Towards Empathetic Car Interfaces: Emotional Triggers while Driving

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ABSTRACT

Monitoring the emotions of drivers can play a critical role to reduce road accidents and enable novel driver-car interactions. To help understand the possibilities, this work systematically studies the in-road triggers that may lead to different emotional states. In particular, we monitored the experience of 33 drivers during 50 minutes of naturalistic driving each. With a total of 531 voice self-reports, we identified four main groups of emotional triggers based on their originating source, being those related to human-machine interaction and navigation the ones that more commonly elicited negative emotions. Based on the findings, this work provides some recommendations for potential future emotion-enabled interventions.

KEYWORDS

Affective Computing; empathetic interfaces; road safety

Figure 1: Study route during the driving study. The main areas included:

1) Mercedes-Benz laboratory (yellow triangle)
2) EDEKA Dagersheim (yellow diamond)
3) City area (red)
4) Country road (green)
5) Freeway driving (blue)

INTRODUCTION

Emotions regulate important areas of our daily activity including learning, decision-making, and productivity. In addition, our emotional state plays a critical role when interacting with other people and technology. In the context of driving, the emotional state of drivers plays a critical role in road safety as it has been shown that negative emotions like anger can significantly increase accidents [10]. To help minimize this problem, an increasing number of studies has considered the problem of the automated emotion measurement from different signals such as facial expressions, physiology and speech. However, there is little work studying the external triggers eliciting the driver's emotions which are important toward finding suitable interactions for different situations. Therefore, the goal of this work is to identify the most relevant and frequent emotional triggers in the context of real-life driving.

RELATED WORK

Several researchers have studied the impact of emotions on driving performance, adaptations and interventions among others. For instance, Underwood et al [10] investigated the effect of anger while driving, and found it to be associated with risky driving and negative performance. Similarly, Jeon et al [2] found negative performance associated with sadness and anger states. In terms of adaptations, Nass et al [5] showed that changing the in-car voice according to the emotional state of the driver can improve driving performance. In a separate study, Hernandez et al [1] described a set of potential interactions to help manage stress and, more recently, Paredes et al [7] thoroughly investigated breathing exercises to help drivers calm down. While the results are encouraging, few studies have systematically studied the distribution of emotional triggers in real-life scenarios that can be used to trigger the interventions. One exception is the study by Roidl et al [8] which used online surveys to investigate the influence of specific traffic situations. In particular, they found that the elicitation of emotions heavily depends on whether an event is goal congruent or incongruent (i.e., helping/preventing achieve the destination) and who/what is to blame for the specific event (e.g., another driver). In a separate study, Mesken et al [4] conducted a real-life driving experiment to investigate the occurrence and triggers of anger, anxiety and joy. In particular, they found that anxiety occurred the most frequently, especially in association with situation-blame and a lack of safety, followed by anger, which was mostly associated with other-blame. However, the study only considered three emotions and participants could have been biased by the presence of the experimenter inside the car. In contrast, this study similarly performs a naturalistic driving study but excludes the experimenter and allows participants to report any event that may have had an influence on their emotional state.

Figure 2: Overview of the sensors used in the vehicle

1) GoPro Hero 4 to capture driver's face and audio

2) GoPro Hero 4 to capture environment and audio

3) Samsung Galaxy Tab 6 to capture voice recordings, GPS and acceleration

4) Empatica E4 to capture heart rate, electrodermal activity, and skin temperature of the driver

DATA COLLECTION

Fig 2 shows the study vehicle which included an Android tablet to allow participants provide emotional ratings via voice while driving. The car also included other sensors to capture other sources of data that will be analyzed in future work (see Fig. 3). To collect naturalistic driving data, participants were requested to follow the instructions of an in-vehicle navigation system that would guide them on a pre-defined route which included city areas, country roads, and freeway driving (see Fig. 1). In addition, they were encouraged to operate the car and its features as they would during their daily life (e.g., switching on the radio). The length of the route was 14 km which was repeated twice by each participant and required around 50 minutes in total. During the driving, participants were instructed to report any event that may have affected their emotional state (e.g., car performance, weather, personal thoughts, environmental factors) via a 15-second voice recording. In contrast to previous studies, there was no regular reminder to give ratings, but participants were instructed to give spontaneous ratings which should include a description of the situation as well as the resulting emotional state. Overall, a total of 34 participants (20 male, 14 female) completed the experiment with a mean age of 44.6 years old, ranging from 21 to 67 (SD = 13.8). Due to failure of the rating tablet, one of the participants had to be removed, thus 33 participants were included in the analysis. To minimize the novelty effect, participants of the study were required to primarily use a Mercedes-Benz E-Class or similar car during their everyday life.

RESULTS

To start analyzing emotions while driving, this work focuses on the analysis of the 531 voice recordings. To do so, we first transcribed the voice recordings and assigned the emotional terms to either positive (POS) or negative (NEG) valence based on the circumplex model of emotions by Russell [9]. We then identified the different emotional triggers which were grouped into four main groups based on the originating source (see Fig. 3). Table 1 highlights the most frequently occurring triggers for each group.

1) *Traffic & Driving Task.* This group contains triggers that are directly connected to the task of driving or getting to the destination. The most frequent triggers were related to traffic management, followed by the ones related to the behavior of other road users, traffic density, and reactions to his/her own behavior (e.g., driving mistakes). Regarding the ones associated with traffic management, the most frequent triggers were traffic lights followed by road design and speed limits. As could be expected, green and red traffic lights led to a more positive or negative emotional states, respectively, which could also accumulate over time. When considering the behavior of other road users, the ratings were mostly negative due to traffic violations or rude behavior, while only a few ratings highlighted polite behavior. For instance, participants reported negative emotions when other drivers *"jostle"* and "[*pedestrians] walk across the street in red.*"

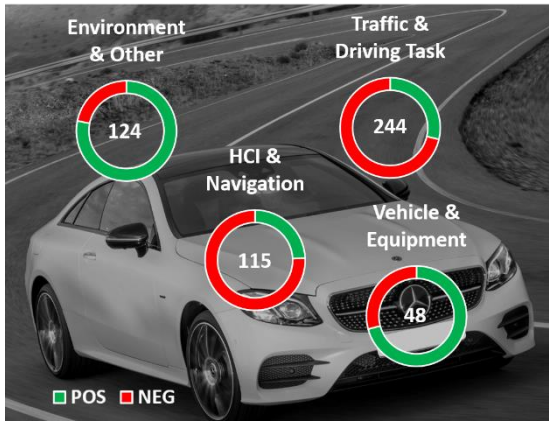

Figure 3: There were four main types of emotional triggers depending on their origin. Each of the groups shows the distribution of positive (green) and negative (red) emotional responses as well as the number of self-reports (number inside the circle).

As in previous studies (Roidl et al [8] and Mesken et al [4]), these results support that goal congruent events (e.g., low traffic density, green traffic lights) are associated with positive emotions and goal incongruent events (e.g., high traffic density, red traffic lights) are associated with negative emotions.

2) *HCI & Navigation*. This group comprises every trigger associated with the interaction between the driver and the car. The leading number of triggers were focused on the navigation system, followed by the radio, and the manual setting of certain car functions such as the cruise control. In particular, the navigation system mostly caused negative emotions by a lack of foresight and unclear route guidance (e.g., last-minute commands, missing intelligent recommendations for lane changing) which elicited states described as stress and annoyance. In contrast, the successful setting of the navigation system led to positive emotions. For instance, one participant stated *"I am super happy, [the navigation system is] easy to use, great"* and another one said *"super, the speech control worked well."* Overall, the reports suggest that interfaces that are intuitive, simple, and easy to use can help promote positive emotional states.

3) *Vehicle & Equipment*. This group covers the triggers associated with the equipment of the car and the driving experience. The most frequent reports focused on driving dynamics (e.g., acceleration, gear shifting) which were commonly connected with positive emotions. For instance, several participants reported *"joy"* and *"fun"* when entering the freeway and experiencing increased acceleration. This effect was more pronounced after speed blocking traffic conditions (e.g., traffic lights, stop signs) which some participants described with statements like *"finally, I can accelerate"* or *"speeding is fun!"*. Finally, comfort functions of the vehicle were perceived very positive, especially in extreme situations. For instance, the air conditioning and the seat cooling systems were considered as a nice-to-have feature due to the high temperatures during the days of the study.

4) *Environment & Other*. This group covers the triggers that were focused on environmental factors and other potential triggers that did not belong to any of the previous groups. The most frequent trigger were objects in the vicinity (e.g., buildings, construction sites), followed by weather and internal thoughts (e.g., family, vacations). For instance, one participant appreciated seeing *"a beautiful bridge"* and another one *"a nice motorcycle on the roadside."* Additionally, several participants referred to the clouds in a positive way with statements like *"the clouds are fantastic"* and *"there are beautiful cloud pictures."* On the other hand, people gave negative ratings to uncomfortable conditions such *as "hot and stuffy"* weather or unpleasant scent caused by other vehicles. Furthermore, the arrival at the destination commonly caused a positive feeling such as joy or relief. For example, even in case of a delay, participants made statements like *"super happy to finally have reached the destination after missing the route several times."*

	POS	NEG	Total
Traffic & Driving Task	**29%**	**71%**	**244**
Behavior of Others	*9%*	*91%*	*68*
Traffic Lights	*31%*	*69%*	*65*
Traffic Density	*53%*	*47%*	*53*
Road Design	*57%*	*43%*	*21*
Own Mistakes	*0%*	*100%*	*14*
Other	*65%*	*35%*	*23*
HCI & Navigation	**24%**	**76%**	**115**
Route Guidance	*12%*	*88%*	*65*
Radio Show	*47%*	*53%*	*15*
Navigation Settings	*69%*	*31%*	*13*
Unknown Warnings	*0%*	*100%*	*4*
Other	*22%*	*78%*	*18*
Vehicle & Equipment	**71%**	**29%**	**48**
Acceleration	*100%*	*0%*	*18*
Air Conditioning	*83%*	*17%*	*6*
Assistance Systems	*100%*	*0%*	*5*
Other	*53%*	*47%*	*19*
Environment & Other	**78%**	**22%**	**124**
Reaching Destination	*91%*	*9%*	*45*
Weather	*67%*	*33%*	*9*
Buildings & Sites	*78%*	*22%*	*9*
Thoughts	*63%*	*37%*	*8*
Other	*72%*	*28%*	*53*

Table 1: Most frequent emotional triggers based on the originating source

INTERVENTIONS

Participants of the study provided an emotional rating around every 2.7 minutes, providing a rich source of events that can be used to trigger emotion-enabled interventions. To help explore some of the possibilities, this section more deeply considers the triggers of the most frequent group (i.e., Traffic & Driving Task) and highlights some potential interventions.

Events associated with traffic management was found to be the most frequent source for negative states (e.g., frustration, annoyance, stress) probably because they counteracted the achievement of the drivers' main goal (i.e., reaching the destination). If the car detects one or several of the highlighted triggers (e.g., red lights, speed signs), the car could provide information about any potential time loss to help correct unnecessary biases or expectations by the driver [3]. This information may help appease the negative mood and help overlook potential goal-incongruent events.

The behavior of other road users was another common source of negative emotions, most commonly focused on other cars but also pedestrians and bicycles. Future driver's assistance systems may be able to detect such behaviors to provide contextual information for interventions. On the one hand, when detecting positive behaviors (e.g., somebody allowing the driver to retract at an intersection), the car could share the information with other users [1], which may further reinforce a positive feeling for the driver. On the other hand, when detecting negative behaviors (e.g., lane cutting or unnecessary overtaking), the car could guide the driver through slow breathing exercises [7] that can reinforce a more focused and calm driving.

When considering triggers associated with own behavior, missing the route was the most frequent and negative one. Such events may be currently detected by a combination of leaving the actual route displayed by the navigation system as well as a confused or annoyed facial expression. Since it is difficult to discriminate between missing the route due to inattention or due to a bad route guidance, a car reaction that is appropriate for both explanations may be needed. For instance, one option might be to show empathy by switching the in-car voice to an apologetic tone [5].

Finally, another important trigger that elicited negative emotional states was the high traffic density which require high cognitive demands. In the future, a possible method to help relax the driver may be activating the self-driving mode so the driver can divert the attention. Alternatively, the car could more actively engage with the driver by recommending breathing exercises [7] or mindful virtual reality experiences, such as ocean scenes [6].

DISCUSSION AND CONCLUSIONS

This work provides initial insights into the origins and frequencies of emotional triggers during a real-world driving study. Overall, triggers associated with the traffic and the driving task most frequently elicited negative emotions, closely followed by triggers associated with the HCI and Navigation. In contrast, the vehicle itself and its equipment as well as other environmental factors were more associated with positive emotions. In addition, we outlined potential interventions that could be applied to help cope with some of the negative triggers and better regulate emotional states. While the analysis is still ongoing, it is important to note that some of the findings are dependent on the study. For instance, we avoided having an accompanying experimenter in the vehicle to keep the situation as natural as possible. However, the addition of sensors like cameras and the conscious activity of providing emotional ratings may have still biased the participants. Furthermore, we focused on participants with similar cars to minimize the novelty effect. However, drivers of different cars may show a different distribution of emotional triggers. In addition, the route was predefined to ensure consistency across drivers. However, more uncontrolled routes may offer different sets of emotional triggers. Future work will expand the analysis by considering other sources of data (e.g., camera, physiological sensors) and settings that can help provide a more complete understanding about the relationship between emotional triggers, emotional states, and appropriate interventions to help improve road safety and enhance the driving experience.

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