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Research article

Attention and driving performance modulations due to anger state: Contribution of electroencephalographic data

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HIGHLIGHTS

- The influence of anger on attentional processing was observed during driving.
- Anger provoked a reduction of visual N1 peak amplitude.
- The standard deviation of lateral position was higher for angry drivers.
- Anger may combine the effects of a high arousal and mind-wandering episodes.

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ABSTRACT

Driver internal state, including emotion, can have negative impacts on road safety. Studies have shown that an anger state can provoke aggressive behavior and impair driving performance. Apart from driving, anger can also influence attentional processing and increase the benefits taken from auditory alerts. However, to our knowledge, no prior event-related potentials study assesses this impact on attention during simulated driving. Therefore, the aim of this study was to investigate the impact of anger on attentional processing and its consequences on driving performance. For this purpose, 33 participants completed a simulated driving scenario once in an anger state and once during a control session. Results indicated that anger impacted driving performance and attention, provoking an increase in lateral variations while reducing the amplitude of the visual N1 peak. The observed effects were discussed as a result of high arousal and mind-wandering associated with anger. This kind of physiological data may be used to monitor a driver's internal state and provide specific assistance corresponding to their current needs.

1. Introduction

Anger, which is a negative and highly arousing emotion, is commonly experienced while driving [1]. A consequence of experiencing this emotional state can be outward expression of aggression through verbal or behavioral means [2]. Such expression can include the use of one's vehicle to show own frustration to other road users or to frustrate another driver [3]. Furthermore, studies have linked driving anger to traffic rules infringements [4,5], a reduction of lateral control [6], and a reduction of following distances [7]. One frequently reported effect of driving anger is its ability to modulate driving style, leading to higher driving speeds and stronger accelerations [5,6,8].

The impact of anger on driving performance involves more than just behavioral modifications. Several negative effects also occur at a cognitive level, including the tendency to use a heuristic processing style, making drivers rely on superficial cues rather than on the significance of stimuli and leaving drivers unlikely to care-

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fully analyze their environments [9]. For example, increased driving speeds caused by anger seem to be predominantly mediated by a situational awareness deficit [8]. Angry drivers are less likely to be aware of critical information or potential hazards on the road.

Although a number of studies have investigated the impacts of anger state on driving behavior, its impact on attentional processing while driving has rarely been studied. Basic research studies assessing the efficiency of attentional processing have revealed that emotions could improve the most basic perceptual abilities [10]. Concerning anger, Techer et al. [11], used the Attention Network Test – Interactions (ANT-I) [12] to investigate the impact of anger on attention. The ANT-I is a modified version of the Attention Network Test (ANT) [13] that can be used to study the influence of several contexts on attentional processing of neutral stimuli. This test, based on the model of attentional networks [14], allows the evaluation of the three attention sub-systems: the alerting, the orienting and the executive control networks. Techer et al. [11] found a positive impact of anger on the alerting network, probably attributable to its high level of arousal.

Such effect on attention may also be observed using physiological measures such as Event Related Potentials (ERP). This electrophysiological technique is based on the observation of averaged brain electrical signals after a repeated stimulus presentation so as to infer on the underlying cognitive processes [15]. According to ERP literature, the first negative electrical peak after stimulus onset (N1) mainly reflects the perceptual processing stage of a target [15,16]. The amplitude of this component seems partly linked to the quantity of attentional resources allocated to sensorial processing. Additionally, this component is also sensible to the task. Its amplitude and latency are higher during a discrimination task than during a simple detection task [16,17]. For its part, the positive P3 peak is thought to inform on the cognitive processing of information and the inhibition of non-pertinent stimuli or responses [15,18]. During the ANT, both alerting and orienting signals could impact N1 amplitude [19], the largest amplitude being elicited during trials with alerting and orienting cues. As for P3, changes in amplitude were observed when target stimulus was flanked by incongruent stimuli, suggesting an effect of the executive control network [19]. Thus, changes in the efficiency of one attentional network may be observed with ERP measures.

Modulations of ERP amplitudes can also be observed during emotional information processing. Literature suggests that the valence dimension of a stimulus seems to affect preferentially early components [20,21]. For example, unpleasant picture processing can lead to larger P1 amplitude when compared with pleasant picture processing. As for late components, their amplitude can increase when processing highly arousing stimuli [20]. The effects on ERPs provoked by stimulus arousal are also observed during neutral information processing according to individual's arousal level [18]. It has been interpreted as an arousal-related modulation in the quantity of available attentional resources. Therefore, in a driving context, physiological arousal and negative valence evoked by an angry mood may impact the electrophysiological response of drivers.

To our knowledge, no study has ever measured the impact of an anger state on ERPs while driving. Additionally, the relationship between anger and the alerting network [11] is of particular interest due to the relative importance of this network during driving. Alerting signals are common and represent critical information for driving safety. Thus, a more efficient alerting network would allow the driver to take a greater advantage of the numerous alerting signals. However, ERP technique is particularly sensitive to motor activation, which may be a limitation to its usability in a driving context. For that reason, Bueno et al. [22] developed a simulated driving task (consisting in a motorcycle following paradigm, on a straight rural road) compatible with ERPs collection. It successfully revealed several effects of a forward collision alerting system as well as cognitive distraction on ERPs. [22]. Thus, the use of this ADAS reduced P3 latency evoked by the motorcycle's braking lights.

The aim of this present study was to investigate the impact of an anger state on attention while driving, using the ERP technique, and its impact on driving. Anger was expected to influence ERPs following auditory alert and braking light of the leading motorcycle due to increased arousal level and the greater efficiency of the alerting network. Such effect would imply an increase of auditory N1, and visual N1 and P3 amplitudes. Additionally, anger was expected to disrupt driving performance as measured by reaction times, control of speed and lateral position.

2. Participants

Thirty-three participants (19 females) aged between 25 and 40 ($M = 32.3$; $SD = 5.5$) were involved in this study and received a financial compensation. They reported a normal or corrected to normal vision, no neurologic disease and no medical treatment. Every participant was right-handed and had more than three years of driving experience. The research protocol was carried out in accordance with The Code of Ethics of the World Medical Association.

3. Material

3.1. Mood induction and measurement

Two experimental sessions were used. In the Anger session, participants were induced using the autobiographical recall procedure [23]. They had ten minutes to recall and write down a personal event during which they experienced anger, and were encouraged to provide as many details as they could. In the Control session, participants were not induced. In order to keep their natural mood, they had ten minutes to complete questionnaires about their driving habits. Mood states were measured using a modified version of the Brief Mood Introspection Scale (BMIS) [24]. The BMIS is a 16-item self-report questionnaire in which each adjective refers either to anger, happiness, sadness or calmness. It is rated on a 7-point scale, ranging from "not at all" to "absolutely", providing a score for the valence and the arousal dimensions of the emotional state.

3.2. Apparatus

The experimental scenario was presented to participants in a driving simulator composed of a 24" screen, an adjustable car seat, a steering wheel and three pedals.

Electroencephalographic data was collected using the Biosemi ActiveTwo system® sampled at 1024 Hz. Electrodes were placed on an electrode cap which was organized according to the international 10–20 system. Two mastoids electrodes were also placed on Ma1 and Ma2, and one EOG electrode was placed near the right eye. The reference electrode was placed on the nose. Event related potentials were extracted offline using the ELAN software [25].

4. Procedure

Each participant completed an Anger and a Control experimental session with a weekly interval. The session order was counterbalanced between the participants. Each session followed the same structure. After completing the informed consent form, the EEG recording apparatus was set on participants. They were seated in the simplified driving simulator at 90 cm eye-screen distance and completed a 13.5-min training scenario based on the procedure of Bueno et al. [22], in which they were instructed to fol-

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