Abstract

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Driving Support Technology with Human Emotion Regulation: A Review

Alan Y.-N. Shen

Abstract: Driver emotions play an important role in driving behaviour. Understanding how human emotions affect driving behavior is essential to enhance modern driver support systems, which aim at adjusting the mental and emotional states of a driver in order to improve road safety. In this paper, we first discuss the latest work on how to enhance driver emotions and how to improve driving habits with human emotion regulation, through the analysis of facial expressions, emotions, and driving behaviours of the subjects during different driving situations. Then, we study various driving support systems, and look at current findings and into potential applications of artificial intelligence for road safety via driver emotion regulation. Finally, further research directions are identified, and conclusions are drawn.

1. Introduction

Emotion regulation usually involves specific emotions (e.g., sorrow, nervousness, annoyance), is well-organized and involves the ability to manage the individual's emotions. Conceptualizations of an individual's emotion regulation involves internal and external processes to complete their goals and functions flexibly [1]. Emotional regulation is conceptualized to include controlled, purposeful efforts. Under stress, coping is one way to regulate an individual’s emotion. As regulating emotions is conceptualized as a process that is continuously happening under circumstances that can cause stress and circumstances that do not cause stress, coping skills can be considered as a different way of regulating emotions under pressure [2][3]. Coping mechanisms and the regulating of emotions are different in individuals and are conceived as temporal functioning that evolves as people grow and mature. Emotion regulation includes one's attempt to manage their emotions in different situations, while dealing with different stimuli [4].

Regulating emotions involves various procedures across the broad spectrum of emotions under standard, non-stressful situations. As a result, it allows emotion regulation to occur in different circumstances and helps individuals who are dealing with many emotions. Emotion regulation will influence individuals by affecting their intrinsic processes (which are the emotions being managed by the individual) and extrinsic processes (the emotions caused by an external element) [5]. Emotion regulation is more extensive than trying to cope, after a negative event, because it surrounds current emotional situations and the part of our natural responses to negative reactions [6]. There are several ways to control emotions while driving. Drivers taking control of their thoughts can manage their emotions better. Taking deep breaths at a slower place is another way that drivers can do to relax and reduce their racing thoughts. Waiting is also a good idea when drivers have issues that they cannot stop thinking about; they should wait until they get to their destination to deal with that issue, because thinking about it while driving does not solve anything. Sleeping well will be beneficial for the driver as they will be more aware of their surroundings and better handle their emotions that come up, which can directly affect their driving behaviour since they will be in better shape mentally when they are driving. Planning is another good strategy to prevent getting upset while on the road. Leaving at a time when the driver is in a good mood can keep them calm. Planning ahead may also help the driver choose a better route with less delays and reduce any unnecessary stress. If the driver is truly unable to calm down their thoughts and emotions, it may be better to pull over and resume driving only after they have settled down [7].

1 This study was carried out when the author was a volunteer research assistant during 2020-2021 at Waterloo Cognitive Autonomous Driving (CogDrive) Lab, Department of Mechanical and Mechatronics Engineering, University of Waterloo, Waterloo, Ontario, Canada.
2. Regulating Emotions and Reducing Distracted Driving

Emotions must be properly managed to positively shape and improve the individual’s psychological abilities and well-being, so that they are able to reach their goals [8][9]. The continual use of reassessments corresponds with well-being, but not with the signs and symptoms of psychopathology [10]. However, using expressive prevention, emotional regulation is related with signs of negative mental health issues, such as depression, and is inversely related with happiness in relationships with other people. It is found that being flexible in general has always been a key part of a person’s overall health and well-being [11]. There are models delineating adaptive ways of emotion regulation when using various techniques, which depend on the individual’s circumstances and demands [12]. Psychological issues and non-adaptive behaviours (such as affective disorders and borderline personality disorders) can be distinguished by the inability to adapt to different situations, when using different emotion regulation techniques [13]. The utilization of different techniques pertaining to managing emotions need to be suited to the individual's current desires and personality traits. The techniques that help regulate one’s emotions allow them to meet the normative objectives when completing tasks in different subject areas, and support their mental and emotional health, along with their extended prosperity. Different situations may need an individual to have a different mindset when handling their emotions in an effective manner and to complete their ambitions. Note that individuals handle their emotions differently and can use different approaches more skillfully or effectively.

By properly regulating their emotions, an individual will be able to effectively achieve their psychological health and well-being, while dealing with any negative parts of their lives, especially events that cause them the most stress [12]. The inability to regulate emotions can lead to psychological disorders. As a result, effective psychotherapy, along with different avoidance techniques, should include strengthening the individual's ability to manage their emotions. The effectiveness of emotion regulation strategies depends on the situational circumstances and changes with the individuals. Based on their thoughts, habits, personalities, and characteristics, it would be helpful to identify the most effective methods to manage their emotions. Emotion regulation techniques have many benefits and are very flexible. They include better mental and emotional well-being, superior social functioning, and effectively dealing with difficult situations [14]. Being able to adapt to different regulation techniques when managing emotions is necessary to prevent and treat affective distractions for those battling multiple affective disorders [12]. With an in-depth understanding of various contingent and personal character factors in emotion regulation strategies, professionals can plan different interventions for specific individuals to address their emotions in different situations. Such interventions should emphasize learning and using the wide range of available techniques, and identifying when they are effective and when they are not. People receiving emotional support should get involved and be conscious of their own attributes and predispositions, both of which can change the utilization of these skills and how effective the strategies are [15].

Road rage and other types of outrage usually occur because an individual who is driving and upset sees the other driver's actions as intentional. Further, the upset driver must see the other driver's actions as erroneous and can cause an accident. Their feelings of fear will likely turn to anger and rage. This leads to violent outbursts and the possibility that someone can get hurt. A quick apology to the angry driver that the mistake was not intended to upset them will likely diffuse the situation before it escalates [16]. When a driver can identify and control their emotions while driving, they need to turn their attention to other factors that influence their driving ability, including preventing accidents before they occur. Distracted driving presents a serious risk to the safety of everyone on the roadway. To prevent distracted driving, drivers should exit the roadway to deal with what have caused a distraction. They can continue to where they are going, as long as they are able to pay attention to operating vehicle safely. An individual can be aroused and become more aware of their surroundings via activating the reticular formation in the brainstem, the endocrine system, and the autonomic
nervous system. It will cause the individual's heart rate and blood pressure to go up, their alertness to increase, and reaction time to be faster. Arousal is an important aspect in attention, consciousness, and information processing regulation [17].

With many people using smartphones nowadays, cellphone blocking technology is easily accessible from service providers and businesses that specifically develop these apps. The most fundamental blocking software platforms will block incoming calls and texts when the individual is on the road driving. Systems that are more developed and advanced can stop audio features from affecting the driver and can track increased speed and sudden braking. Numerous technologies can send alerts by text or email, providing supportive resources for the parents or guardians of young drivers [18].

3. Car Design and Voice User Interface

Speech-based interfaces can provide a better, improved communication mechanism than graphical user interfaces that have an increased demand for attention and are often seen on desktop programs. Despite that, they can lead to unnecessary cognitive needs that could affect the safe operation of a vehicle. Speech-based interaction will lead to significant cognitive demands on drivers. In recent years, voice recognition tools and auditory displays are an important part of the features in vehicles, and speech-based interaction technology can often take away a driver's focus off the road and lessen safety [19]. The safe operation of in-vehicle information devices often depends on the driver and whether their interactions affect their driving abilities, whether the drivers realize that their minds are being interfered by the interactions, and whether the individuals can effectively switch their attention from the road to the information system and back to minimize the effects of the distraction. Note that the technology detecting speech (speech-based interfaces) is also a source of distraction for drivers [20]. Due to the demands of speech-based interaction that is put on the driver cognitively, researchers have determined that the driver's reaction time is 30 percent slower, along with a greater subjective workload. Although the complexity of the devices had no direct negative effect on drivers’ reaction time, it did negatively affect their subjective workload and their attention. This demonstrates that speech-based interactions can negatively affect an individual's mental capacity when driving, which will affect their skills negatively and lead to an accident. It also will increase the time for an individual to deal with the sporadic deceleration of the vehicle in front of them by 310 milliseconds.

4. Driving Support Technology

There exist various engineering solutions to facilitate driving beyond speech-based approaches, such as cruise control, alert/warning signals, and electronic signage, which are getting more and more important for road traffic safety, especially when the roads become more congested with high traffic volumes. When a driver does not feel well mentally or emotionally, there are in-vehicle supporting mechanisms, such as an electrical steering system that helps the driver to get better steering gear control, and other active control systems to compensate road deviations and facilitate braking management. Figure 1 [21] shows some popular driving support applications, most of which are available in present vehicles, including following distance alert, lane departure warning, and lane change support. In developing an effective driver support system, as illustrated in Figure 2 [21], essential issues include driver capabilities, psychological association of driving behaviour with the traffic environment, how driving support systems affect driving behaviour, and technical solutions to prevent or reduce human errors. In driving support technology development, it is necessary to integrate the research on driving behaviour with human emotions, along with the brain and nervous system, to customize to human characteristics for road safety enhancement. Driving behaviour and performance are associated with multifaceted mental and action processes in decision making and in physical responses, and depend on mental state such as concentration, vigilance, and mindfulness [22].
There are engineering solutions in place for the measurement of physiological data in different driving situations. One example is a bioharness, which can measure heart rate and breathing rate, among other metrics [23]. The researchers looked at four different physiological signals and eight affective states, through twenty twenty-five-minute recording sessions once a day. In the study, nine of the twelve drivers were measured to be in a supine posture (face up) and the other three were found to have a prone posture (face down). The drivers also had an activity level, measured in Vector Magnitude Units, of 0.058g. The thirteen drivers in the study had an average heart rate of 82 beats per minute. Their average temperature was 34°C (Celsius). Electrodermal activity sensors were used to measure the changes in conductivity produced in the skin resulting from increases in the activity of sweat.
glands [24]. The average change in the thirteen drivers was 5.3 μS (microsiemens) with a standard deviation of 3.8 μS.

A platform has been developed to detect how driver’s physiological parameters change with the road environment and has been applied to collect various driving measurement data [25][26]. Some of the measurement data are shown in Figures 3-5 for the heart rate, breathing rate, and stress level of the drivers, respectively. The physiological responses are recorded on the annotated bioharness of the drivers, while the stress metric not only is derived based on measured physiological signals (including electrocardiogram, electromyogram, skin conductance, and respiration) but also is validated by input from the drivers. The figures clearly demonstrate that the drivers’ physiological changes in response to the different road situations (i.e., rest, city and highway driving). In general, city driving represents a more complex task than highway driving, leading to higher heart rate and breathing rate of the drivers. When a person becomes stressed, they release hormones to help combat it. The body’s release of adrenaline leads to the deactivation of the parasympathetic nervous system and activation of the sympathetic nervous system. Adrenaline creates changes in the body such as increasing sweating, increased pulse and blood pressure. The average driver’s heart and breathing rates are both at their lowest point while at rest and increase while on the roads. Furthermore, the physiological changes are closely correlated with the stress metric (normalized to the interval [0, 1], with 0 for no stress and 1 for the maximal stress level). Drivers are more stressed under a more challenging driving situation.

Driving support systems aim to foster situational awareness and help with instantaneous risk evaluation, while providing drivers with reminders or warnings. Advanced support systems should account for diversity and individuality of drivers, to maximize their benefits for road safety enhancement. Individual driving behaviour is a result of complex process of interactions among the driver, vehicle, and environment (including the dynamics of other vehicles in proximity, traffic flow and density, road condition, and weather situation). The driving style of individuals has an impact on their safety and environmental friendliness. Hence, for customized driving support, the in-vehicle support system should differentiate how the driver reacts to particulars in the environment, where their emotions can be important, together with their mental and physiological states.

Figure 3. The heart rates of 6 drivers in various driving environments.
Advanced high-tech safety features can also help drivers who are absent-minded. For safety and collision avoidance, some studies have found that the reduction in vehicular accidents can be as much as a third if all vehicles are assembled with forward collision warning (FCW), blind spot vehicle detection sensors, and headlights that adapt to the environment [27]. These features provide warning signals or intervene to avoid a potentially dangerous situation. The FCW provides an audible, observable, and/or tactile warning to alert drivers of a potential crash with other vehicles. According to the Insurance Institute for Highway Safety (IIHS), FCW can reduce rear-end collisions by 27 percent reduction for vehicles with the function. A system that can sense a collision that is about to happen is the automatic emergency braking (AEB). If the driver does not properly react in time to the dynamics of other vehicles in proximity and traffic flow, the system automatically engages the brakes.
Based on the IIHS data, vehicles with both FCW and AEB will reduce rear-end collisions by 50 percent. Lane-Departure warning (LDW) systems will inform drivers when their vehicle passes over markings on the road without having their turn indicator being activated. IIHS studies indicate that, if vehicle manufacturers in the United States installed an LDW system within their vehicles, nearly 85,000 crashes and over 55,000 injuries would have not occurred in 2015. To some extent, the function of Lane-Keeping Assist (LKA) helps steering and/or braking to prevent a vehicle from drifting out of a lane [28]. The IIHS reviewed over 5,000 crashes in multiple states in the United States for seven years and established that the lane departure warning systems have lowered potential collisions by 11 percent, and all the related injury crashes by 21 percent [29]. Many vehicle manufacturers now offer monitoring systems and drowsy driver detection to alert drivers if they are tired or falling asleep. Different warning signs, such as a sound notification, pull on the seatbelt, turning on the air conditioner or turning on the windshield wipers, can notify the individual driving that they should pull over and take a break. Many vehicles now have technology that can connect with Bluetooth technology on their phone. This allows the individuals to use their cellphones and media devices without holding/touching them. Additionally, features in the vehicle can be activated by the driver's voice, which allow them to use commands to control the systems and features in the vehicle, such as the electronic systems (e.g., radio, GPS) [30]. System integrity and security are serious issues that need to be addressed by technology developers and vehicle manufacturers. There are several policy implications which cause policymakers to streamline and regulate different operating constraints to vehicle manufacturers. In addition, it is a significant task for vehicle manufacturers and legislature to make sure that individuals know what their vehicles can do and are able drive them in a safe manner [31].

In providing driving support via in-vehicle high-tech solutions, a crucial and challenging issue is how to make the solutions adapt to driver’s individual characteristics in helping with the complex recognition and judgement process and with making appropriate real-time decisions to maximize road safety. For instance, the best frequency and timing of warning signals not only depend on the road situations, but also vary with driving experience, behaviour patterns, emotional and psychological states of the driver. This is because the effectiveness of the warning signals closely relates to whether the driver is paying attention to the signal and how they would react to the warning, which not only deviate from driver to driver, but also change significantly for the same driver over different emotional states. As a result, for advanced driving support solutions, impact of driver diverse emotional states should be evaluated and properly accounted in supporting drivers making correct instantaneous decisions to avoid road accidents. There is no doubt that such multidisciplinary studies are technically challenging and require insight into how driving behaviours are interwoven with human emotions and psychological reactions, especially in an extreme situation with potential dangers. Human characteristics play a significant role in driving support system development.

With new technology constantly being developed and older technology being enhanced, autonomous vehicle (AV) technology has recently emerged. It aims at decreasing the number of vehicle accidents, limiting energy usage, improving air quality, and reducing traffic jams while improving the accessibility of public transport (which can get expensive). The AV is related to many beneficial social transformations, including better usage of the road by all drivers, a more economic transportation system, and the development and limiting the use of accessible vehicles for the non-ambulatory and handicapped individuals, along with those in lower income households. Technology that helps connect vehicles to one another can achieve better safety on the road, improve air quality, and lessen the time that people spend in traffic jams. In a world with many vehicles on the road, the communication of prominent bits of information between drivers, vehicles, roadways, and everything else in the environment is much better than before, and driver behaviour will shift correspondingly because of the growth of external stimulation [32]. These useful tools are the reasons behind the development and usage of AV technology, allowing it to be a feasible, cost-effective framework in
the near future [31]. The general effect of how the AV affects traffic flow needs further investigation. Today, driving mainly involves the relationship between the drivers and their vehicles. With the advanced information and communication technologies (ICT), connected vehicles will be in place via vehicular communications and networking especially with the emerging fifth generation (5G) communication networks. An important goal of the vehicular communication technology is to improve road safety, by letting nearby vehicles directly communicate with each other such as for the instantaneous movement information (i.e., moving velocity, acceleration/deceleration, sudden braking, turning, and so on). Hence, in the near future, with connected vehicles, driving will rely more on coordination with other people and vehicles in proximity on roads. Technological advances in both telecommunications and automobile sectors change the ways that drivers communicate and interact with other people and other vehicles on roads. The distribution of vehicle detection resources between different vehicles and the surrounding roadside infrastructure by using vehicle-to-everything (V2X) communication has the capability to improve the driver’s situation consciousness. The practical performance of a technological system can be different as there are variations in a vehicle’s system equipped ratio and driver's reception. As a result, it is necessary to research and look into the equipped ratio of the technological systems and the driver's reaction [33]. The development of driving support systems will need to accommodate the increased association of nearby drivers in their experiences of driving connected vehicles. Advanced ICT can help to facilitate more functionalities of driving support systems. However, further research is required to understand how the advances in driving support and connected vehicle technologies can change the complex relations between driver emotions and driving behaviours. Such studies of multifaceted behaviours will provide a foundation for smart driving support to enhance road safety.

5. Conclusions and Future Research

Feeling emotions is a part of neurobiological activity and is an element of emotion-cognition interactions. Emotions play a significant part in the evolution of a driver’s awareness and in the operation of their mental processes. Different emotion types associate differently with various types or levels of consciousness. How driving emotion affects driving behaviour and how to regulate driving emotion and encouraging safe driving behaviour via technological support are multidisciplinary and technically challenging. How emotions affect driving normally are task-specific and are highly dependent on the attention demands associated with the driving task and the emotion-related event [34].

The path to improving technology that deal with driver emotions is still problematic and faces many issues. How a driver perceives their environment is still the biggest issue and a major challenge when it comes to good and safe driving behaviours [35]. Other concerns include, but not limited to, how drivers like their vehicles, impacts on the environment and society, technologies helping with communication, ethical concerns, car designs and standards, and legal policy [36][37]. Further research should look into the effect of adjusting a vehicle's system/operation in response to different inside and outside environments and to driver emotions. One way to do so is to have the vehicle show compassion by changing the tone of the voice assistant in the vehicle to compliment the user’s emotions and to have the vehicle's technology adapt to the environment [38].

A driver’s mental state and emotional levels affect how their cognition is able to do its job. Even though some people believe they can get behind the wheel and drive after an argument or emotional event, they do not realize that any high-level emotional change can alter their judgment, reaction time, and focus. When driving, alterations in the driver’s mental state will cause their focus to change. Besides their outward physical expression, a driver’s emotional response also includes their personal feelings and thoughts, along with the different internal mental and physical changes of which the individual experiencing the emotion probably does not know that is occurring. If a driver does not
have emotional self-regulation, it is necessary for them to avoid driving until the emotions have subsided. More comprehensive research should investigate how a driver’s thoughts can cause them to lose focus on what is in front of them and why this occurs. Educational and therapy tools also need to be developed to prevent this from happening. In terms of how positive emotions influence driver’s behaviour, there needs to be more in-depth further studies as there is a lack of empirical evidence on how it influences driving behaviour. Emotions can affect driving behaviour in both positive and negative manners. Sometimes their impact occurs but may not be persistent. The effects of emotions depend on the exact driving task [34]. Future research on driver’s emotion state should include context variables when predicting how emotions will affect driving behavior.

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References


