



Brake lamp detection in complex and dynamic environments: Recognizing limitations of visual attention and perception

Scott McIntyre*, Leo Gugerty, Andrew Duchowski

Clemson University, 418 Brackett Hall, Clemson, SC 29634, United States

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ABSTRACT

Worldwide, both brake lamps and tail lamps on motor vehicles are required to be red. Previous studies have not examined the effect of this confound in a complex, high-traffic scenario in a driving simulator or on visuomotor behavior. In the first experiment, drivers detected brake lamps on nine lead vehicles and lane changes on two rear vehicles in a 15 min simulated night time highway drive. A second experiment was used to examine the findings in the context of pre-attentive visual processing research. A third experiment analyzed visuomotor behavior and subjective workload during a vigilance task to further evaluate this hypothesis. For all studies, tail lamp color was manipulated, resulting in two conditions: the currently mandated red tail lamps and red brake lamps vs. yellow tail lamps and red brake lamps. Compared to current rear lighting, employing yellow tail lamps with red brake lamps reduced RT, error, subjective workload, improved performance in detecting lane changes and also changed visuomotor behavior. It is suggested that the mechanism allowing better performance is pre-attentive, parallel visual processing.

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These studies are an extension of research previously published in this journal which examined automobile rear lighting (McIntyre, 2008). In this paper we will provide further evidence that the current international automobile rear lighting standard, which requires both tail and brake lamps to emit a red hue, is suboptimal given the cognitive and perceptual demands of driving. While there are a number of psychological phenomena that bear on this topic, we will focus on how limitations in underlying processes of visual attention and perception affect brake lamp detection behavior. Our claim is that when brake and tail lamps are both the same color, it increases subjective driver workload, requires more effortful eye scanning, and increases brake lamp detection time and missed braking signals relative to a system where the tail lamp color is changed while brake lamps remain red. In addition, we suggest that the superior performance attained when tail and brake lamps do not share the same color is due to automatic (or pre-attentive) processes guiding visual attention. We present three studies to investigate these claims.

Both brake (stop) lamps and tail (rear position) lamps on motor vehicles are required to be red (NHTSA, 2010; UNECE, 2006, 2008). Brake lamps are activated only when drivers depress the brake pedal, which typically indicates vehicle slowing or stopping. Tail lamps are activated whenever the vehicle lighting system is turned

on and indicate the presence of a vehicle. Moore and Rumar (1999) present a history of the international evolution that led to this confound whereby two lamps with separate functions are coded with the same color. The key step in this process occurred when the color red was chosen for rear position lamps prior to the introduction of brake lamps. Attempts to disentangle this misstep have focused on attempts to make the red of the brake lamp more conspicuous than the red of the tail lamp by adding greater luminance to the brake lamp and later an additional lamp with a unique location, the center high-mounted stop lamp (CHMSL). However, these changes to the brake lamp have met with limited success (Lee et al., 2002). One example of the difficulties caused by these color similarities is that daytime running lights do not allow the daytime illumination of tail lamps due to the attenuating effects of daytime ambient light on luminance differences between red tail and red brake lamps. Recent proposals being studied by NHTSA once again involve adding features to the brake lamp, e.g., flashing, in hopes of attracting driver attention to braking (Wierwille et al., 2003, 2006).

Efforts to improve brake lamp detection have received consideration from researchers and policymakers because of the importance of the brake lamp signal to safe driving, as failure to detect a brake lamp may lead to a rear-end collision. Approximately two million rear-end collisions occur in the United States each year resulting in billions of dollars in loss, nearly one million personal injuries and around 2000 fatalities, constituting roughly 25% of all collisions and approximately 5% of fatalities (NTSB, 2001; Sullivan and Flannagan, 2003). The traffic conditions faced by drivers vary widely, from simple, low-traffic situations to complex, high-traffic ones. While many

* Corresponding author. Tel.: +1 516 455 3431.

E-mail addresses: bcstat@yahoo.com (S. McIntyre), gugerty@clemson.edu (L. Gugerty), andrewd@cs.clemson.edu (A. Duchowski).