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Effects of emotions on driving behavior

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ABSTRACT

Understanding how emotional states influence driving behavior is crucial for the development of advanced driver assistance systems that improve safety by flexibly adapting to the current state of the driver. However, studies on emotional effects on driving behavior have revealed heterogeneous results. This might reflect that emotion induction methods differed in the extent to which they distracted attention. In the present study, we investigated how positive and negative emotions affect driving behavior, and which of these effects are related to emotional effects on attention. We conducted a driving simulator study in which tonic states of anger, happiness and calmness were induced using a combination of autobiographical imagination and music. Participants completed two driving tasks which involved brake and gas reactions as well as tracking, and in which demands on dual tasking and selective attention were further varied. We found that emotions influenced driving behavior in these tasks in two ways. Emotions changed behavior either directly (e.g., by promoting aggressive driving), or indirectly by altering attentional effects on driving (e.g., by attenuating dual task costs). Our results demonstrate that emotional effects on driving are highly task-specific and crucially depend on attentional demands involved in the driving task and the emotion-inducing event.

1. Introduction

Research has shown that inattention of the driver due to additional tasks, fatigue or eye movements played an important role in 78% of car accidents on the road (Neale, Dingus, Klauer, Sudweeks, & Goodman, 2005). Internal or external distraction can slow down the reaction time (RT) of the driver by up to two seconds, thereby raising the risk for accidents significantly (Zwahlen, Adams, & DeBals, 1988). Investigating the origins of distraction and its influence on driving behavior is very important for improving safety on the road. For instance, research in this field could contribute to the development and improvement of advanced driver assistant systems (ADAS) that help to reduce the number of accidents by flexibly adjusting to the current driver state. The present study aims to investigate how emotions influence driving behavior, and to which extent these effects are mediated by effects of emotion on the attentional state of the driver.

Basic laboratory research on the influence of emotions on cognition typically rely on dimensional accounts that categorize emotions in terms of positive vs. negative valence and low vs. high arousal (Lang & Bradley, 2010). Corresponding studies

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have shown that not only the level of arousal but also the valence of emotional states determines how cognition is influenced. Negative emotions support adaptive shifts of attention (Kuhbandner & Zehetleitner, 2011) and help to focus on the prioritized task in dual tasking situations (Zwosta, Hommel, Goschke, & Fischer, 2013). However, negative valence is not always beneficial for attention. While negative valence paired with low arousal improves attentional control, the opposite is obtained if negative valence is paired with high arousal (Jefferies, Smilek, Eich, & Enns, 2008). Positive valence has frequently been associated with a broadening of attention, which can be advantageous or disadvantageous. On the one hand, positive valence leads to higher interference by incompatible distractors, resulting in slower RTs (Rowe, Hirsh, & Anderson, 2007), and an increased amount of fixations to peripheral stimuli (Wadlinger & Isaacowitz, 2006). On the other hand, it is accompanied by an increased cognitive flexibility (Dreisbach & Goschke, 2004) and an increased ability to find semantic associations (Rowe et al., 2007).

Due to the robust influence of emotions on attention, it is not surprising that the influence of emotions on driving behavior has been investigated in numerous studies. Drivers tend to fixate emotional advertisements longer that neutral ones (Megías, Maldonado, Catena, et al., 2011). Similar effects can be found for emotional words and emotional images on signs at the roadside, causing reduced speed (Chan & Singhal, 2013; Hancock, Hancock, & Janelle, 2012), reduced lane control (Hancock et al., 2012; Jeon, Walker, & Yim, 2014; Trick, Brandigampola, & Enns, 2012) and a reduced perception of hazard situations (Jones, Chapman, & Bailey, 2014). However, driving behavior appears to be influenced by specific emotional states only. Higher risk taking, aggressive driving and violations of traffic rules seem to be specific for angry drivers (Abdu, Shinar, & Meiran, 2012; Jeon et al., 2014). Hancock et al. (2012) reported a reduction of speed only after pleasant images but an impaired lane control only after unpleasant images (see also, Trick et al., 2012; Chan & Singhal, 2015). Interestingly, other studies found an opposing pattern with positive valence leading to impaired lane control (Pêcher, Lemercier, & Cellier, 2009) and negative valence leading to improved lane control and reduced speed (Chan & Singhal, 2013; Pêcher et al., 2009). The reason for these contradicting findings is unclear but could be a result of differences in the induction methods, the driving tasks, or both.

Emotional states in driving simulations were most frequently induced using visual stimuli (Chan & Singhal, 2013; Hancock et al., 2012; Jones et al., 2014; Megías, Maldonado, Catena, et al., 2011; Megías, Maldonado, Cándido, & Catena, 2011; Trick et al., 2012), whereas only few studies used other methods like auditory stimuli or autobiographical recall (Abdu et al., 2012; Chan & Singhal, 2015; Jeon et al., 2014; Pêcher et al., 2009). As a consequence, it is unclear whether driving behavior was affected directly by the emotional state or indirectly by the distracting effects of the visual stimuli. Indeed, also non-emotional advertisements at the roadside have been shown to attract visual attention and eye movements (Edquist, Horberry, Hosking, & Johnston, 2011), and emotional stimuli generally attract attention more strongly than neutral ones (Phelps, Ling, & Carrasco, 2006; Schupp, Junghöfer, Weike, & Hamm, 2003). Another disadvantage of emotion induction based on visual stimuli is the time course of the induced emotion. Autonomous responses to affective visual stimuli (e.g., blink rate, heart rate, skin conductance) last only for a few seconds (Codispoti, Bradley, & Lang, 2001), indicating only a brief duration of the induced emotions. While this is sufficient to investigate immediate, phasic changes in emotional state, it is not possible to infer effects of long-lasting, tonic emotional states (i.e., moods) on driving behavior.

1.1. Rationale of the present study

The goal of the present study was to investigate effects of positive and negative emotions on driving behavior while elucidating the contribution of attention for these effects. Our methodological approach differs in two crucial aspects from that in other studies: First, we used an induction method that ensures a long-lasting effect of the induced emotional state. Second, we constructed driving tasks in which demands on selective attention and dual-tasking were systematically varied. In this way, we could analyze whether effects of emotion on driving behavior are affected by attentional demands, and thus might reflect effects of emotion on attention.

As discussed above, affective visual stimuli presented during driving typically create distraction and presumably induce only phasic changes in emotional valence and arousal. We therefore utilized a combination of autobiographical imagination and music that has previously been shown to effectively induce emotions in laboratory tasks (Jefferies et al., 2008; Kuhbandner & Zehetleitner, 2011). Using this method, we induced happiness and anger because these are frequently investigated emotions in driving simulations and are known to influence attentional states (Jefferies et al., 2008; Kuhbandner & Zehetleitner, 2011; Rowe et al., 2007). As a baseline, a condition was used in which calmness was induced (Kuhbandner & Zehetleitner, 2011). Prior to completing the driving task, participants were instructed to recall a situation in which they had experienced happiness, anger, or calmness. During driving, the associated emotional state was refreshed by repeatedly presenting brief periods of happy, angry or calm music. This method induces a tonic emotional state while minimally interfering with the visuomotor driving task. Moreover, it has a high ecological validity because it relies on the (in sensu) experience of individualized emotional events.

We chose two previously established driving tasks and further modified them to obtain four conditions differing in attentional demands. In a modified version of the Three Vehicle Platooning Task (m3VPT) (Angell et al., 2006), participants were required to follow a car with a constant speed and to make an emergency braking whenever brake lights flashed. We created two conditions: While the standard task was used in the *low selective attention* condition, a *high selective attention* condition imposed additional attentional demands due to foggy weather and random flashing of distractor lights resembling the brake lights. The modified Continuous Tracking and Reaction Task (mConTRe) (Mahr, Feld, Moniri, & Math, 2012) required