EXPLORING THE LINKS BETWEEN AFFECT AND DRIVER BEHAVIOR: A SYSTEMATIC REVIEW

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ABSTRACT

Driving, as a multifaceted daily task, is intricately intertwined with our emotional states. However, the integration of affective states into driving research is conspicuously lacking in the existing literature. The primary goal of this study is to systematically examine and elucidate the relationship between these affective states and driving actions, with a particular focus on driving behavior. The review synthesizes findings from 21 articles that specifically address the interplay between emotional states and driving behaviors. Despite the complexity and variability of the relationship between emotional states and driving, the review highlights that both positive and negative affect are associated with risky and reckless driving behaviors. The synthesis of findings presented in this review serves as a comprehensive and holistic overview of affect-integrated driving studies. Based on the findings, future intervention techniques, such as in-vehicle assistance systems, could be developed to assist drivers in managing their emotional states while driving.

Key Words: *emotions, affective states, negative affect, positive affect, driving behaviors*

Duygulanım ve Sürücü Davranışları Arasındaki Bağlantıların İncelenmesi: Sistematik Derleme

ÖZET

Araç kullanımı karmaşık doğası gereği duygu durumlarından bağımsız olarak düşünülemez. Literatürde olası ilişkileri test eden çalışmaların varlığına rağmen duygulanım konusunda bilgi karmaşıklığı mevcuttur. Bu çalışmanın temel amacı, özellikle sürüş davranışlarına odaklanarak, duygulanım ve sürücü eylemleri arasındaki ilişkiyi sistematik olarak araştırmak ve aydınlatmaktır. Araştırma, özellikle duygulanım ve sürücü davranışları arasındaki etkileşimi ele alan araştırma sonuçlarını incelemekte ve 21 makaleden elde edilen bulguları sentezlemektedir. Mevcut inceleme özellikle duygulanım faktörlerinin negatif ve pozitif duygulanım çerçevesinde çelişkili bulgularını vurgularken, pozitif ve negatif duygulanım faktörlerinin riskli ve dikkatsiz sürüş davranışlarıyla ilişkili olduğu görülmektedir. Bu çalışma mevcut ilişkilerin bütüncül bir şekilde anlaşılması için temel sağlamaktadır. Çalışmanın öne çıkan bulguları, duygusal faktörlerin trafik kazaları ile doğrudan ilişkili olan riskli sürücü davranışlarıyla bağlantılı olduğunu göstererek, müdahale teknikleri için önemli bilgiler sunmaktadır. Gelecekte sürücülere özel duygu düzenleme stratejileri veya sürücülerin sürüş sırasında duygusal durumlarını yönetmelerine destek olmayı amaçlayan kişisel önlemler ya da teknolojik önlemlerin tasarımları için önemli bilgiler sunulmaktadır.

Anahtar Kelimeler: *duygu, sürücü davranışları, pozitif duygulanım, negatif duygulanım, riskli sürücü davranışları*

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1. Introduction

Road traffic accidents remain one of the world's leading causes of death, with the latest statistics from the World Health Organization revealing that 1.19 million people died due to road traffic accidents and related injuries in 2023. Despite accidents often being perceived as chance events, the reality is that traffic accidents are not random occurrences. Therefore, investigations into the causes of traffic accidents hold critical importance for road safety (Shinar, 2007). To address this public health issue, a growing body of literature has investigated the primary and subsidiary factors associated with accident rates, aiming to reduce mortality and injury rates over time. As a result of these research, human factors have emerged as the predominant leading cause of traffic accidents among the various causative factors (Evans, 2004).

Human factors in traffic safety focus on understanding how human behavior, capabilities, and limitations influence the safe and efficient operation of transportation systems. This interdisciplinary field explores the interactions between road users, vehicles, and the traffic environment to reduce accidents and enhance overall safety (Shinar, 2007). Driver behavior, given its direct association with crashes, is a primary focus of human factor research within traffic safety. Driving behaviors encompasses various actions and reactions of drivers while operating a vehicle, including attention management, decision-making, speed control, adherence to traffic laws, interaction with other road users, use of safety devices, response to environmental conditions, and risk management. Understanding driver behavior is paramount for improving road safety, as it significantly influences accident likelihood and the effectiveness of safety interventions. Consequently, driver behavior is extensively studied and considered the most critical variable in implementing countermeasures (Evans 2004; Omidi et al., 2021; Reason et al., 1990; Shinar 2007).

While many researchers focus on studying cognition-related factors to comprehend human-related actions and behaviors, the complex and challenging nature of driving warrants attention to emotions as well (Jeon, 2015; Jeon & Zhang, 2013). Emotions are inseparable from human beings, and it is virtually impossible to think of a person performing, thinking, or acting without engaging in the emotional system (Nass et al., 2005). Given the significance of emotions in driving behavior, investigating emotions and understanding their influence on driving are crucial in unveiling the true nature of this task. Despite the profound impact of affective states on driving, there is a scarcity of systematic studies exploring affective effects and drivers' behavior (Jeon, 2015). This study is designed to deepen the understanding of the relationships between driver behaviors and affective states.

Before summarizing the links between affective states and particularly driver behaviors, it's crucial to grasp the fundamental definitions and categorizations of these states, as well as the mechanisms related to affective states and research on affect-driven driving. Hence, it would be beneficial to elucidate the terminology pertaining to affect and driving initially, facilitating a better understanding of the literature findings regarding affective states and driving behaviors.

1.1. Affects and Affective States in General

Similar to other studies investigating affect-related constructs, determining the focus of investigation becomes crucial due to the interchangeable use of terms such as affect, emotions, feelings, and mood, coupled with the absence of consensus regarding their exact definitions (Buck, 1990; Forgas, 1992). At this point, "Affect" serves as a broad label encompassing various emotion-related constructs, inclusive of emotions (defined as "physiological and automatic responses related to the brain and body"), feelings (termed as "cognitive representations of emotions"), and mood (considered as "conscious perceptions and

interpretations that can influence plans, behaviors, and thoughts in living creatures") (Damasio, 2001; Ekkekasis, 2012; Gross, 1998; Petty et al., 1991). In this study, 'affect' or 'affective states' will be utilized to encompass these interchangeable constructs comprehensively. At times, conventional terms will also be used, aligning with the nature of the studies being summarized.

Apart from the complexity of affect-related concepts, taxonomies pertaining to affective states vary across studies. In traffic safety studies, approaches like categorical and discrete emotions (such as Ekman's basic emotions (1992)), dimensional viewpoints such as negative and positive affect or emotions (following Russell's Circumplex Model, 1989), and categorizations distinguishing affects as integral or incidental based on their source and relevance to tasks have been predominantly used. While debates persist about the conceptual taxonomies related to emotions, both classifications have been employed within the scope of the studies discussed in subsequent sections of this study as results.

1.2. The Mechanism of Affect in Shaping Behavior (Attention, Judgment and Decision Making)

Taking "affect" as an umbrella term actually facilitates a more comprehensive understanding of the multifaceted affective mechanism. As in the introductory section, it was mentioned that researchers tend to focus more on cognition-related factors in the initial understanding of human behavior. Therefore, as the first step in understanding human behavior from an affective states perspective, it is necessary to discuss some conceptual relationships (Jeon, 2015; Jeon & Zhang, 2013).

Recent research challenges the traditional belief that affect and cognition are two separate, independent entities. Instead, researchers argue for the integration of emotion and cognition to comprehend emotional phenomena (Leventhal & Scherer, 1986). This integration is essential because emotions cannot be processed, elicited, or experienced without cognitive processing; likewise, emotions also influence some basic cognitive processes (Storbeck & Clore, 2007). While the scope of cognition and affect is broad, understanding the mechanisms of affective states, particularly in judgment (evaluating and estimating outcomes related to future events to cope with ambiguity), decision-making (selecting options based on these judgments), and attention (the first step in cognitive processes, involves mental effort and selective processing to focus on environmental stimuli), is crucial for understanding driving behaviors (Jeon, 2015; Blanchette & Richards, 2010; Jonston & Heinz, 1978; Styles, 2005).These cognitive systems are evolutionary, as is the emotional system, which aids primitive decision-making, judgment, and attention processes (Toda, 1980).

During the shaping of behavior, summarizing the primary functions of these mechanisms with a few key examples, we can outline as follows. Affective states influence judgment and decision-making in various ways, sometimes beneficially and sometimes detrimentally (Lerner et al., 2015). Affect shapes decision-making processes by influencing the accessibility and evaluation of targets. For instance, positive affect tends to lead to more optimistic evaluations and overestimations of positive outcomes (Schwarz, 2000). This can result in differences in risk perception, information assessment, and social perception in judgment processes, impacting behaviors such as risk-taking and policy choices in decision-making (Angie et al., 2011). Emotionally relevant targets receive more attention, but the effects of attention processes are complex and extend beyond mere selectivity (Yiend, 2010). Negative affect narrows attention, while positive affect broadens it, facilitating global processing. However, the outcomes may not be straightforward; for example, reduced cognitive processes

related to attention processes may distract individuals more in positive states, yet diverse information may be better integrated with broad attention (Jeon, 2015).

In summary, while theories and views on cognitive processes and emotion vary, their reciprocal relations profoundly influence human behavior. It's important to remember that affective states play a fundamental role in shaping human behavior, particularly by influencing the underlying cognitive mechanisms that drive actions and behaviors. Each cognitive, psychomotor, and individual-specific factor contributes to shaping these behaviors, with affective states playing a foundational role in this influence.

1.3. Affect Mechanism and Driving Behaviors

At the outset of this paper, it's emphasized that human beings cannot perform, think, or behave without the emotional system. After exploring the interplay between the emotional system and cognitive processing, this perspective appears logical (Nass et al., 2005). Since driving is a complex task, successful driving actions require adequate perceptual and cognitive processes. Drivers must select relevant information and interpret it effectively to make sound decisions that facilitate safe driving actions (European Road Safety Observatory, 2006). As discussed earlier, affective states significantly impact decision-making and attention mechanisms, potentially leading to risky behaviors or inattention while driving. Despite limited attention to affective research in traffic and considerable conceptual and measurement differences regarding affective states, it's widely acknowledged that these states have significant consequences on driving behaviors (Pecher et al., 2009).

While it is commonly recognized that affective states have an impact on driving behaviors, it's important to recognize that not all basic or discrete emotions are extensively studied in driving literature. This is because not all emotions exert the same level of influence on driving. For instance, while disgust is not typically highlighted in driving research, there is significant attention given to strong negative emotions like anger, fear, or anxiety (Jeon, 2015). In addition to influence, the frequency of the affective states also has an influence on why some emotions were studied in driving literature more than others. For example, in the study of Roidi, Freshe, Oehl, and Höger (2013), the frequency of emotions while driving simulator was tested, and the participants mostly reported anger, relief, anxiety, surprise, and satisfaction while driving. Moreover, Mesken and his colleagues reported anxiety, anger, and happiness as the most occurring emotions (2007).

Why drivers experience these emotions or affective states is not the scope of this study. However, it should be noted that driving situations are emotional triggers and consist of many goals promoting and blocking events that trigger positive and negative emotional states. Moreover, the uncertainty related to the outcome of traffic events and the responsibility related to adverse events in traffic situations (blame party) also can have the influence of the frequency and type of emotional experience in traffic (Zhang & Chan, 2014). Therefore, it can be deduced that while integral affects have an influence on all our daily actions, incidental affect related to traffic situation and driving acts in itself might increase the frequency of some kind of affective (for example anger) experience.

It's worth noting that in addition to their impact and prevalence, certain patterns emerge when summarizing the general affective states and driving behavior literature. For example, negative states have often been studied in driving literature as outcomes of negative emotions, sometimes supported by the "sadder but wiser" perspective (Jeon, 2015; Jeon & Zhang, 2013). Conversely, positive emotions, under the "happy drivers are better drivers" viewpoint, have not been extensively explored, although some studies have presented contrasting findings based on different cognitive mechanisms of positive emotions (Eyben et al., 2010; Jeon, Walker, & Yim,

2014). While certain affective states, such as anger, are consistently associated with risky and aggressive driving, leading to an increased risk of crashes, inconsistencies persist regarding the influences of other negative and positive affective states and emotions beyond their valence (Deffenbacher et al., 2003; Mesken et al., 2007). For instance, while fear and anxiety are often used interchangeably, some studies delve into the distinct mechanisms of these states on driving behaviors (Barnard & Chapman, 2016; Schmidt-Daffy, 2013). Therefore, reviewing articles on affective driving research is essential to understand the nature of the relationship between affective states and driving behaviors, considering the various approaches to studying affective states and outcome behaviors related to driving.

1.2. Aim of the Review

With the light of previous information, the focus on driver behaviors as driving acts stems from both the cognitive mechanism of affect and the general tendency of literature to concentrate on driving behaviors when investigating affective effects. Previous research has reviewed topics such as risky, aggressive, and emotional driving (Dula & Geller, 2003), affect, cognition, and driving behaviors in general (Jeon, 2015), or emotions and adolescent drivers (Scott-Parker, 2017). However, there hasn't been a specific review focusing on driving behaviors as outcomes of affect. Therefore, this study aims to fill a gap in the existing literature, which primarily focused on trait-related experiences rather than state affect, by emphasizing studies examining state affects and driving behaviors as primary outcomes.

2. Method

This review focused on examining literature related to driving behaviors and affective states. A comprehensive search was conducted using Scopus database (www.scopus.com). Keywords encompassing emotions, mood, feelings, and affects were used interchangeably to ensure inclusivity. Searches were refined using specific phrases like "Emotion and Driving/Driver Behavior," "Mood and Driving/Driver Behavior," and others.

Initially, 815 articles were identified. Non-English articles, inaccessible full texts or abstracts, and duplicates were excluded, leaving 664 articles. From these, 221 articles related to driving environments were found, of which 88 investigated driving behaviors and emotions. After excluding articles focusing on traits, personality measures, emotion regulation, or lacking affect/emotion measurements, 21 articles met the study criteria (See Figure 1).

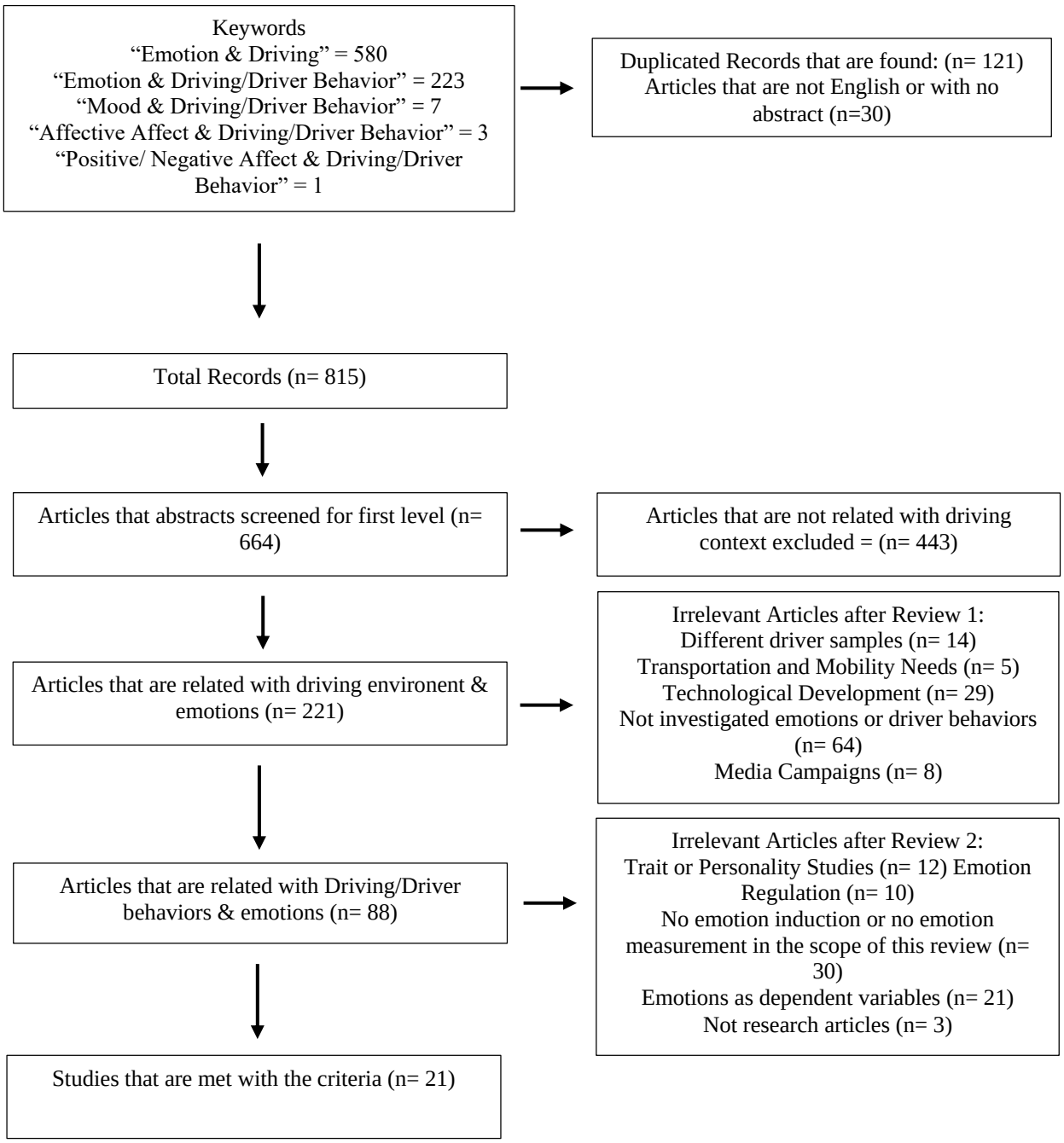

Figure 1: Flowchart - Phases of Systematic Review

3. Results

This section presents findings from studies exploring the relationship between affective states and driving behaviors. Studies' results are categorized based on emotions' valence (negative affect, positive affect, or both) due to the diverse approaches used in these studies. Variables related to affects were predominantly investigated concerning valence rather than specific behavioral outcomes. As a result, some studies are presented across multiple sections based on their focus.

The summarized articles in this review are detailed in Appendix 1. Additionally, this section outlines various measurement techniques employed in assessing driving behaviors and affects across the reviewed articles.

Following the systematic review, the predominant behavioral outcomes identified were often associated with risky driving, particularly reckless driving and inattention. Notably, while reckless driving is a subset of risky driving, the literature often treats it as a distinct concept. Hence, articles are categorized as general risky driving studies and those specifically examining reckless driving and inattention. Therefore, in the context of the relationship between affective states and driving behavior, findings related to risky driving are presented first.

3.1. Affects and Risky Driving

Risky driving behaviors can be defined as any action that increases the probability of crashes on roads. Examples of such behaviors include aggressive driving, speeding, not wearing a seat belt, running red lights, driving under the influence of alcohol or drugs, fatigue driving, and driving while distracted (Scoot-Parker, 2012; Dula & Geller, 2003; Lajunen & Summala, 2004). Additionally, risk attitudes and perceptions are sometimes used as determinants in studying these behaviors (Arnau-Sabates et al., 2012).

3.1.1. Studies that Investigate both Negative and Positive Affect and Risky Driving

Studies categorizing risky driving behaviors based on valence reveal that some research simultaneously examines both ends of the valence spectrum as negative and positive. An example of such studies is the research conducted by Hu, Xie, and Li in 2013. In a study by Hu, Xie, and Li (2013), the aim was to explore how two affective states influence risky driving behaviors through risk perception and attitudes. It was found that after negative emotion induction via video presentations as traffic-related stimuli, participants perceived increased traffic risk, whereas no significant change was observed in positive and neutral conditions. Participants experiencing negative affect showed higher acceptance of risky driving, such as speeding and dangerous driving. Notably, the impact of negative affect was stronger than that of positive affect on driving behaviors.

Conversely, Jeon, Walker, and Yim's study (2014) examined negative affect by assessing anger, sadness, happiness and fear. Results indicated that angry and happy participants committed more driving errors compared to fearful and neutral participants. Angry individuals exhibited more errors in lane-keeping, traffic rule adherence, and aggressive driving, while happy participants showed decreased performance in lane-keeping and adherence to traffic rules. Moreover, anger was associated with lower perceived safety and higher risk perception, while happier individuals demonstrated higher driving confidence and safety levels.

Eherenfreund-Hager, Taubman-Ben-Ari, Toledo, and Farah (2017) investigated the influence of positive and negative affect on actual risk-taking behaviors in a simulator. Positive affect was categorized into arousal positive and relaxing positive to assess arousal's impact. Findings revealed that participants experiencing negative affect had shorter headway distances compared to those with neutral or relaxing positive affect. Positive affect was linked to lower risk compared to arousing positive and negative affect. Moreover, the duration of opposite lane travel was longer for individuals experiencing arousing positive and negative affect compared to relaxing positive and neutral conditions. Speeding and exceeding speed limit behaviors were more pronounced in arousing positive and negative affect states compared to relaxing positive and neutral conditions, with the lowest speeding observed in relaxing positive affect. The study concluded that arousing positive and negative affect led to greater risk-taking behaviors, while relaxing positive affect showed a moderating effect. Lastly, Serrano, Stasi, Megias, and Catena (2017) focused on examining the influence of affective sounds on driving behaviors, particularly regarding speeding. Their research consisted of two studies involving experimental

tasks related to both risky and non-driving scenes. Despite emotional sound presentations, braking reactions were faster in risky scenes compared to non-risky ones, with no discernible impact from emotional cues. In risky road situations, negative emotional cues elicited faster reactions compared to positive and neutral ones, while no other discernible influences from emotional sounds were observed.

Essentially, a plausible interpretation based on the results of these three studies suggests that the intensity of emotions may be more relevant to risky behaviors than their valence. While Hu, Xie, and Li (2013) found no effect of positive emotions, Jeon, Walker, and Yim's study found that they led to errors, and yet Eherenfreund-Hager, Taubman-Ben-Ari, Toledo, and Farah (2017) emphasized the importance of intensity over valence. Thus, it can be concluded that it is not what we experience but rather how intensely we experience it that matters.

3.1.2. Studies that Investigate Negative Affect and Risky Driving

In the second stage of examining affective states and risky behaviors based on valence, negative-valence affective states stand out. The literature features six articles solely investigating negative affect and its relation to risky driving behaviors. In the first study by Abdu, Shinar, and Meiran (2012), the focus was on examining situational anger, one of the most arousing negative affect, and its impact on driving behaviors, particularly risky driving. The study aimed to discern the current anger state's influence on driving tendencies. Results revealed that participants in angry conditions drove faster than the neutral group, although the differences weren't significant. However, the angry group significantly exhibited more yellow-light crossings than the neutral group. Additionally, those in the angry group were more likely to simulate pedestrian collisions, though no cause-effect relation between current anger state and driving behaviors was established.

Distinct emotions may have differing influences even with similar valences. Jeon and Zhang (2013) investigated both sadness and anger as negative affects to comprehend their mechanisms in terms of risk perception, driving performance, and perceived workload. The study indicated no significant difference in risk perception between sadness and anger conditions. However, both angry and sad participants displayed more speed violations, harsher braking, and longer driving times compared to the neutral condition.

Roidi, Freshe, and Höger (2014) explored anxiety and anger in driving behaviors, also including fright and contempt in their study. Their simulator-based research highlighted anger's association with strong acceleration and higher speeds. Anxiety and contempt correlated with dangerous driving behaviors, with anxiety notably linked to prolonged higher velocity and increased speeding. Fright, induced after critical event presentations, was associated with intense braking and reduced speeds. Drivers in both anxiety and anger conditions exhibited comparatively worse performance.

Carey and Sarma's study in 2016 focused on driving anger and behaviors, incorporating fear to explore threat-based messages. They used self-reports and advertisements to trigger emotions while measuring participants' state anger. Findings indicated that high-threat messages, paired with self-efficacy, reduced speed choices. Elevated levels of anger countered the effects of fear and efficacy in message effectiveness.

Two studies preferred inducing negative feelings rather than specific emotions for negative affect. Lewis-Evans, Jolij, and Brookhuis (2012) delved into implicit and unconscious negative emotions' influence on speeding behaviors using masked images. However, no significant differences in emotional valence impacting driving behaviors were found, except for a notable relationship between negative images and lower speeds among female participants.

Similarly, Lee and Winston (2016) explored the overall impact of negative affect on young male drivers' behaviors. Their study presented stressful traffic events to participants, collecting data through self-reports and a driving simulator. Results revealed a positive correlation between negative emotions and unsafe driving behaviors, categorized as tickets and an unsafe score based on speeding and late recognition of red lights.

In summary, when examining risky driving and negative valence, the primary emotion that stands out is anger (as stated in Abdu, Shinar & Merian, 2012; Jeon & Zhang, 2013; Roidi, Freshe & Höger, 2014; Carey & Sarma, 2016), which has been associated with risky behaviors such as running red lights, speeding violations, and harsh braking. While emotions like sadness anxiety or also come into play, the most notable findings are related to the emotion of anger and its association with speeding behavior and light violation.

3.1.3. Positive Affect Studies and Risky Driving

The literature on affect-related driving tends to focus more on negative states than on positive affect. Consequently, only one article was found that specifically studied the influence of positive affect while driving.

Rhodes and Pivik (2011) conducted a study exploring the relationship between risk driving and positive affect. They proposed a model where perceived risk and positive affect acted as mediators in the relationship between age, gender, and risky driving behaviors. Results from the model testing indicated that positive affect and risk perception independently predicted risky driving. Additionally, positive affect emerged as a stronger predictor for males than females and for teens compared to adults concerning participants' tendencies towards risky driving behaviors. Indeed, this observation aligns with the suggestion made by Eherenfreund-Hager and colleagues (2017) that positive and negative valence may both be relevant to risky driving, with the intensity of emotion playing a key role.

3.2. Affects, Reckless Driving, and Inattention

Another behavioral categorization related to affective states, following risky driving behavior, appears to be reckless driving and inattention. Reckless driving, inattention while driving, and distracted driving fall under the umbrella of risky driving behaviors (Scoot-Parker, 2012). However, in the literature, these behaviors are studied as distinct constructs. This differentiation could stem from the diverse cognitive mechanisms associated with affective states concerning various risky driving behaviors and inattention. Hence, although the measured outcome behaviors may align, for this review, these factors were explored under separate titles as reckless driving, inattention, and distraction.

3.2.1. Studies that Investigate Negative and Positive Affect and Reckless Driving, and Inattention

In parallel with studies on risky driving, research focusing on reckless driving and inattention can be classified into studies that investigate both negative and positive affective states based on valence. Within this scope, the first study examining these two emotional states in the same research was conducted by Pecher, Lemercier, and Cellier (2009). In this study, they investigated the impact of affective states on drivers' attentional behaviors using musical excerpts. Results from this simulator study indicated that participants in the happy condition showed decreased mean speed, whereas only a slight decrease in mean speed was observed for the sad condition. Additionally, while lateral control improved for the sad and neutral conditions, deterioration was observed for participants in the happy condition.

Another study exploring the effects of positive, neutral, and negative affect on driving behaviors was by Taubman Ben-Ari (2012). The researcher aimed to investigate reckless driving as a dependent variable across five different studies. The findings revealed that a higher propensity for reckless driving was associated with a positive affective state, particularly a state of happiness. However, no significant relationship was found between anger-evoking memories and willingness to engage in reckless driving, as measured by self-report instruments. Participants in a high arousal positive affect condition exhibited more anxious, angry, and risky driving behaviors compared to those in a relaxation-positive state.

Similarly, Trick, Brandigampola, and Enns (2012) investigated arousal effects alongside valence effects. Their study focused on examining the relationship between emotion and attention while driving, specifically testing hazard perception and steering as outcome variables. Results indicated that valence of the images played a crucial role in steering behaviors. Participants in low arousal negative affect conditions exhibited significantly poorer performance compared to those in positive conditions. Arousal was found to be a significant factor in hazard detection, with high arousal participants showing faster braking reaction times in short durations, while the relationship reversed in longer durations. An interactive effect between valence and arousal was also observed for lateral position and hazard detection.

Chan and Singhal (2013) delved into investigating the distracting effects of emotional information (positive, negative, neutral) on simulated driving. Their study revealed that both negative and positive words led to an immediate speed decrease after presentation compared to the neutral condition. Additionally, positive words had a lingering effect on driving behaviors, particularly in speed choice, compared to negative words. Moreover, more steering activity was observed for the neutral condition than for the emotional conditions.

Zimasa, Jamson, and Henson (2017) explored the influence of mood (sad, happy, neutral) on driving safety and attention. They found that participants in happy and neutral conditions reacted to hazards faster than those in a sad mood. Responses to hazards were faster for the neutral condition compared to the happy condition. Conversely, participants in a sad mood exhibited longer response times and fixation durations compared to the other groups. The interpretation of the results concerning the effect of positive mood was less evident.

Lastly, Steinhauser and colleugues (2018) investigate the impact of positive and negative emotions on driving behavior and found that emotions impact behavior both directly, such as encouraging aggressive driving, and indirectly, by modifying attentional focus during driving, they highlighted that emotional influences on driving behavior vary significantly based on the specific driving task and the attention required, influenced by the emotional event itself.

The examination of studies investigating two affective states simultaneously reveals a significant finding: positive affective states, particularly in the happy condition, may be linked to more reckless behavior. Conversely, positive affective states are generally associated with safer and more cautious choices compared to the sad condition. Predictions regarding different types of reckless driving behaviors based on attentional mechanisms and similar behaviors may suggest the presence of another factor beyond valence.

3.2.2. Negative Affect and Reckless Driving, and Inattention

Some studies specifically delve into investigating the influence of negative affective states—specifically inattention and distraction—while driving. First example could be the study conducted by Zhang, Cahn, Ba, and Zhang (2016), which explored the impact of situational driving anger. The researchers aimed to understand the effects of state anger on driving behaviors and the allocation of visual attention. Results indicated that drivers experiencing anger tended to drive faster, maintain less following distance, accept shorter gaps in left turns,

engage in more abrupt and faster braking, and demonstrate less appropriate reactions to an imminent crash compared to the neutral group. Visual data revealed that angry drivers tended to scan narrower areas and adopt a more heuristic processing style. Surprisingly, the researchers found that prior experience had no effect on preparing for the adverse influence of situational anger.

Similarly, Techer, Jallais, Corson, Moreu, Ndiaye, Piechnick, and Fort (2017) sought to explore the effects of an angry state on attention while driving. They used simulator and electroencephalographic data, employing event recall techniques for anger induction. The study revealed no discernible effect of anger on response times or speed control. However, participants in the anger condition demonstrated compromised lateral control of the vehicle.

In a different approach, Jallias, Gabaude, and Paire-Ficout (2014) investigated the influence of anger and sadness on driving behavior, specifically focusing on inattention while driving. The attention of participants was measured based on the localization of road elements, induced by music and guided image presentations for anger and sadness, respectively. Findings indicated that participants in the anger condition were slower to locate road elements compared to the control and sadness groups, suggesting delayed detection of atypical hazards on roads. Moreover, sadness was associated with more localization errors compared to both the anger and neutral conditions.

To sum up, studies focusing on reckless driving and negative affective states, particularly anger, consistently show that as levels of anger increase, individuals exhibit more reckless driving behaviors and become more distracted while driving. Specifically, behaviors such as reduced following distance, inappropriate reactions, scanning deficiencies, problems with response times, and delayed detection of hazards are observed during states of anger.

4. Discussion

The literature on affect-related driving can be categorized into two groups: studies exploring affect as a whole (negative or positive) and those investigating discrete emotions with negative or positive valence. Typically, when researchers examine both negative and positive emotions in the same study, they tend to group negative emotions together (such as anger or sadness) and positive emotions together (often as happiness). However, studies directly comparing negative and positive states are less frequent. While the assumption generally suggests worse driving outcomes for negative affect and better driving acts for positive affect, the literature's results are nuanced, revealing an intricate relationship between affect and driving behaviors.

In general, studies focusing on valence-based approaches in examining driving behaviors often center around risky and reckless driving. While the associations for negative affect was stronger than positive affect, the lingering influence of positive emotional induction was longer than negatives for both risky and reckless driving behaviors (Chan & Singhal, 2013; Eherenfreund-Hager, 2017; Hu, Xie & Li, 2013; Taubman-Ben-Ari, 2012). Participants with negative affect showed the higher perception of risk and higher acceptance of risky, aggressive and dangerous driving (for example driving with less headway distance and not obeying speed limits) (Eherenfreund-Hager, 2017; Hu, Xie, & Li, 2013; Lee & Winston, 2016). Even mostly risky driving was observed after negative affect, it should be noted that positive affect is not innocent. There is a huge difference between relaxing positive affect and arousal positive affect in terms of risky driving behaviors which stresses the importance of arousal as well. For example, duration traveling in opposite lane, exceeding speed limit behaviors were observed after induction of arousal positive emotions while relaxing positive affect is generally related

to safer performance (Eherenfreund-Hager, 2017). On the other hand, there are some contradictory findings as well. For example, while risky driving was observed after positive affect induction, positive affect and risk perception was found as independent predictors for risky driving and no relationship was found between positive affect and risky driving in the study of Rhodes and Pivik (2011). Moreover, Lewis-Evans (2012) and his colleagues and Megias and Catena (2017) found no significant association between valence differences, emotion induction, and driving acts.

Apart from these studies, as it is mentioned before, discrete emotions were also studied in order to investigate the associations between negative and positive affect and driving acts. In the literature, the most salient and most studied negative affect could be anger and the findings related to anger and the findings of driving acts' research were much more consistent. Anger especially situational anger found as related to both risky driving behaviors and reckless driving behaviors. For example, in general, it was found as angry participants showed more speeding behaviors, stronger acceleration, more yellow light and red light passing, less following distance, worse lateral control, shorter gaps, later response time, more errors, less proper reactions, focusing and scanning narrower area, slower detection of hazards while driving (Abdu, Shinar, & Meiran, 2012; Carey & Sarma, 2016; Jallias, Gabaude, & Paire-Ficout, 2014; Jeon & Zhang, 2013; Jeon, Walker, & Yim, 2014; Roidi, Freshe, & Höger, 2014; Techer et al., 2017; Zhang et al., 2016). Moreover, lower level of perceived safety and a higher level of risk perception was observed for anger condition participants (Jeon, Walker & Yim, 2014). Besides them, only in one article, no relationship was found between anger and response time and speed control related to reckless driving (Techer et al., 2017).

The other discrete emotions that are studied as negative emotion induction is sadness, anxiety, and fear. While there are not much more studies in order to see the inconsistencies or consistencies, general findings could be summarized. The findings related to sadness were a bit complex, while some studies found that the performance could be better after sadness induction (for example better lateral control) (Pecher, Lemercier, & Cellier, 2009). The others pointed that the reckless driving (for example, worse localization of road elements, and longer fixation time) could be higher for sad participants (Jallais, Gabaude, & Paire-ficout, 2014; Zimasa, Jamson, & Henson, 2017). Besides them, while sadness seems like generally related with reckless driving, Jeon and Zhang revealed that sadness could also be related to risky driving (more speeding violations) (2013).

Anxiety and fear are the other studied emotion states in driving research. The findings showed that anxiety was reported as related to the risky driving such as higher velocity and more speeding violations with lingering influence while fear is associated with lower speeds in general. (Carey & Sarma, 2016; Roidi, Freshe, & Höger, 2014).

The literature findings showed that affect related driving literature generally focus on negative emotions and there are little research and little findings related to positive emotions. As discrete emotional state only happiness was studied as positive affect in the literature. While happiness is the most studied single emotion, still being happy is good or bad while driving is complex. In the study of Jeon, Walker, and Yim (2014) it was found that happy participants' lateral control was worse and they have higher driving confidence and safety level than the other groups. Contrary to higher level of driving confidence and safety level, Pecher, Lemercier, and Cellier (2009) found that happy condition participants engage in lower speed limit. Moreover, while Taubman-Ben-Ari (2012) reported that happy participants were more prone to reckless driving, Zimasa, Jamson, and Henson (2017) found that happy participants react to hazards faster than the other groups. There might be several reasons for these contradictory findings; one of them is especially for positive affect or discrete emotions with positive valence.

The general mechanism of positive affect pointed that the outcome would be experienced in two different way: reduced cognitive processes distract the drivers or broad attention will promote the integration of diverse information, therefore, while drivers will show more reckless driving, this attentional mechanism will promote to attend various stimuli on the road at the same time (Jeon, 2015). However, these two potential outcomes are related with only attentional driving and the contradictory results related to risky driving and positive affect could not be explained by these two potential mechanisms. The complex mechanism of cognition, affective states, and driving acts might be the reason for this complexity. Moreover, the potential reasons would be simply methodological differences between studies, because, besides positive affect studies, there are some contradictory results for negative behaviors as well.

Aside from the mentioned patterns, there could be a simpler explanation available. Amidst these varied outcomes, there exists a fundamental pattern. A plausible interpretation based on the results of these studies suggests that the intensity of emotions may be more relevant to risky and reckless driving behaviors than their valence, as indicated in the results section. Thus, it can be concluded that it is not what we experience but rather how intensely we experience it that matters, as stated in the studies of Hu et al., 2013; Eherenfreund-Hager, 2017; Taubman-Ben-Ari et al., 2012; Chan & Singhal, 2013. This study highlights that particularly arousing positive affect, rather than relaxing positive affect, is associated with inappropriate driving behaviors, emphasizing the importance of emotional intensity in shaping risky and reckless driving behaviors. For example, it may be worth re-exploring whether the fact that the most studied emotion, anger, is more intense than emotions like sadness, leads to more risky and reckless driving.

4.1. Future Studies and Implications

The literature findings suggest that happy drivers are not consistently better drivers, indicating a need for further studies on positive affect to reconcile the differences in the literature. Additionally, it's essential to differentiate between arousal, intensity and valence dimensions for both negative and positive affect in driving research. Even when affective states share the same valence and arousal level, such as anxiety and anger, their outcome influences may differ. Therefore, adopting both valence dimensions and a discrete emotion perspective could aid in understanding the nature of the affect driving mechanism.

Furthermore, while there is a growing literature on affective states and driving, researchers are still uncertain about how to study driving-related affect states and which affective states to focus on and which extend. To comprehensively understand the mechanism, all factors related to experiencing affective states should be explored. Integration of factors such as traffic environment emotional triggers could provide valuable insights into the nature of driving.

Moreover, most studies on affective states and driving have focused on young participants, limiting the generalizability of the results to this age group. Exploring other age groups or specific road user groups could help unravel the complex mechanism between cognition, affective states, and driving acts.

As topics like emotion regulation and in-vehicle system development related to affective states continue to grow, it's crucial to first understand the mechanism related to emotional states and driving acts. Successful interventions or technological developments hinge on this understanding. Indeed, the primary question lies in whether emotions truly create a distraction, whether they are harmful, beneficial, conflicting with the cognitive system, or if they coexist in a regulatory state.

In conclusion, while the complexity of the general affect literature influences affect-related driving research, there appears to be a relationship between affective states, risky driving, and reckless driving. Understanding specific affective states could aid in controlling risky and reckless driving, promoting road safety universally. Further research is warranted to unravel this complexity and enhance road safety measures applicable to individuals worldwide.

Information Note

The article has been prepared in accordance with research and publication ethics. This study does not require ethics committee approval.

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Appendix 1: Studies investigating the relationship between emotions/mood/affect and driving

Study	Purpose	Sample	Measurements	Analyses	Results
Pecher, Lemercier, Cellier (2009)	To examine the effects of emotions (sad, happy, neutral) on drivers' attentional behaviors	17 participants (8 men, 9 women) age between 21 and 29. At least 4 years and 10,000 km driving experience.	Driving simulator Questionnaire (Measure interest to driving and music) Interview (assessing the feelings while driving)	ANOVA	Decreased mean speed for happy music condition while slightly decreased was observed for sad music. No mean speed difference was found for neutral music condition. Deterioration of lateral control for happy music while improved lateral control for sad and neutral music.
Rhodes & Pivik (2011)	To investigate age and gender differences in risky driving and the effects of positive affect and risk perception on risky driving. To understand role of risk perception and positive effect in driving	504 teen drivers (age between 16-20), 409 adult drivers (age between 25-45)	Risky Driving Questionnaire (Musselwhite, 2006) Questionnaire (measures affect towards target behavior) (Alhakami & Slovic, 1994)	Mediation analyses Regression	Positive affect and risk perception found as independent contributors for risky driving. Positive affect was found as a stronger predictor for risky driving for male than female. Positive affect was found a stronger predictor of risky driving for a teen than adult drivers.

Study	Purpose	Sample	Measurements	Analyses	Results
Abdu, Shinar, Meiran (2012)	To examine how situational anger affects driving behavior especially risky driving with comparison angry and neutral mood while driving.	15 male participants (age between 22-27) 4-10 years driving license.	Mood Induction: Event recall (Neutral event recall, angry event recall) Driving Simulator Mood Check Questionnaire	Paired T-Test	No cause-effect relation was found between current anger state and driving behavior. Anger state affect risk-taking tendencies (passing yellow light) but not driving skills (appropriate breaking when emergency situation is not affected) after comparison with neutral mood.

Lewis-Evans, Waard, Jolij, Brookhuis (2012)	To test the influences of implicit and unconscious emotional signals on driver behaviors especially decision-making and speed choices of drivers.	113 participants (74 females, 39 males). At least 1 years driving experience.	Driving simulator Images Presentation: Backward and forward presentation of the masked, negative, and neutral images Psychophysiological Measures (Heart rate measurement)	Full Factorial Repeated Measures Analysis	There was no significant main effect of target images type and driven speed. There was a significant main effect of image target and order. The increase of speed is smaller when the second trail includes negative images. Negative target effects on suppressing speed and familiarity and learning effect. In males, no significant difference - speed data for negative and neutral images. For females, negative images were related to lower speed.

Study	Purpose	Sample	Measurements	Analyses	Results
Taubman Ben-Ari (2012)	To examine the differences between positive, neutral and negative affect in terms in terms of willingness to reckless driving. Also to investigate the influence differences between various positive emotions for reckless driving.	114 young driver participants (52 women, 62 men)	Emotion induction/priming tools (story readings, remembering memory, presenting film segments, etc.) Self-Report scale for proneness to reckless driving	ANOVA	Happy positive affect related to higher proneness to reckless driving than neutral. No relationship found between anger-evoking memories and reckless driving. High arousal (positive affect) found as related to various driving styles (higher on anxious, angry, risky driving, lower careful driving)
Trick, Brandigampola, Enns (2012)	To investigate the effects of emotional arousal (high or low) and valence (positive and negative) on hazard perception and steering as a basic research on emotion and attention while driving.	26 university students having a valid driving license.	Driving Simulator Ratings of the valence of presented images - Pressing buttons - the images positive/negative. Affective Picture System: High/Low arousal of Positive/ Negative Images	Full Factorial Repeated Measures Analysis	The interactive effect of valence and arousal. Arousal as an important factor for hazard detection. High arousals' positive breaking reaction times were higher than low arousals (short delay scenario), The reverse relation was found for the long delay. Valence was found as an important factor for steering, low arousal, negative images related to significantly poorer steering performance than positive.

Study	Purpose	Sample	Measurements	Analyses	Results
Chan & Singhal (2013)	To investigate distracting effects of emotional information (Negative, positive, neutral) on simulated driving.	30 participants	Driving Simulator Emotion Induction (words presentation in Billboards)	ANOVA	Negative and positive words were related to immediate driving speed decrease than neutral. Positive words were found as both immediate and lingering effects on driving behaviors than negative words, especially for speed choice. More steering wheel activity (lane position) was observed for neutral than emotional conditions.
Hu, Xie, Li (2013)	To examine how two states of affect and emotion and mood influence risky driving behavior through risk perception and risk attitude.	Study 1: 218 participants Study 2: 500 participants	Emotion induction: Video clips (Traffic un/related negative, positive emotions). Driving Risk Attitude Scale Self-report of risky driving behavior (speed) - Questionnaire (risk-perception). Profile of Mood States (Anger, Detection, Vigor)	Correlation ANOVA Regression Analysis	Raised perception of traffic risk found for negative emotions than positive and neutral. Negative affect was related to more acceptance of risky driving (study1 speeding, study2 dangerous driving). Negative affects showed stronger effect than positive. The stronger effect of negative mood was found for risky driving attitude and behavior (speed).

Study	Purpose	Sample	Measurements	Analyses	Results
Jeon & Zhang (2013)	To investigate anger and sadness different influence on risk-perception, driving performance and perceived workload.	32 undergraduate students (6 female & 26 male) having a driving license and 2-year driving experience	Driving Simulator Current affective state measurement via scale Emotion induction (remembering and writing past emotional experience) Questionnaire (measure affective states, driving competence, risk perception)	ANOVA	Anger and sadness were related to more errors especially in aggressive behaviors than neutral (violating speed limits, hard brake), (longer driving time). The perceived workload was found higher for anger state than neutral. No risk perception differences were found between anger and sad state.
Jallais, Gabaude, Paire-ficout (2014)	To investigate the effect of emotion (anger, sadness, neutral) on the localization of road elements.	54 participants	Mood induction (music and guided images) (Mayer et al., 1995) Brief Mood Introspection Scale (BMIS) Localization of road elements task	ANOVA	No statistical differences between sadness and control group (using visual schemata to localize targets) but sadness made more error in the localization (forgot the type of the target). Slower detection of the target was observed for angry than the sadness and the control group.

Study	Purpose	Sample	Measurements	Analyses	Results
Jeon, Walker, Yim (2014)	To explore effects of emotions (Anger, fear happiness) on subjective judgments, driving performance and perceived workload.	70 undergraduate students having a driving license and at least 1-year driving experience	Driving Simulator Scale (measure current affective states). Emotion induction (remembering and writing past experiences) Judgment Questions (Driving competence & risk perception)	ANOVA MANOVA	Anger was related to a lower level perceived safety and lead to higher risk perception than fear and happiness. Angry and happy participants showed more errors than fearful and neutral. Fearful one showed more errors than neutral ones. Higher level of driving confidence and safety level for happy drivers.
Roidi, Freshe, Höger (2014)	To evaluate the impact of emotions (anger and anxiety) on driving behaviors and to test emotion-eliciting situational factors and personality characteristics.	79 drivers (48 female, 31 male)	Driving Simulator Geneva Emotion Wheel (happiness, fright & feeling helpless added) Driving Anger State - State-Trait Anxiety Scale	Generalized Linear Model Hierarchical Linear Regression Model	Stronger acceleration and higher speed for anger. The long-lasting effect of anxiety (higher velocity and more speeding). Driving performance was worse for high anxiety and anger.

Study	Purpose	Sample	Measurements	Analyses	Results
Carey & Sarma (2016)	To examine the impact of behavior threat based messages and anger on driving of young male drivers	62 participants with professional/ novice driving license, minimum of 1-year driving experience	Self-report (perceived self/response efficacy, severity, susceptibility) The Speeding and Rule Violation-Subscale of Behavior Scale Driving Anger Scale - State Anger Self-report Video Speed Test - Advertisements Driving Behavior Measure (speed, following distance, gap acceptance & overtaking)	ANOVA	High Treat messages combined with high perceived efficacy lead to a decrease in speed choices. Increased level of state anger counteracts the effect of fear messages and efficacy- building messages.
Lee & Winston (2016)	To induce negative emotional states to young drivers for investigating the relationship between emotional states and driver reactions	33 young driver participants with a driving license less than 6 months	Driving Simulator The Driving Anger Scale Emotional Circumplex (emotional reporting scale)	Correlation Paired T-Test	A positive correlation between negative emotions and number of unsafe behaviors.
Zhang, Chan, Ba, Zhang (2016)	To investigate the effects of situational driving anger on driving behaviors and driver visual attention allocation. To examine how these effects are moderated by driving experience	24 licensed drivers (5 females, 19 males)	Driving Simulator with an Eye Tracker Anger Emotion Induction (with video clips)	ANOVA	Anger state tended to drive faster, maintain less headway while following a car, accept shorter gaps (left turns), tended to adopt later and harder breaking, failure to respond properly to an imminent crash than neutral group. Angry drivers scanned narrower area and applied more heuristic processing style. Experience had no effect to prepare for the adverse influence of situational anger.

Study	Purpose	Sample	Measurements	Analyses	Results
Eherenfreund-Hager, Taubman-Ben- Ari, Toledo, Farah (2017)	To investigate the influence of affect induction on actual risk-taking behaviors and the links between personality variables and the level of risky driving.	80 young drivers (40 male, 40 female)	Driving Simulator Affect Priming (Word presentation) Relevance of Driving to Self-Esteem Sensation Seeking Scale Driving History Questionnaire	MANOVA Correlation ANOVA ANCOVA	Headway distance was smaller for negative affect than neutral and relaxing positive affect. Relaxing positive affect related to a lower risk than arousing positive and negative affect. Risk-taking behaviors were higher for arousing positive and negative affect. Opposite lane travel duration was higher for arousal and negative affect than positive and neutral affect. Speeding was higher for positive arousal and negative affect than neutral and relaxing positive. Exceeding speed limit was higher for arousal and negative affect and lower for relaxing positive affect.
Serrano, Stasi, Megias, Catena, (2017)	To examine emotional-laden auditory signals on the speed of concurrent driving decisions	Study 1: 19 Undergraduate drivers Study 2: 20 Undergraduate students drivers	Emotion Induction: International Affective Digitized Sounds (Negative (sad), Positive (happy), Neutral) Experimental Task (responding presented pictures) Self-Assessment Manikin Scales (SAM)	ANOVA	Independent from emotional sound presentation breaking was faster for risky than non-risky scenes. No emotional cues effects. Reaction times were shorter for negative cues than positive and neutral ones for risky road situation.

Study	Purpose	Sample	Measurements	Analyses	Results
Techer, Jallais, Corson, Moreau, Ndiaye, Piechnick, Fort (2017)	To investigate the influence of anger state on attention during simulated driving.	33 participants with normal or corrected to normal vision, no neurological disease, no medical treatment. More than 3 years of driving experience	Driving Simulator Mood Induction (Anger-recall, Neutral- completing driving habit questions) Brief Mood Introspection Scale (BMIS) Biosema Active Two System	ANOVA	No effect of anger on response times and speed control but anger condition participants showed degraded lateral control of the vehicle.
Steinhauser, Leist, Maier, Michel, Parsch, Rigley, Wurn, SteinHauser (2018)	To explore the impact of positive and negative emotions on driving behavior and discern their correlation with emotional influences on attention.	90 participants (46 female) ranging between 18 and 65 years of age with normal vision and had a valid license	Mood induction (angry, happy, calm) The modified continuous tracking and reaction task The modified Three Vehicle Platooning Task (m3VPT) Situation awareness test	2 × 2 repeated measures ANOVA	Emotions impact behavior both directly, such as encouraging aggressive driving, and indirectly, by modifying attentional focus during driving, like lessening the impact of multitasking. Our findings highlight that emotional influences on driving behavior vary significantly based on the specific driving task and the attention required, influenced by the emotional event itself.
Youssef, Salameh, Abau-Abbas, Salmi (2023)	To investigate the relationship between socio-demographic variables, driving anger, and the self-reported aberrant behavior	Croos sectional study with 1102 drivers (age of the participants ranged from 18 to 82)	Driving anger scale (DAS) Driver behavior questionnaire (DBQ)	ANOVA	Driver anger dimensions were found positively associated with aberrant driver behavior especially with ordinary violations.