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Capturing attention to brake lamps

Scott E. McIntyre *

Graduate School and University Center, CUNY, Department of Psychology, Brooklyn College, 2900 Bedford Avenue, Brooklyn, NY 11210-2889, United States

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Abstract

Rear-end collisions and distraction are major concerns and basic research in cognitive psychology concerning attention in visual search is applicable to these problems. It is proposed that using yellow tail lamps will result in faster reaction times and fewer errors than current tail lamp coloring (red) in detecting brake lamps (red) in a "worst case" scenario where brake lamp onset, lamp intensity and temporal and contextual cues are not available. Participants engaged in a visual search for brake lamps in two conditions, one using red tail lamps with red brake lamps and one with the proposed combination of yellow tail lamps with red brake lamps in which they indicated by keyboard response the presence or absence of braking cars. The hypothesis that separating brake and tail lamps by color alone would produce faster RTs, reduce errors, and provide greater conspicuity was supported. Drivers and non-drivers detect absence and presence of red brake lamps faster and with greater accuracy with the proposed yellow tail lamps than red tail lamps without the aid of any of the aforementioned cues. Vehicle conspicuity will be improved and reductions in rear-end collisions and other accidents will be reduced by implementing the proposed yellow tail lamp coloring.

Keywords: Rear-end collisions; Brake lamps; Tail lamps; Visual search; Conspicuity

Approximately two million rear-end collisions occur in the United States each year resulting in billions of dollars in economic loss, nearly one million personal injuries and around 2000 fatalities, constituting roughly 25% of all accidents and approximately 5% of fatalities (NHTSA, n.d.-b; NTSB, 2001; Sullivan and Flannagan, 2003). There are a variety of approaches to reducing these numbers. Systems to monitor driver arousal as well as countermeasures involving Intelligent Transportation Systems (ITS), such as adaptive cruise control (ACC) and collision warning system (CWS) are being studied intensively. While these systems hold great potential promise, their implementation may be many years away. Additionally, because driving relies heavily on visual stimuli, it seems logical to examine the effectiveness of the present visual cues provided by automobile lighting in capturing attention to brake lamps.

Presently, the visual stimuli used to alert drivers to a stopped or braking vehicle are cues of the color red, the change in intensity from a tail lamp to a brake lamp, and since 1995 the unique location of the lamp (on most, but not all vehicles) in the form of a center high-mounted stop lamp (CHMSL). The vehicle lighting standard is mandated by the National Highway Traffic Safety Administration (NHTSA) under Title 49 of the United States Code, Chapter 301, Part 571, Federal Motor Vehicle Safety Standards (FMVSS), Standard No. 108, Lamps, Reflective Devices, and Associated Equipment (NHTSA, n.d.-a). The stated purpose for Standard 108 is to "reduce traffic crashes and deaths and injuries resulting from traffic crashes . . . by enhancing the conspicuity of motor vehicles on the public roads so that their presence is perceived and their signals understood, both in daylight and in darkness or other conditions of reduced visibility" (NHTSA, n.d.-a). According to the Standard 108, the functional purpose of the tail lamps is to indicate the vehicle's presence and width. The functional purpose of the brake lamps is to indicate braking. Both tail lamps and brake lamps are required to be red, on the rear of the vehicle, symmetrical, and as far apart as is practicable.

Although brake lamps and tail lamps have different functions, they are required to share the same color. To compensate for this color similarity, luminance and location cues have been added to brake lamps. While differing luminance may seem to increase conspicuity, luminance cues are moderated by a variety of environmental factors such as ambient lighting conditions, distance from the source, vagaries of size, shape, and number of bulbs used on different vehicles and the limitations of subjective

* Tel.: +1 516 455 3431; fax: +1 718 276 9927.
E-mail address: bcstat@yahoo.com.

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human perception which prove faulty when judging absolute differences (Wickens et al., 1998). Redundancy of lamps is also unable to compensate for color similarity when one or more vehicle lamps are obstructed from view. With the present color system, the illumination of one corner red lamp could indicate braking, turning, or simply a vehicle with its lights on. Additionally, the initial benefit resulting from the novel change in location provided by the CHMSL has reportedly lost much of its effect since its inception (NHTSA, 2002). The red color requirement for tail lamps has also constrained ideas aimed at increasing conspicuity such as with daytime running lights (DRLs). The implementation of DRLs has not included rear illumination because of tail and brake lamp similarity. This has had the net effect of actually compromising conspicuity of the rear of vehicles during the daytime which may include dim lighting conditions such as overcast skies and fog.

Requiring two lamps with different meanings to share the same color is very problematic if detecting brake lamps is understood as a visual search task. A large body of research investigating how people search a visual scene indicates that in order to automatically capture attention to a target (in this case brake lamps), the target must differ from its potential distractors (here, tail lamps) on salient dimensions, such as color (Treisman and Gelade, 1980; Treisman, 1986). If features are shared by target and distractors, such as being the same color, cognitive resources are needed to search the visual field to locate the target. In this situation, as the number of distractors increase, so does the duration of the search. On the other hand, if the target is a feature singleton and does not share properties such as color with distractors, few attentional resources are needed to detect the target. In fact these salient features are said to make detection of the target stimulus "preattentive" such that a search is preempted. The target is said to "pop-out" of the visual field and increasing the number of distractors does not lengthen the time needed to detect a target (Treisman and Gelade, 1980; Treisman, 1986). Thus, the shared feature of color for tail, directional and brake lamps makes the search for a brake lamp a conjunctive search that impairs brake lamp detection. Seeing red lamps without the attendant consequence of braking becomes a nearly perpetual experience for drivers because of this redundant use of red. Because of the conflicting meanings of presence, width, braking, and direction connected to the color red, drivers cannot use a simple search strategy based on color as a predictive cue of braking. Rather, they must detect multiple cues in a search that is complex, effortful and inefficient. The task is really no longer *detection* of brake lamps but *discriminating* between multiple red lamps.

Beginning in the 1960s it was recommended to the NHTSA to separate the function of rear lighting on vehicles by the dimension of color using yellow for tail lamps and red for brake lamps only (NHTSA, 2002, 2003). More recently, another study found that using yellow tail lamps would improve brake lamp detection. Cameron (1995) examined the use of yellow tail lamps with red brake lamps instead of the conventional use of red tail lamps and red brake lamps in a system he called red light means stop (RLMS). Subjects were tested on detection of activation of rear lighting while performing distraction tasks as they sat in a car viewing the rear of another stationary vehicle during daylight and nighttime conditions. His results showed faster RTs and reduced errors for the RLMS (yellow tail lamps/red for brakes only) compared to conventional lighting.

There is good reason to test the performance of brake lamp detection without moving vehicles as did Cameron (1995). There are a number of other visual cues that a lead vehicle is braking that are independent of vehicle lighting. A stop sign or red light at an upcoming intersection provide contextual cues of the need to brake that may precede or even supercede lead vehicle brake lamp activation. Spatio-temporal cues such as rate of closure on lead vehicle, lead vehicle pitch and the looming cue of increasing vehicle size on the retina may indicate lead vehicle deceleration. Because it is possible that the temporal, spatial and contextual cues are the primary indication of braking used by drivers, in order to examine the effectiveness of Standard 108 in aiding brake lamp detection, the standard should be initially tested in the absence of these cues.

Given the stated purpose of Standard 108 to enhance conspicuity of vehicles such that their presence is perceived and signals understood in all conditions, the present study proposes that the present rear lighting requirements are inadequate based on cognitive psychology research. For this experiment, it was predicted that separating the functional purpose of (target) brake lamps from the functional purpose of (distractor) tail lamps on the single dimension of color would result in faster RTs, fewer errors and less variability in both measures than separating the two lamps on the dimensions of location and intensity as is done with the current lighting system when drivers do not have the cues of lamp onset and perceptual differences in lamp intensity. Thus, this experiment is testing the detection of the brake signal in a "worst case" scenario of complexity, distraction and lighting that negates cues of lamp onset, lamp intensity, and other temporal cues.

1. Method

1.1. Participants

Twenty Brooklyn College undergraduates (10 drivers: mean years driving = 7.8, mean age = 29.8, 6 female, 4 male; 10 non-drivers: mean age = 21.3, 9 female, 1 male) were recruited from an Introductory Psychology subject pool for a within-subjects experimental task. Binocular visual acuity (with corrective lenses if needed) using a Snellen chart on a self-illuminated stand at 4 and 2 m, and color vision using the Farnsworth D-15 test were evaluated for all participants prior to the experiment. All subjects included in the study had acceptable acuity at both distances (20/20 or better at 4 m) and passed the Farnsworth D-15.

1.2. Apparatus

Cedrus Superlab^{TM} software was used to program the presentation of stimuli projected onto a screen through a personal computer and portable projector in a 3 m × 3 m unlit room with no windows and no artificial lighting. Participants sat in a chair