach the statistically reliable level.

Driving Performance

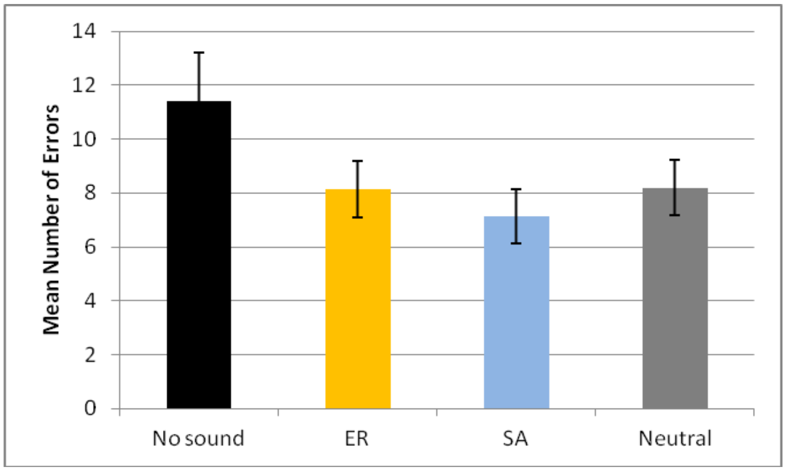


Figure 14. Number of errors across the conditions (manual log). The no-sound condition showed consistently more errors than other conditions. Error bars indicate standard error of the mean.

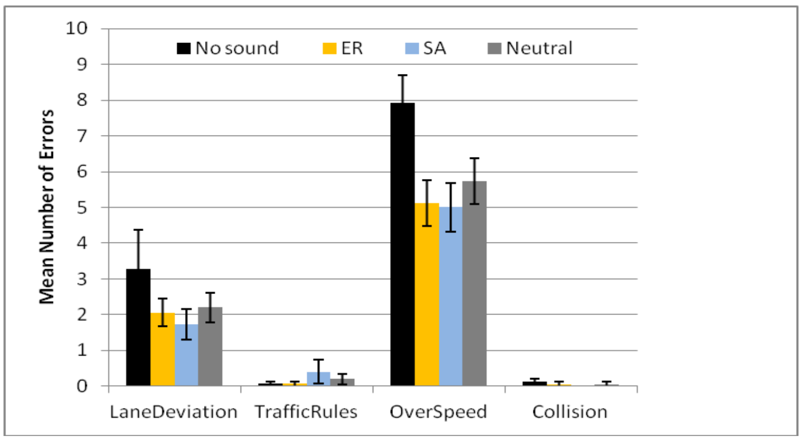


Figure 15. Number of errors according to error type (manual log). Error bars indicate standard error of the mean.

Similarly to Experiment 1, driving performance data was collected (1) manually by a real-time judge who was present at all times and (2) by system logging.

(1) Manual log: Manually counted number of driving errors was aggregated across four performance categories (see Figure 14). An overall ANOVA showed marginally significant results, $F(3, 56) = 2.15$, $p = 0.10$. The no-sound condition (M = 11.4, SD = 7.0) showed consistently more driving errors than other conditions: the ER (M = 8.13, SD = 1.1) (p = .07), the SA (M = 7.13, SD = 0.99) (p = .02), and the neutral (M = 8.2, SD = 3.9) (p = .08). Even though the intervention using both speech-based systems reduced driving errors similarly to the neutral level, the SA system led to a larger improvement. For over speed, a one-way ANOVA showed statistically significant results among conditions, $F(3, 56) = 3.74$, $p < .05$. For the multiple comparisons, a Least Significant Difference (LSD) post-hoc analysis (Fisher, 1935) was conducted. The analysis showed that the no-sound condition (M = 7.93, SD = 2.9) showed consistently higher number of over speed errors than the other conditions: the ER (M = 5.13, SD = 2.5) ($p < .01$), the SA (M = 5.0, SD = 2.7) ($p < .01$), and the neutral (M = 5.73, SD = 2.7) ($p < .05$).

(2) System log: The log data were also analyzed as in Experiment 1. An ANOVA showed that there were significant differences in the number of collisions, $F(3, 56)$ = 7.44, $p < 0.\ 01$. An LSD post-hoc analysis showed that the SA condition (M = 0.80, SD = 0.8) led to significantly fewer number of collisions than the no-sound condition (M = 2.13, SD = 1.5) ($p < .01$) and the neutral condition (M = 2.21, SD = 1.9) (p < .01). The ER condition (M = 1.13, SD = 0.7) also led to significantly fewer number of collisions than the no-sound ($p < .05$) and the neutral condition ($p < .05$). In conclusion, both of the

speech-based systems significantly reduced the number of collisions compared to the no-sound condition and even the neutral condition. No other comparison reached a statistically reliable result.

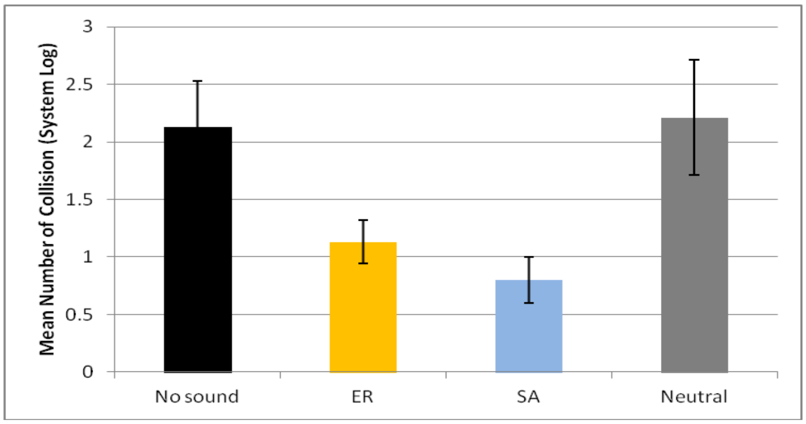


Figure 16. Number of collisions (system log). Error bars indicate standard error of the mean.

These consistent results were confirmed by correlations between the manual log data and all of the system log data (with lane deviation, speed, steering angle, and brake pedal force, *ps* $< .05$). For driving experience, years of driving did not show a significant correlation with the number of errors ($p > .05$).

Situation Awareness

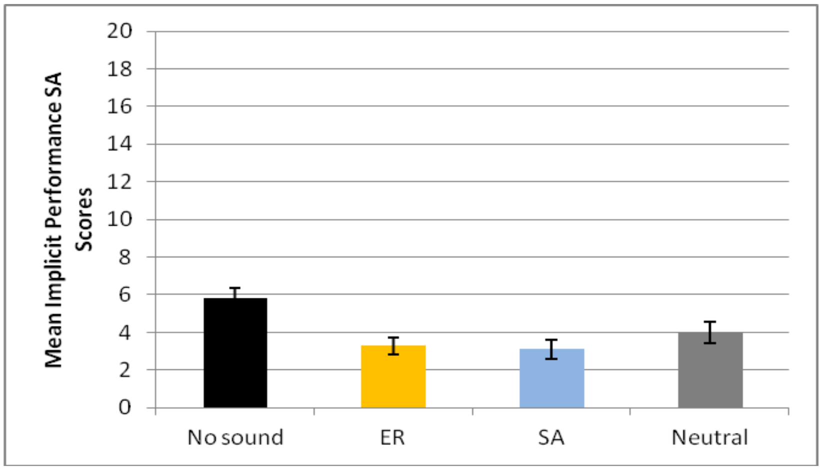


Figure 17. Implicit performance SA scores. In the no-sound angry condition, the score was higher than in other conditions, which means lower driver situation awareness. Error bars indicate standard error of the mean.

Because all parts of the offline questionnaire scores were not significantly different, the analysis focused on implicit performance measures. Figure 17 shows the mean implicit performance scores. Note the "backwards" scale in implicit performance measures, as in Experiment 1. There were significant differences among the conditions, $F(3, 56) = 5.25$, $p < .01$. Subsequent LSD post-hoc analyses showed that the induced anger in the no-sound condition ($M = 5.8$, $SD = 2.2$) led to significantly higher (worse) scores than the neutral condition ($M = 4.0$, $SD = 2.2$) ($p < .05$), the ER condition ($M = 3.3$, $SD = 1.8$) ($p = .002$), and the SA condition ($M = 3.1$, $SD = 1.9$) ($p = .001$). These results mean that participants in the angry state without intervention had lower driver situation awareness than in the neutral state or in both of the speech-based system intervention conditions.

Implicit performance SA scores were significantly positively correlated with the number of over speed in the manual log ($R^2 = .335$, $p < .01$), the average speed in the system log (R^2 = .468, $p < .001$), and the number of collisions in the system log (R^2 = .358, $p < .01$). Offline SA questionnaire part 1 scores were also significantly negatively correlated with the number of collision in the system log (R^2 = -.281, $p < .05$). Years of driving did not show significant correlation with situation awareness scores ($p > .05$).

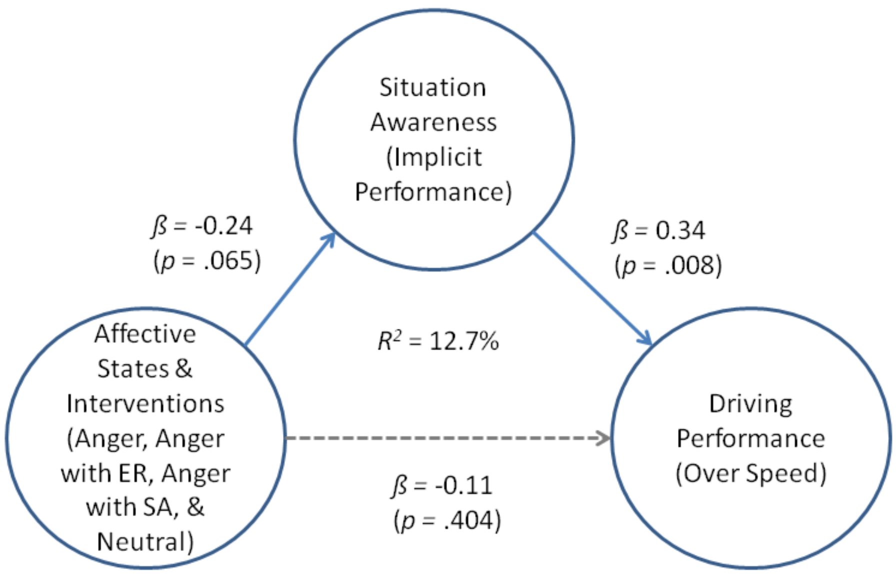


Figure 18. The mediation effects of implicit performance SA scores in the relationship between affective states and the number of over speed. Affective states influenced over speed only through situation awareness, which means a full mediation.

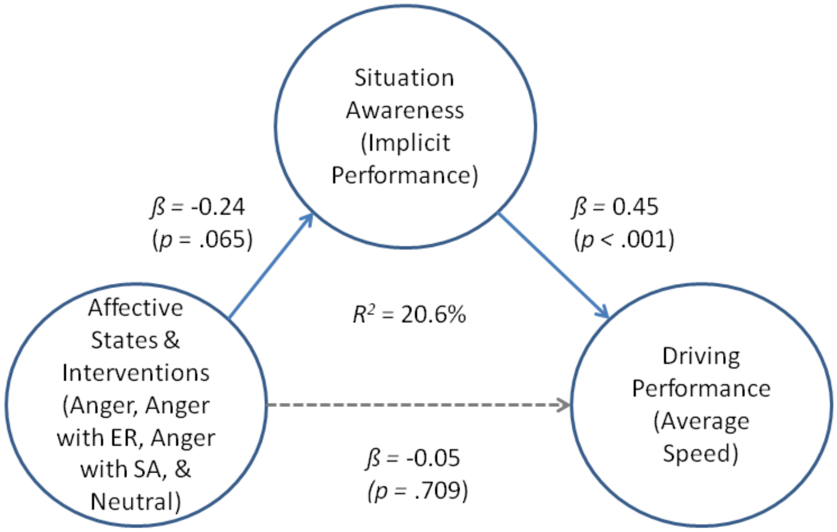


Figure 19. The mediation effects of implicit performance SA scores in the relationship between affective states and average speed. Affective states influenced average speed only through situation awareness, which means a full mediation.

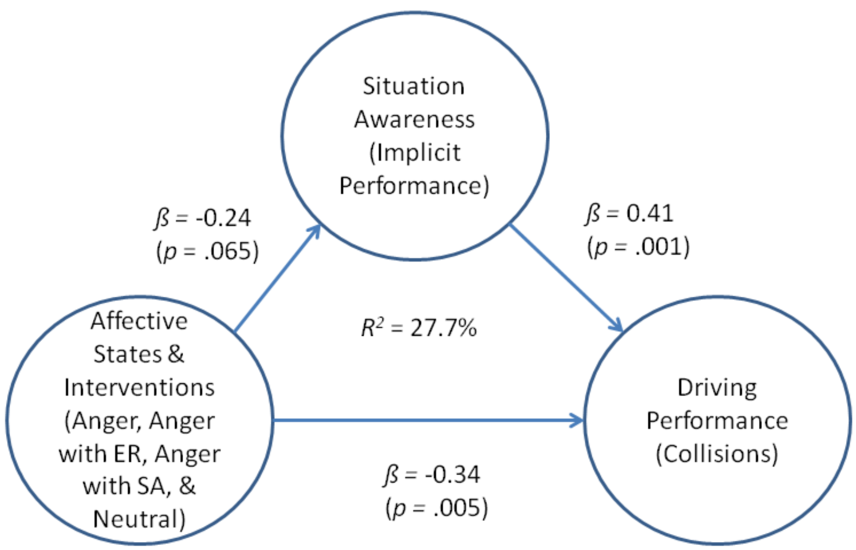


Figure 20. The mediation effects of implicit performance SA scores in the relationship between affective states and the number of collision. Affective states directly influenced the number of collisions as well as through situation awareness, which means a partial mediation.

These consistent results in Experiment 1 and Experiment 2 supported the main hypothesis of this dissertation that induced affect would decrease driver situation awareness and then driving performance in turn. This hypothesis was statistically tested with path analysis using multiple regression. Based on the hypothesis, mediation models were constructed among affective states, implicit SA scores, and various driving performance measures. Three mediation analyses showed predictive models (Figures 18-20). First, affective states and interventions predicted implicit SA scores, $F(1, 58) = 3.54$, $p = .065$ ($p = .043$ in Experiment 1). Implicit SA scores also predicted the number of over speed (manual log), $F(1, 58) = 7.62$, $p = .008$. However, affective states and interventions did not predict the number of over speed when controlling for implicit SA scores, $F(1, 58) = 2.00$, $p = .162$. Therefore, in this case, affective states and interventions influenced over speed only through situation awareness and when controlling situation awareness, affective states and interventions did not directly influence over speed, which shows a full mediation model. This full mediation model could account for 12.7% of the variance in over speed.

Second, a similar pattern appeared when setting average speed (system log) as a driving performance variable. Implicit SA scores predicted average speed, $F(1, 58) = 14.57$, $p < .001$. However, affective states and interventions did not predict average speed when controlling for implicit SA scores, $F(1, 58) = 1.15$, $p = .29$. Therefore, in this case, affective states and interventions influenced average speed only through situation awareness and when controlling situation awareness, affective states did not directly influence average speed, which also shows a full mediation model. This full mediation model could account for 20.6 % of the variance in average speed.

Third, a different pattern appeared when setting the number of collisions (system log) as a driving performance variable. Implicit SA scores predicted the number of collision, $F(1, 58) = 11.53$, $p = .001$. In addition, affective states and interventions also predicted the number of collision, $F(1, 58) = 11.54$, $p = .001$. Therefore, in this case, affective states directly influenced the number of collisions as well as through situation awareness, which shows a partial mediation model. This partial mediation model could account for 27.7 % of the variance in the number of collisions.

Perceived Workload

Figure 21 shows the weighted overall perceived workload scores. An ANOVA revealed a statistically significant difference in perceived workload among the four conditions, $F(3, 56) = 2.82$, $p < .05$. The LSD post-hoc tests showed that the ER (M = 61.6, SD = 20.3) ($p < .05$) and the SA (M = 60.9, SD = 18.5) ($p < .05$) significantly reduced perceived workload compared to the neutral condition (M = 76.4, SD = 13.7). A separate ANOVA for the non-weighted mental demand also showed a statistically significant difference, $F(3, 56) = 2.94$, $p < .05$. The LSD post-hoc tests showed that the SA (M = 67.0, SD = 26.9) ($p < .05$) significantly reduced mental demand compared to the neutral condition (M = 91.0, SD = 24.4).

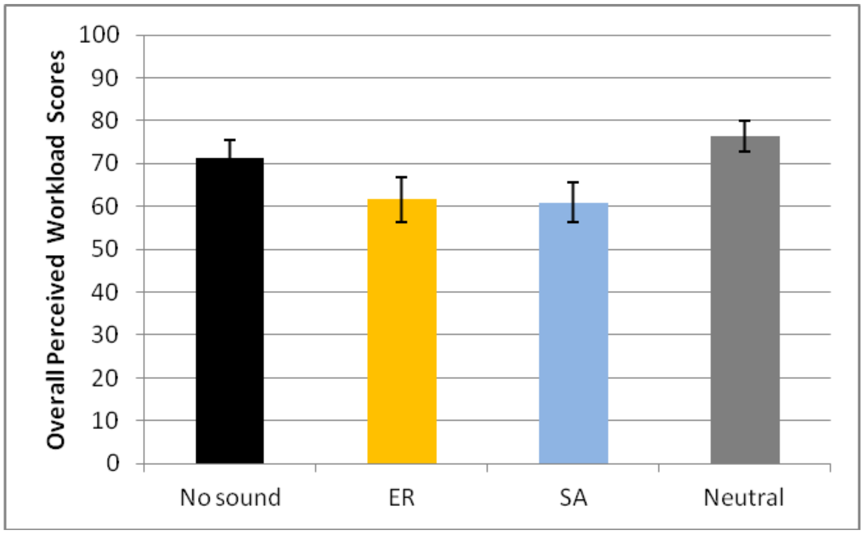


Figure 21. Overall perceived workload scores. Workload scores in the two speech-based system conditions (ER and SA) were significantly lower than that in the neutral condition. There was no difference between the no-sound and the neutral conditions. Error bars indicate standard error of the mean.

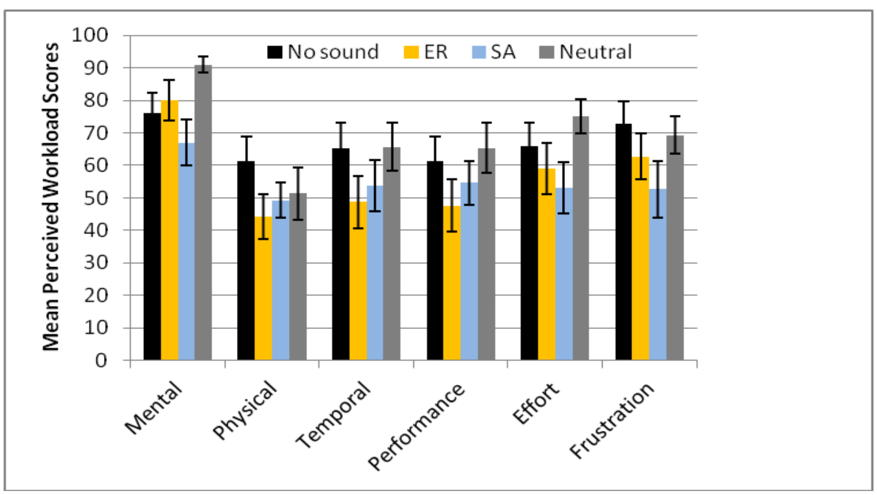


Figure 22. Subcomponent scores of perceived workload. The mental demand score was significantly lower than in the SA condition than in the neutral condition (see leftmost cluster of bars). Error bars indicate standard error of the mean.

Speech-Based System Assessment

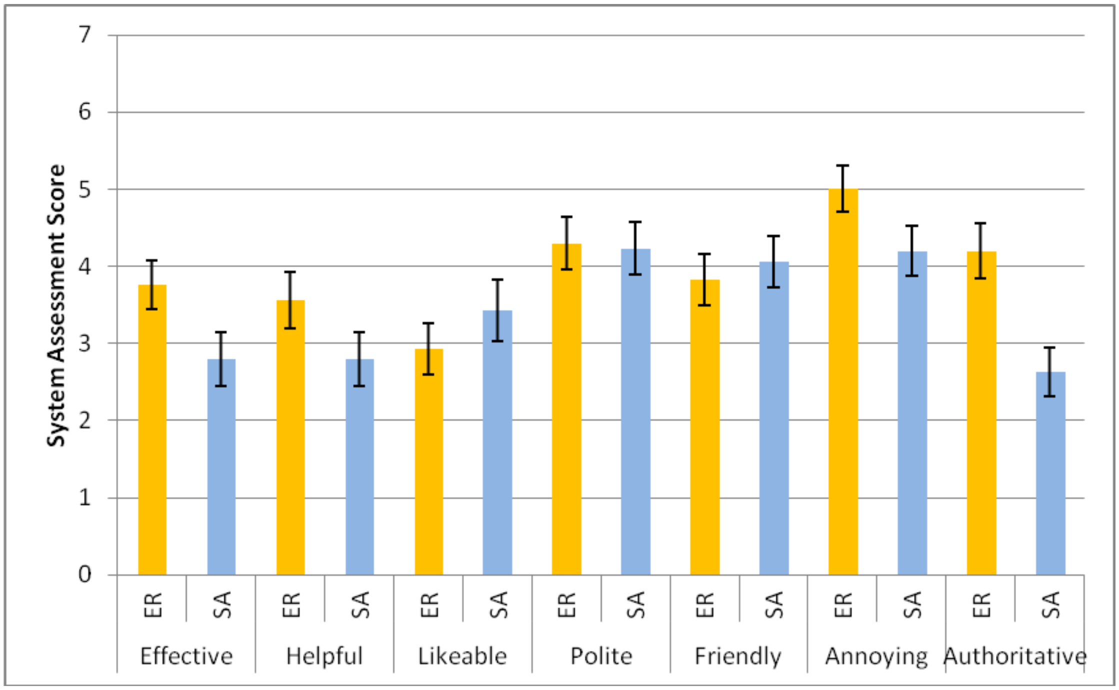


Figure 23. System assessment scores for both speech-based system conditions. 'Effective' and 'authoritative' scores in the ER condition were significantly higher than in the SA condition. Error bars indicate standard error of the mean.

For the analysis of system assessment questionnaire results, paired samples t-tests were conducted. The ER (*M* = 3.77, *SD* = 1.8) showed significantly higher 'effective' scores than the SA (*M* = 2.80, *SD* = 1.9), *t*(29) = 2.23, *p* < .05. However, the ER (*M* = 4.20, *SD* = 2.0) showed significantly higher 'authoritative' scores than the SA (*M* = 0.67, *SD* = 0.7), *t*(29) = 2.77, *p* = .01. Moreover, the ER (*M* = 5.00, *SD* = 1.7) showed marginally higher 'annoying' scores than the SA (*M* = 4.20, *SD* = 2.0), *t*(29) = 1.69, *p* = .10. In addition, participants showed a tendency to react or respond more to the speech-based system in the SA condition (*N* = 9, *M* = 1.64, *SD* = 0.7) than in the ER condition (*N* = 5, *M* = 0.67, *SD* = 0.7), *t*(23) = -5.51, *p* = .061. To illustrate, participants in the SA condition were likely to respond to #1 (restaurants), saying the name of the restaurants they saw and #2 and #3 (wild driver detector), agreeing, laughing, or asking about it.

Discussion of Experiment 2

Experiment 2 replicated and extended Experiment 1 to assess the effectiveness of the speech-based systems (the ER and SA conditions) compared to the induced anger state (the no-sound condition) and the neutral state (the neutral condition) as a baseline. Just as in Experiment 1, various dependent measures were evaluated including subjective judgment, driving performance, situation awareness, and perceived workload across four different conditions. The overall results demonstrated that angry effects on situation awareness and driving performance can be mitigated by the intervention of the speech-based systems using the attention deployment strategy. Moreover, both speech conditions significantly reduced perceived workload compared to the neutral condition as well as the angry state compared to the no-sound condition. Interpretations of the detailed results on those variables and practical applications of the speech-based system are discussed further.

Affect Induction

Following Experiment 1, Experiment 2 supported the idea that writing about past experiences works well as affect induction for this type of driving experiment. Given that driving studies seem to require a more complicated and longer-lasting task than in traditional psychological affect research, this new protocol looks promising for further affect research in a driving domain.

In all three anger conditions (the no-sound, ER, SA), the angry state increased after induction and decreased as the experiment went on. However, in the no-sound condition, even after the experiment a certain amount of anger still remained significantly higher than before induction, which accounts for the source of degenerated situation awareness and driving performance in that condition. In contrast, in the two speech-based system conditions, the angry scores after the experiment significantly decreased compared to the scores after induction and these values returned to the same level as before induction. It was expected that the angry rating score in the ER condition would become higher or at least, stay at a similar level after the experiment because young drivers were expected to resist the system that gives direct commands or tries to regulate participants' affective state (Jeon et al., 2011). In fact, the participants did not show a high resistant tendency to the ER system. That might be because they felt the system was 'effective' and 'helpful' for obtaining their task goal, which is safe driving.

Again, there were some accompanying affective changes. In all of the conditions, the happy state decreased after anger or neutral induction and these reduced happy states did not return to the level before induction. It might be because the driving task was quite demanding with successive hazard events. In the no-sound and the neutral conditions, the relieved-score decreased after induction, but increased again after the experiment, which seems intuitive. In the SA condition, the confused state decreased after anger induction. It might be explained by the cognitive appraisal mechanism, in which anger is deeply related to 'certainty' (Ellsworth & Smith, 1988; Smith & Ellsworth, 1985). Just as in Experiment 1, the embarrassed-score increased in the no-sound condition. In this case, however, it increased after the experiment (in Experiment 1 it sharply increased after anger induction). The relationship between angry and embarrassed states needs to be further explored.

Subjective Judgment

Even though subjective judgment results were not statistically reliable, the pattern of the results was exactly the same as in Experiment 1. Anger led to a numerically higher risk perception and lower safety level, which is also consistent with previous research (Jeon, Yim, & Walker, 2011). In addition, anger led to a slightly higher confidence in their general driving compared to neutral. Again, this can be interpreted by two different mechanisms. Participants in the angry state might feel lower safety and higher risk based on their socio-cultural stereotype ("an angry driver is generally risky"), whereas they might feel more confident with higher controllability based on the cognitive appraisal theory.

Two reasons can be discussed as to why the results did not lead to the conventionally significant level. First, the driving questions used in the current dissertation might be deeply related to participants' *specific* driving experience rather than being *general risk* judgment (e.g., death rate from a disease) as is normally used in traditional social judgment studies. According to Forgas (1995), if the judgment is required on the topics to which respondents have direct access from their past experience (i.e., their usual driving), then affective effects are unlikely to appear. Another reason could be the small number (45 in all angry conditions) of participants in the study compared to hundreds in the traditional affect-judgment research. Both of these reasons could reduce statistical power in the subjective judgment ratings in the current dissertation.

Driving Performance

Similar to the results of Experiment 1, angry participants consistently showed more errors than neutral drivers, in most error types. Both of the speech-based systems significantly reduced overall driving errors and number of collisions. Taking Experiment 1 and Experiment 2 together, an angry state can significantly degrade various driving performance dimensions, including lane deviation, over speed, and ultimately the number of collisions. This result supports the contention that driving while angry may be as serious as driving while performing a secondary task, and therefore needs to be further investigated.

Situation Awareness

As expected, driver situation awareness was degenerated by induced anger when measured using implicit performance. The offline questionnaire did not show a similar pattern to that in Experiment 1. Again, the one time survey at the end of the experiment may not have had sufficient statistical power. Implicit performance scores were also positively correlated with several driving performance variables, but driving experiences were not. These positive results motivated a push to identify causal relationships between affective states, situation awareness, and driving performance. In addition to correlation, path analysis clearly supported the main hypothesis of this dissertation, thereby confirming that induced affect decreases driver situation awareness and then driving performance in turn.

There were affective effects on situation awareness, but those effects were not statistically significant. It could be explained by looking at the components of the affective state conditions. Affective states included three induced anger conditions and a neutral condition: the no-sound (anger induction without intervention), the ER (anger induction with the ER system), the SA (anger induction with the SA system), and the neutral (neutral induction without intervention). The statistical power might be reduced because there were only 15 participants in the neutral group and two other angry conditions were also with the intervention, instead of purely angry states.

The association between affective states and speed-related performance variables (i.e., over speed and average speed) was fully mediated by situation awareness. These full mediation models imply that affective effects appear only via the effects of reduced situation awareness. On the other hand, the association between affective states and the number of collisions was partially mediated by situation awareness. This partial mediation model implies that affective states can have an impact on the number of collisions either with or without the effects of situation awareness. In other words, affective effects could influence collisions through other plausible channels (e.g., motor planning and control, Eccles, Ward, Janelle, Le Scanff, Ehrlinger, Castanier, and Coombes, 2011). Given that a collision is a much more complicated outcome compared to speeding, these results accord closely with our intuition. As mentioned, research has shown positive associations between situation awareness and one or more dimensions of driving performance (Ma & Kaber, 2005, 2007). However, constructing prediction models is expected to contribute more to identifying relationships and mechanisms of affective effects and other theoretical constructs. In this light, the results are very promising for the future use of implicit performance measures for driver situation awareness assessment and prediction of driving performance.

Given that situation awareness is a necessary but not a sufficient condition for performance (Endsley, 1995b), the fact that the speech-based system using SA prompts consistently improved not only driver situation awareness, but also driving performance, is promising for applications of this strategy in speech-based affect mitigation systems. In addition, it bodes well that several performance measures in the SA condition for angry drivers were even better than in the neutral condition. That is, using the speech-based system does not add any workload to a primary driving task, but rather outperformed the neutral state as well as the angry state in some performance metrics.

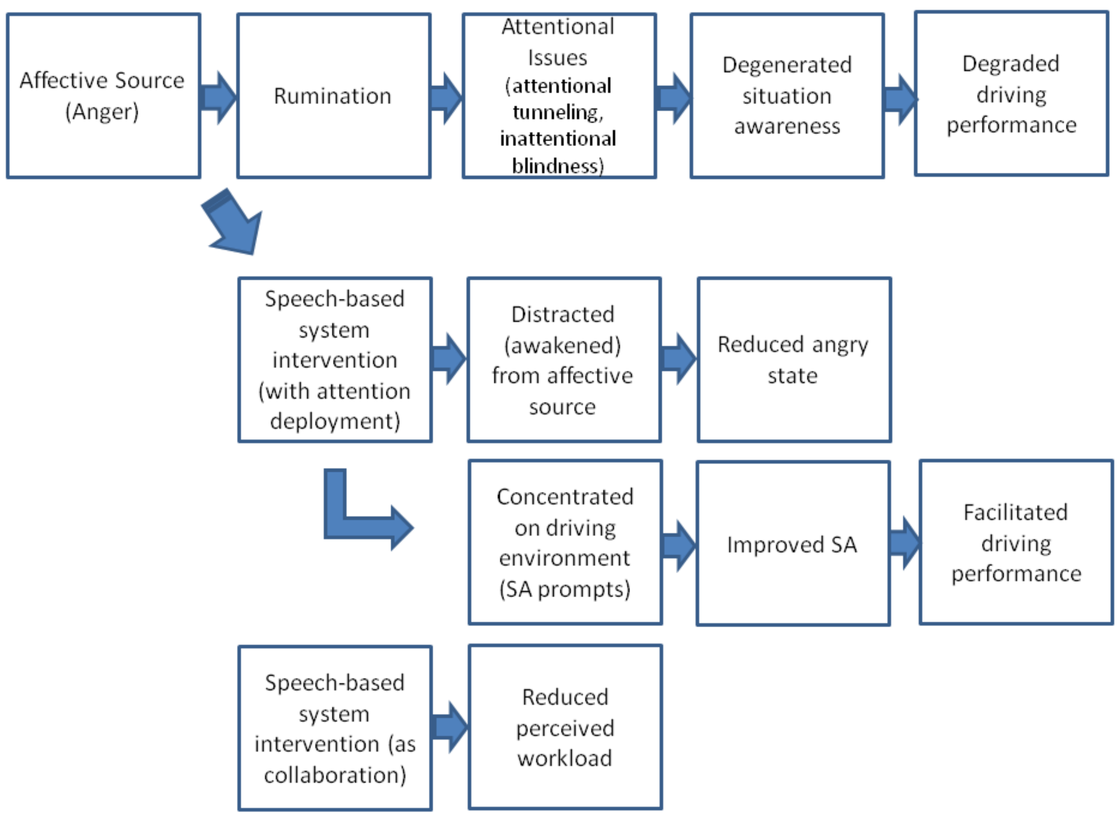


Figure 24. A logical flow chart about the phenomena and mechanisms across Experiment 1 and Experiment 2.

A partial but logical flow chart about the phenomena and mechanisms can be drawn based on Experiment 1 and Experiment 2 (see Figure 24). Induced affect (anger) resulted in rumination followed by further attentional issues such as attentional tunneling or inattentional blindness. These issues brought about degenerated situation awareness and then reduced driving performance (Experiment 1). The intervention of the speech-based systems using an attention deployment strategy was conducted here. It consisted of two different components, distraction and concentration. By distracting (or awakening) participants from their affective source, their angry state was decreased. By concentrating them on the driving environment using the SA prompts, their situation awareness increased, which led to the increase of driving performance. Note that in both speech conditions, there were situation related prompts and this might be a confounding variable for the effectiveness of the ER system. In addition, collaboration with the speech-based system in an unfamiliar, demanding driving task seemed to make participants' perceived workload decrease, compared to independent driving in the neutral state.

Perceived Workload

Experiment 2 confirmed the results of Experiment 1, showing that induced anger does not increase perceived workload. Additionally, it shows that using either the ER or the SA speech-based system can decrease driver perceived workload compared to the neutral state. In the SA condition, specifically, mental workload was significantly reduced and this can account for the reduction of overall workload.

In addition to the different subjective assessment results, the different patterns in the results of workload subcomponents between the two speech-based systems can delineate their different mechanisms. The SA system led to the lowest scores in mental demand, efforts, and frustration, whereas the ER system led to the lowest scores in physical demand, temporal, and performance. It can be cautiously inferred that the SA system might influence more covert, psychological components, but the ER system might influence more overt, performance-based components. That is, even though the two systems seemed to reduce overall perceived workload similarly, underlying mechanisms could be differentiated. Thus, they could be applied to different populations or different situations.

Some researchers (Horrey & Wickens, 2004; Wickens & Liu, 1988) have proposed that a discrete auditory task may cause a brief lapse in the performance of a continuous visual task while the auditory stimulus is attended to based on the auditory modality's superiority to attract attention (Spence & Driver, 1997; Stanton, Booth, & Stammers, 1992). In fact, a number of studies have shown an auditory cost in the use of in-vehicle information displays (Dingus et al., 1997; Horrey & Wickens, 2004; Lee et al., 1999; Matthews, Sparkes, & Bygrave, 1996). Related research has shown that even hands-free, auditory cell phone conversations (Strayer & Drews, 2007) or the speech-based e-mail system (Lee, Caven, Haake, & Brown, 2001) can impair driver attention, which may result in degenerated driving performance.

The speech-based systems used here, however, did not preempt a driving task. Rather, it improved driving performance and reduced perceived workload. Therefore, the effects of the auditory user interfaces may depend on the level of processing or the distraction level caused by the auditory modality interaction. For instance, even in the similar affect mitigation system, if the intervention system requires deep, complex cognitive processes (e.g., cognitive reappraisal of the situation), it might be able to increase a driver's perceived workload.

System Assessment and Design Implications for Affect Detection and Mitigation

Interfaces

Even though the two systems similarly reduced the angry state and perceived workload and improved situation awareness and driving performance, the results of the subjective assessment were different from those results. The ER system was rated more 'effective' than the SA system. Participants might think that way because directive messages felt more 'helpful' in such a highly demanding situation, even with an angry state. Nonetheless, simultaneously, the ER system turned out more 'annoying' and more 'authoritative'. Research has shown that performance enhancement of the auditory user interfaces may not guarantee subjective preference or actual use of the system (Edworthy, 1998; Jeon & Walker, 2011c). In other words, young drivers might turn off the speech-based system if they do not like it, regardless of whether the system can improve driving performance and safety. Motivated drivers with TBI, however, might want to use such a directive command style system (Jeon et al., 2011) despite its authoritative attitude because they eagerly want to recover their independent driving and reintegrate into the community (Jeon & Walker, 2011a). However, young drivers without such motivation might not want to use it.

On the other hand, the SA system was rated slightly more 'likable' (M = 3.4) and 'friendly' (M = 4.1) and less 'annoying' (M = 4.2) than the ER system. Even though those results seem to be very subtle, that may be an important distinction for the intervention for *young* drivers. Research has proposed that a more indirect and unobtrusive approach for the intervention, or even an intervention below a user's conscious awareness, may be better for a complex driving task (Jeon & Walker, 2011b). In any case, both of the two speech-based systems need to be iteratively improved in order to overcome existing caveats in terms of low subjective ratings and acceptance level (e.g., likable and friendly scores in the SA system are below or around 4, a mid point).

Drivers in an angry state showed lower situation awareness and worse driving performance just as drivers usually show with a secondary task. However, as mentioned, there is one important distinction between them. Drivers are seldom aware of the decrease of their situation awareness (Walker et al., 2006). Even worse, drivers with anger did not show any attempt to compensate for their performance compared to drivers who perform secondary tasks while driving and try to appropriately compensate for their degraded driving. Therefore, the intervention system may also need to be designed to help drivers compensate for their driving behavior in addition to trying to mitigate their affective effects. This can be done when the system gets intelligent enough to detect any hazard situations and then accordingly manage the timing and duration of the affect interventions in addition to alerting drivers of the dangers and safety issues on the road, just as passengers easily adjust the conversation in such a situation (Ferlazzo, Fagioli, Di Nocera, & Sdoia, 2008).

CHAPTER 7

CONCLUSIONS AND FUTURE WORKS

The present dissertation investigated the relations between various affective effects on driver situation awareness and performance. This big picture on the theoretical framework has been narrowed down and empirically tested with a focus on anger. Experiment 1 demonstrated that the induced angry state degenerated driver situation awareness and negatively influenced multiple variables of driving performance in turn. However, there were no effects of anger on perceived workload, which suggests that researchers need a different approach to affective effects from a traditional workload mechanism. Further, given that anger seemed not to increase perceived workload, and in fact increased a driver's confidence level, affective effects might be more serious than the effects of secondary tasks, for which a driver is likely to show some adaptive compensation.

Experiment 2 showed the effectiveness of the use of a speech-based in-vehicle system to mitigate affective effects on driver situation awareness and performance. In order for drivers in the angry state to concentrate more on the driving environment as well as to distract and awaken them from rumination or obsession with their affective source, the system included situation awareness prompts based on the attention deployment strategy in the process model of emotion regulation. Additionally, both the ER and the SA systems successfully reduced the angry level and perceived workload. Nonetheless, it was also shown that more research is needed, with considerably more variables in order to arrive at an optimal design for the speech-based system. In addition, based on the results of Experiment 2, several prediction models between affective states and driving performance were constructed with partial or full mediations from the effects of situation awareness.

These fruitful results could contribute to both theoretical and practical aspects in further affect-driving research. First, the relationships among various affect, cognition, and performance constructs were more deeply explored, especially by integrating the construct of situation awareness into affect research. Second, a reliable new experimental protocol was set up for identifying affective effects on driving-related variables. Finally, design guidelines for more refined speech-based in-vehicle intervention systems can be drawn, which can also be used with an affect detection system in the near future.

Despite all of these contributions of the current dissertation, more research topics remain to be addressed.

(1) The self rating of particpants' affective states in an experimental protocol may be improved by adding more systematic affect detection systems, such as facial and speech detection or physiological sensing (Jeon & Walker, 2011a). For practical applications, how to effectively integrate an affect detection system with an affect mitigation system is also a crucial challenge.

(2) The plausible interaction effects between transient affective states in the current dissertation and a long-term trait such as mood or personality (Simer, Lajunen, & Oezkan, 2005) should be further investigated.

(3) Mechanisms and mitigation strategies for other affective states can also be explored, including not only negative affect such as fearful or sad states, but also positive affect such as happy or relieved states. Depending on the type of affective states,

affective effects and underlying mechanisms might be different and thus, the intervention strategy should be specified for each type of affect (Jeon et al., 2011a).

(4) Within the process model of emotion regulation, there are other plausible strategies (e.g., cognitive reappraisal) that can be applied to drivers (Harris, 2011; Harris & Nass, 2011). Even though attention deployment seems to work fine in the current dissertation, and may be the most appropriate based on the existing literature, a conclusion should be drawn through iterative empirical comparisons.

(5) Even within attention deployment, the speech-based system can still be elaborated with more variables such as timing and duration of the speech, gender of speech, partnership, acoustical parameters, or more contextual parameters.

(6) In the same line, the speech-based system using prompts in the form of discrete speech clips can evolve into a more intelligent agent along the lines of the iPhone Siri (Speech Interpretation and Recognition Interface), so that drivers could have an adaptive conversation with the system. The system may also be more intelligent and more effective, with more precise analysis of the environment and judgment about the start and end of the intervention.

(7) Various vulnerable classes of drivers can be examined with this type of affect-driving research, including older drivers, student drivers, and drivers with Traumatic Brain Injury or Post Traumatic Stress Disorder. Based on their unique needs, characteristics and (dis)abilities, a specific mitigation approach might be required when designing an in-vehicle assistive system for a certain target user group (Jeon, Roberts, Raman, Yim, & Walker, 2011).

(8) An investigation of affective effects in addition to secondary task effects on driving is also of interest in order to identify incremental effects in each case, and mitigate complicated effects on driving performance and safety with more sophisticated interventions.

Research on emotions and affect have not had a long history in the in-vehicle research as well as human-machine system research in general. However, traditional affect research has proposed a considerable amount of constructs, taxonomies, hypotheses, and theories that can, and should be applied to affect-related driving research. The approach outlined in this dissertation is expected to help close the existing gap between the traditional affect research and the emerging field of affect-related driving research, and to contribute to each area. The evidence shown here can also guide researchers and practicioners in designing an effecctive in-vehicle affect mitigation system.

APPENDIX A. OFFLINE SA QUESTIONNAIRE

SA Questionnaire

[Part1]

1. What was the maximum and minimum speed of the sign on the highway?
(1) max: 60 min: 50
(2) max: 65 min: 55
(3) max: 60 min: 45
(4) max: 65 min: 50
(5) I don’t know

2. How many exits have you passed on the highway?
(1) 0
(2) 1
(3) 2
(4) 3
(5) 4

3. What was your vehicle speed (mph) at the time you stopped?
(1) 20-30 mph
(2) 30-40 mph
(3) 40-50 mph
(4) 50-60 mph
(5) I don’t know

4. How far away did you stop from the police cars?
(1) less than 500 feet
(2) 500-1000 feet
(3) 1000 feet -2000 feet
(4) more than 1 mile
(5) I don’t know

5. What was the name of the road of the sign you saw last?
(1) Cheboygan
(2) Kalamazoo
(3) Sagatauk
(4) Ypsilanti
(5) I don’t know

6. What was the distance to the road of the sign you saw last?
(1) 1 mile
(2) 3 mile
(3) 1/4 mile
(4) 3/4 mile
(5) I don’t know

7. What was your last lane?
(1) Left lane
(2) Right lane
(3) I don’t know

[Part2]

8. How far have you gone since you entered the highway?
(1) less than 2 mile
(2) 2-4 mile
(3) 5-7 mile
(4) more than 8 mile
(5) I don't know

9. What is **NOT** the name of the street in the intersection you passed?
(1) QUEEN ST
(2) KABER ST
(3) COBB DR
(4) HOLT LN
(5) I don't know

10. What was the gas station that you turned at?
(1) CITGO
(2) BLT
(3) QT
(4) SHELL
(5) I don't know

11. What was the color of the car behind you when you start to drive?
(1) White
(2) Black
(3) Red
(4) Blue
(5) I don't know

12. List all the potential hazard or weird events you saw while you are driving

[Part3]

13. How far apart were the last two intersections in the city?
(1) less than 1 mile
(2) 1-2 mile
(3) 2-3 mile
(4) 3-4 mile
(5) I don’t know

14. What sign was not in the road?
(1) Fish&Chips
(2) Get Away
(3) Gray’s Papaya
(4) Chilichili
(5) I don’t know

15. List all the fast food restaurants you saw while you are driving

APPENDIX B. MOTION SICKNESS ASSESSMENT QUESTIONNAIRE

Motion Sickness Assessment Questionnaire

Part #: _______

On a scale of 0 to 10, where 0 is "not at all" and 10 is "severely," answer each question with the number that best describes how you feel right now.

I feel…	Response
1. sick to my stomach	
2. faint-like	
3. annoyed/ irritated	
4. sweaty	
5. queasy	
6. lightheaded	
7. drowsy	
8. clammy/ cold sweat	
9. disoriented	
10. tired/fatigued	
11. nauseated	
12. hot/warm	
13. dizzy	
14. like I am spinning	
15. as if I might vomit	
16. uneasy	
17. floating	

APPENDIX C. AFFECT-INDUCTION SAMPLE PARAGRAPHS

ANGRY

Example 1

I was so excited to start my first internship experience. I was assigned to develop a webpage for the company and I spent all nights to finish the assignment to meet the short deadline I was given. It was a startup company where everybody was busy and I had nobody to get a tip or feedback from for what I designed. After several attempts to ask for a feedback only to be brushed off, I decided to get it done and then ask for a final checkup instead. After finalizing the work, I reported my work to one of associates, and he showed an attitude of indifference towards my work and told me although not satisfied he'll report my work to the manager for me. I thanked him and continued on to other projects assigned for me. After two months, I was summoned to the manager that I didn't report any progress regarding my first assignment like all the other interns had. To my bewilderment, he told me that he had waited till now thinking that I needed more time to finish it and disappointed that I failed to do so. He even showed me an exemplary work done by another intern which looked exactly like mine! Then did I realize that the associate who I reported to was no associate but an intern who took credit.

Example 2:

This committee was a chance for me to finally show my ability to the senior directors. It was a chance I have been waiting for and had been preparing myself for it for a while now and it has been set for the next day. I had to stay up late to do the final touchups when without realizing, I suddenly fell asleep and it was already late for the meeting when I woke up. I nimbly packed all resources I organized last night and drove my car in a hurry. But after a while, a huge truck blocked the road and series of cars were waiting for that truck to make a U-turn. I saw there was not enough space for the truck and all cars had to back their car one by one to make more space during the already hectic morning hours. It was a disaster!

Neutral

Example 1:
I went to the grocery store to pick up a new carton of milk to replace the one that ran out the day before and some ingredients to make my dinner. I entered the store and grabbed a grocery cart. First, I headed over to the pasta section and picked up a bag of pasta shells and a can of tomato sauce. Then, I went to the fresh produce area to pick out some vegetables for the pasta. Finally, I went down the dairy section to grab a carton of milk. I went to the cashier to check out, unloaded the groceries into the car and drove home.

Example 2:
I needed to pick up my sister from school. The route is one that I am very familiar with. I pulled out from my driveway and drove down my street. I made a right turn at the first stop sign and continued to drive until I reached the main entrance. Then, I turned left onto the main road. I drove down the main road outside my neighborhood and turned left at the third intersection. I continued to drive for about three miles and then made a right turn on the road where the school is located. I turned into the pick-up lane and waited for my sister to come outside. The traffic flow that day was relatively normal and I arrived on time as I had expected.

APPENDIX D. AFFECT RATING QUESTIONNAIRE

	A	B	C	D	E	F	G	H	I	J	K	L
1	Please indicate your current emotional status.											
2	You can input a digit for each affect using 1, 2, 3, 4, 5, 6, 7 on your keyboard.											
3	1 is "not feel at all, 4 is "neutral", and 7 is "strongly feel".											
4												
5		**Emotions**	**Score**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	
6	**1)**	**Fear**			not feel at all			neutral			strongly feel	
7	**2)**	**Happy**										
8	**3)**	**Angry**										
9	**4)**	**Depressed**										
10	**5)**	**Confused**										
11	**6)**	**Embarrassed**										
12	**7)**	**Urgent**										
13	**8)**	**Bored**										
14	**9)**	**Relieved**										
15												
16	**Age**	**Gender (m=0, f=1)**		**Year of driving experience**								
17												
18												

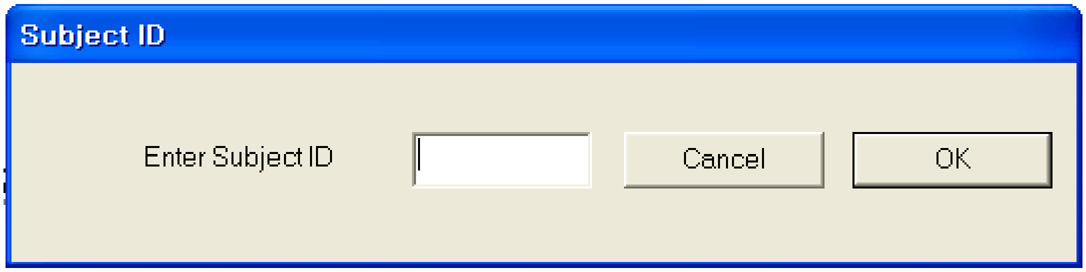
APPENDIX E. SUBJECTIVE JUDGMENT QUESTIONNAIRE

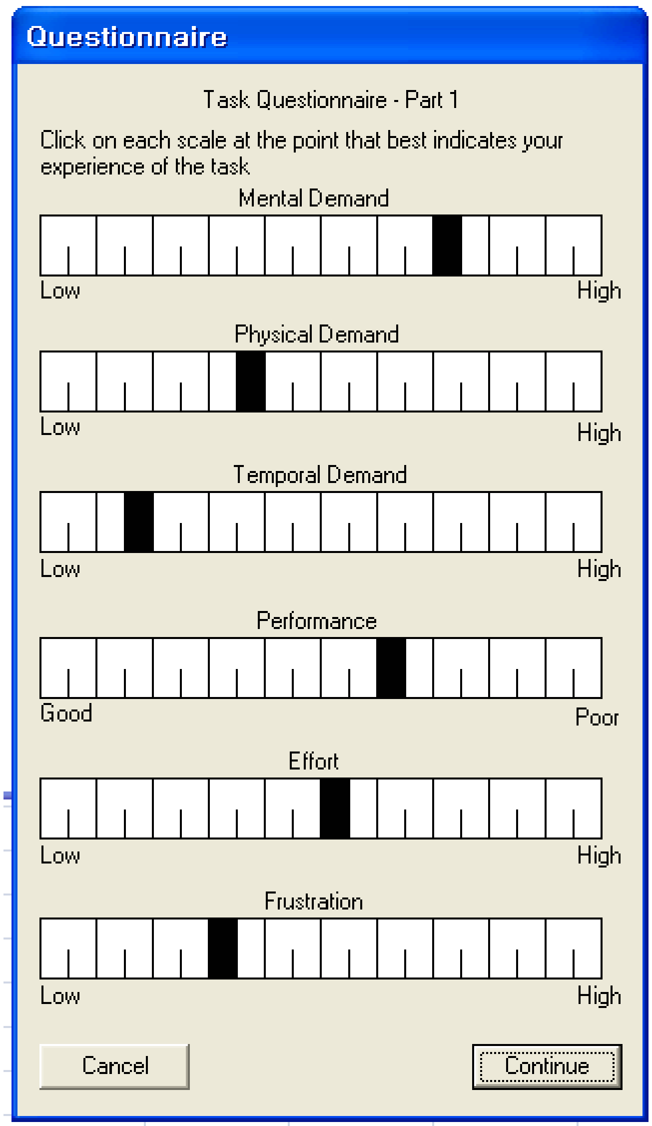
	A	B	C	D	E	F	G	H	I	J	K	L
1	Please indicate your thoughts about your driving behaviors.											
2	You can input a digit for each affect using 1, 2, 3, 4, 5, 6, 7 on your keyboard.											
3	1 is "not at all", 4 is "neutral", and 7 is "strongly".											
4												
5					**1**	**2**	**3**	**4**	**5**	**6**	**7**	
6	**1)**	**How do you feel about your confidence level for usual driving?**			not confident at all			neutral			strongly confident	
7	**2)**	**How much do you generally feel accident risk in your driving?**			not feel at all			neutral			strongly feel	
8	**3)**	**Do you think your driving is safer than other drivers who are your same age and gender?**			not safer at all			neutral			strongly safer	
9												
10												
11												
12												
13												

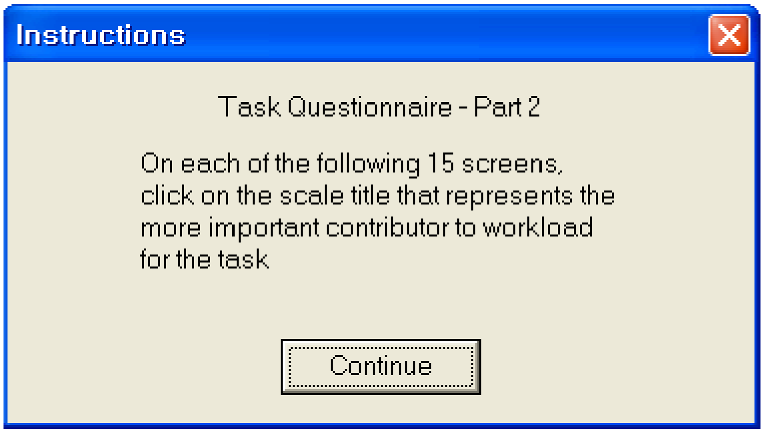
APPENDIX F. SPEECH-BASED SYSTEM ASSESSMENT QUESTIONNAIRE

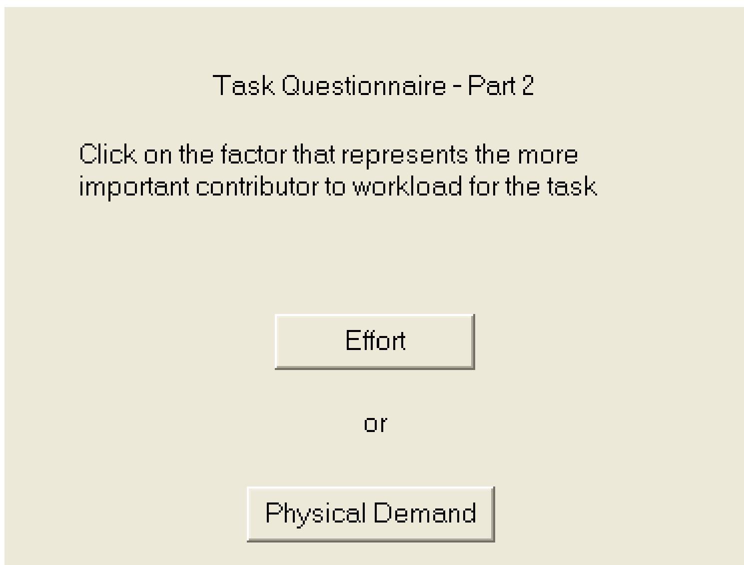
	A	B	C	D	E	F	G	H	I	J	K	L
1	Please indicate how well do the following words describe about speech clips you heard whild driving.											
2	You can input a digit for each adjective using 1, 2, 3, 4, 5, 6, 7 on your keyboard.											
3	1 is "not feel at all, 4 is "neutral", and 7 is "strongly feel".											
4	**Condition A:**											
5		**Emotions**	**Score**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	
6	1)	**Effective for Driving**			not feel at all			neutral			strongly feel	
7	2)	**Intelligent**										
8	3)	**Helpful**										
9	4)	**Likable**										
10	5)	**Polite**										
11	6)	**Friendly**										
12	7)	**Annoying**										
13	8)	**Authoritative**										
14												
15	**Condition B:**											
16	Please indicate in the same way for the other condition											
17												
18		**Emotions**	**Score**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	
19	1)	**Effective for Driving**			not feel at all			neutral			strongly feel	
20	2)	**Intelligent**										
21	3)	**Helpful**										
22	4)	**Likable**										
23	5)	**Polite**										
24	6)	**Friendly**										
25	7)	**Annoying**										
26	8)	**Authoritative**										

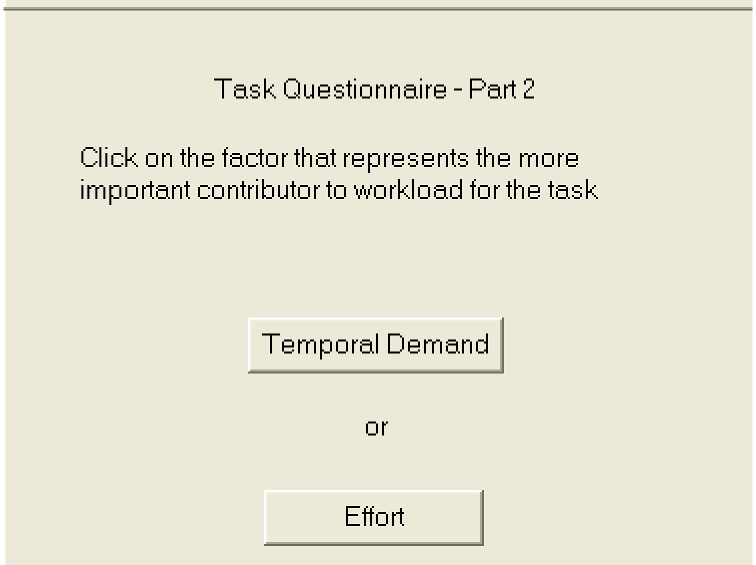
APPENDIX G. ELECTRONIC NASA TLX SCREENSHOTS FOR PERCEIVED WORKLOAD

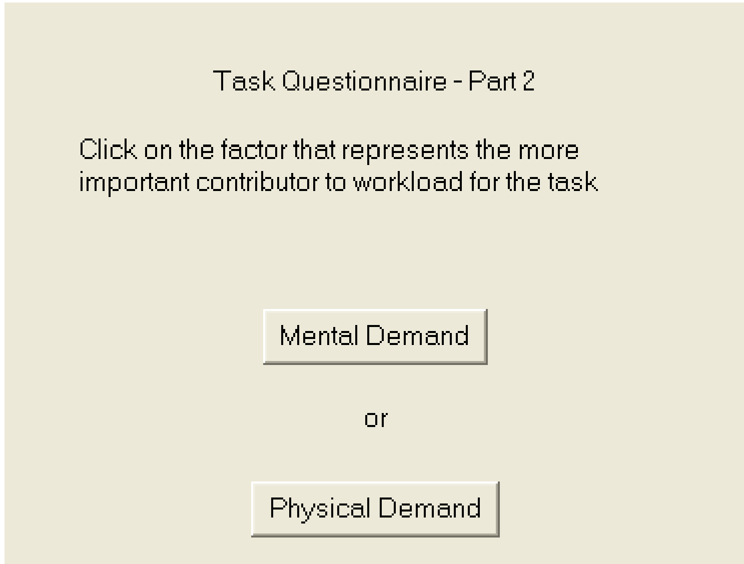


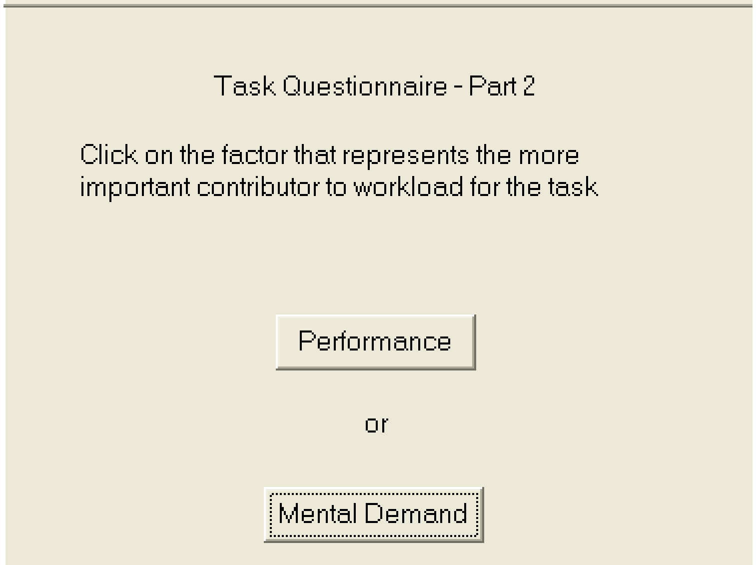


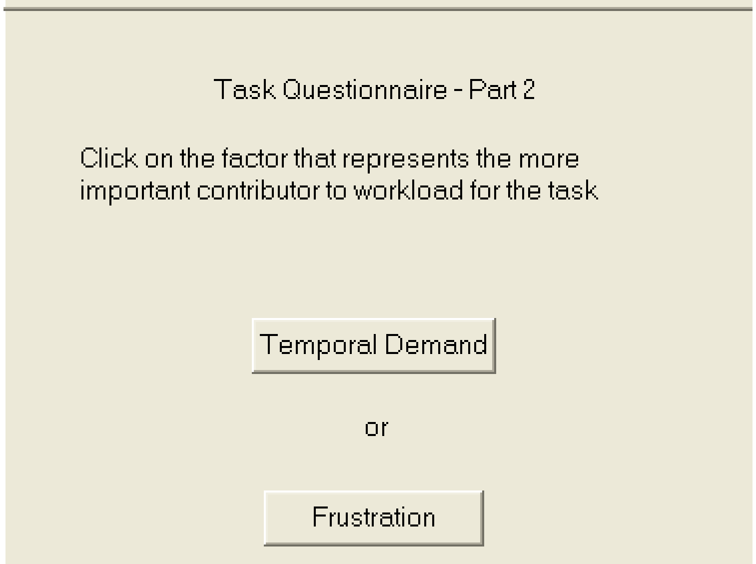

Instructions
Task Questionnaire - Part 2
On each of the following 15 screens, click on the scale title that represents the more important contributor to workload for the task
Continue

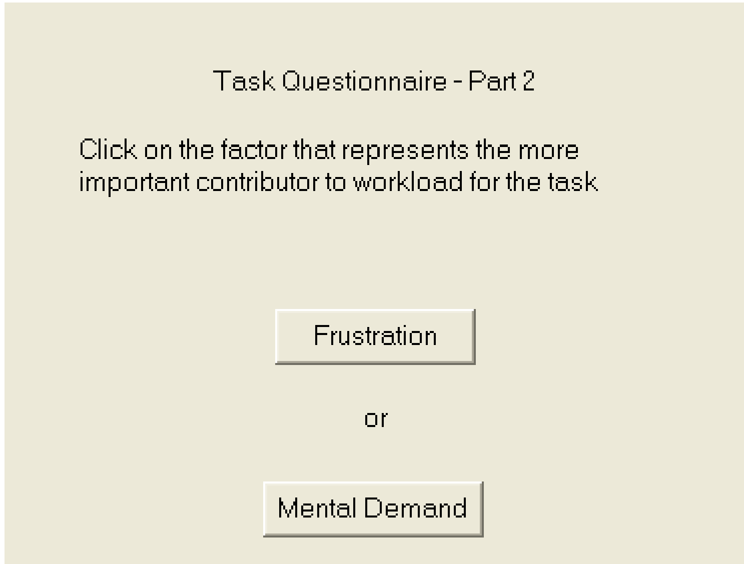

Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Effort
or
Physical Demand

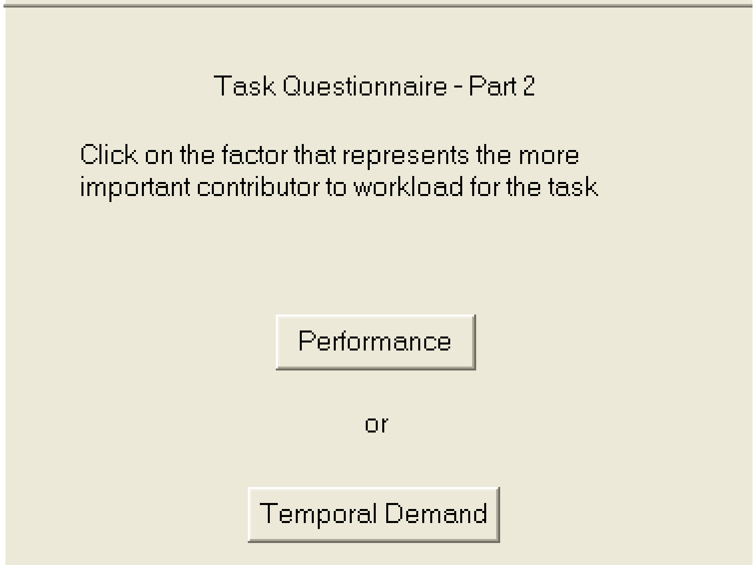

Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Temporal Demand
or
Effort

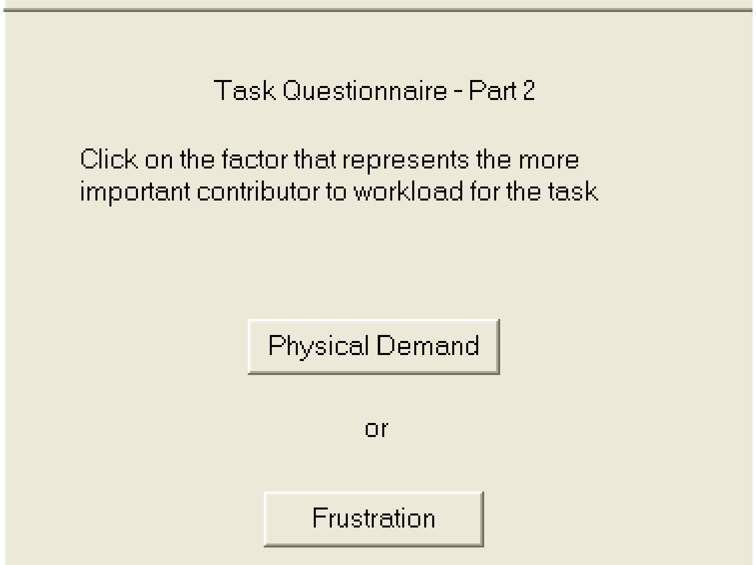

Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Mental Demand
or
Physical Demand


Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Performance
or
Mental Demand


Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Temporal Demand
or
Frustration


Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Frustration
or
Mental Demand


Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Performance
or
Temporal Demand


Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Physical Demand
or
Frustration

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Physical Demand

or

Temporal Demand

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Mental Demand

or

Effort

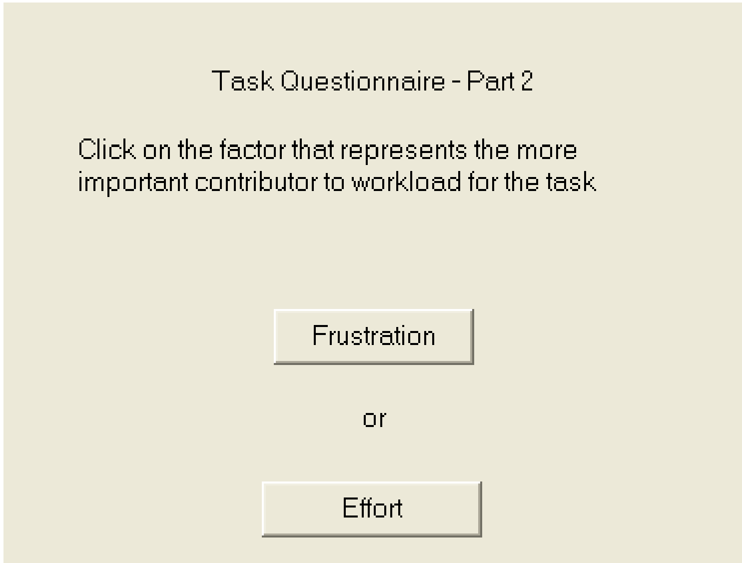
Task Questionnaire - Part 2

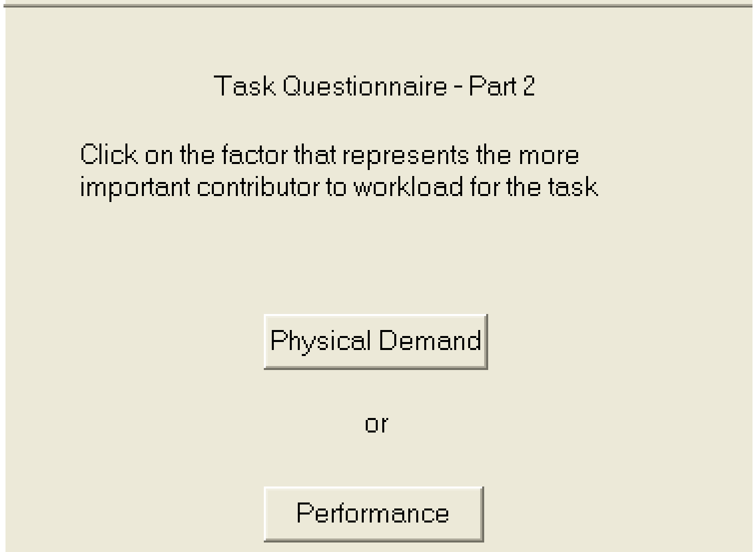
Click on the factor that represents the more important contributor to workload for the task

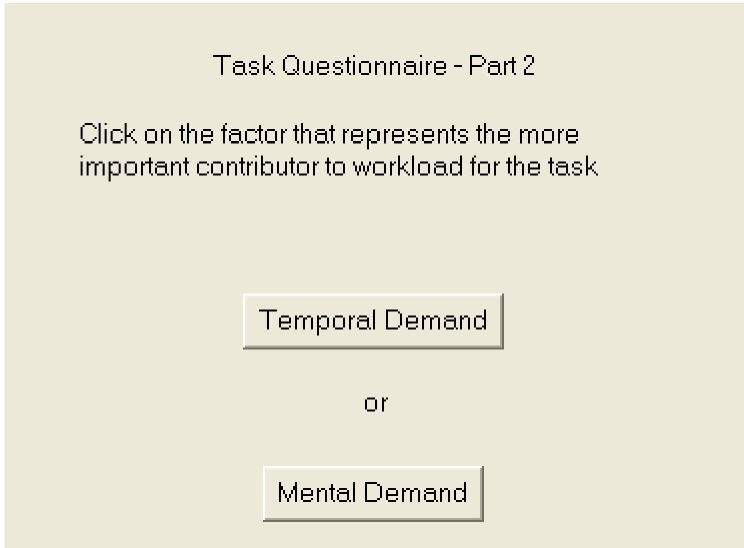
Performance

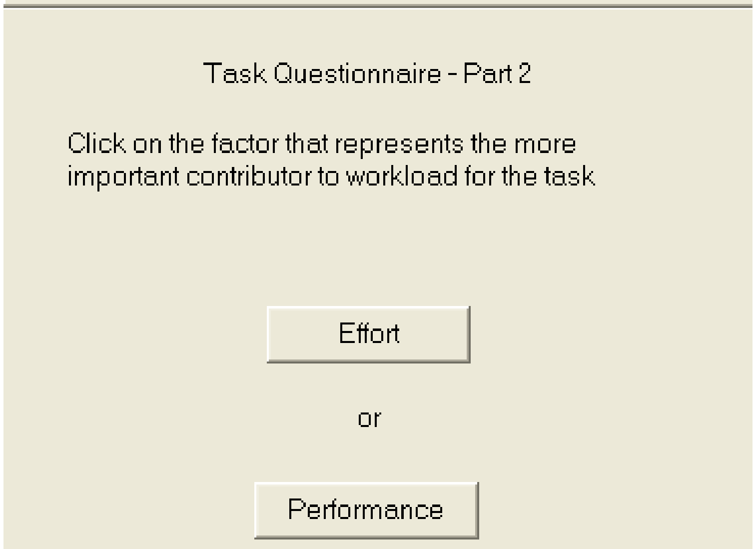
or

Frustration


Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Frustration
or
Effort


Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Physical Demand
or
Performance


Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Temporal Demand
or
Mental Demand


Task Questionnaire - Part 2
Click on the factor that represents the more important contributor to workload for the task
Effort
or
Performance

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