Increasing Speed Estimation Accuracy Through Daytime Headlight Usage

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Abstract

Perception of oncoming vehicle speed was examined with regard to headlight usage. Subjects produced speed estimations during daylight conditions on a two-lane rural road for a vehicle with its headlights on and the same vehicle with its headlights off. The speed of the vehicle, which was controlled to five incremented speeds, was estimated to be greater in videos where the vehicle's headlights were on. This finding suggests that headlight usage may be an effective means of compensating for individuals' tendency to underestimate vehicle speed by increasing the contrast of the vehicle in the visual field.

Keywords: vehicle speed estimation, headlight usage, speed perception

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Introduction

A disproportionate amount of fatalities are caused by head-on collisions, with numbers nearing half of all deaths for motor vehicle collisions in certain countries (Mwesige, Farah, & Koutsopoulos, 2016). There is no current explanation for this phenomenon. One of the situations that exposes drivers to a risk for head-on collisions is the undertaking a passing maneuver (Bar-Gera and Shinar, 2005). Mwesige, Farah, and Koutsopoulos (2016) identify the speed of the oncoming vehicle as a factor that influences drivers' decisions to pass. It stands to reason that more accurate estimations of speed for oncoming vehicles could reduce the number of head-on collisions.

Speed Estimation

A factor that influences the level of danger associated with passing is the ability to estimate the speed of oncoming vehicles. The less capable a driver is of discerning the speed of an oncoming vehicle, the more likely it is that a driver will attempt a passing maneuver without enough space to complete it, resulting in a head-on collision. Passing maneuvers can require drivers to accelerate above the posted limit, and excessive speed is a factor in 30 percent of all fatal crashes (National Highway Traffic Safety Administration, 2014). Schutz and colleagues (2015) conducted an experiment which tested drivers' ability to estimate their speed as both passenger and driver. Drivers who were blind to the speedometer were instructed to accelerate to a specific speed, and then indicate to the experimenter when they felt they had reached that speed. The experimenter then recorded the actual speed of the vehicle. For speeds ranging from 31 to 50 kilometers per hour, the tendency for drivers was to exceed the instructed traveling speed by an average of 20 percent. Passengers were asked to make a judgement of the speed at which the vehicle they were in was traveling at a time designated by the experimenter. The tendency for passengers was to underestimate the driven speed by an average of 24 percent. It was also discovered that this bias applied to estimations made by drivers of the speed of oncoming cars, leading drivers to underestimate oncoming vehicle speed in the 31 to 50 kilometer per hour range by an average of 24 percent (Schutz et al., 2015). The results of this study suggest that underestimation of vehicle speeds are doubly responsible for head-on collisions, as drivers underestimate their own speed as well as oncoming vehicle speed, compounding the error in determining whether a passing maneuver can be successfully made. It is reasonable to assume that a driver attempting a passing maneuver would seek the most accurate estimate of oncoming traffic speed possible, but if that means an estimate that appears twenty percent slower than it actually is, accidents are bound to happen. Conchillo and colleagues (2006) supported Schutz's findings with regard to passenger speed estimation, concluding that passengers underestimate their speed by an average of 5 kilometers per hour when traveling at a speed of 50 kilometers per hour. This effect was noted on both a closed track and an open roadway which was not a highway. They also found that passengers' estimations of their own speed on a highway are more accurate, possibly due to the presence of additional vehicles traveling in the same direction as the passenger which may provide additional stimuli to aid in speed estimation (Conchillo et al., 2006). If this is true, then it could explain the prevalence of head-on collisions; when trying to estimate the speed of an oncoming vehicle in a non-highway setting, there is no other stimulus traveling in the same direction at roughly the same speed to assist the driver in the accuracy of said estimation.

Headlights

In low-lighting conditions such as night or inclement weather, headlight usage plays an important role in helping to increase vehicle conspicuity (Gould et al., 2012). In standard daytime conditions, however, headlight usage is not common. It remains to be seen if the usage of headlights during the day could have an effect on vehicle conspicuity. Horswill and colleagues (2005) had subjects view footage of a van, car, and motorcycle each traveling toward the camera at the same speed in separate instances. They found that larger vehicles are perceived as approaching a driver more quickly than smaller ones. It has been shown that a vehicle’s headlights afford a driver critical information about its size in low-light conditions, as subjects underestimated the approach speed of a single-headlight motorcycle by an average of 56 miles per hour, where the approach speed of a car with two headlights was underestimated by an average of less than 10 miles per hour (Gould et al., 2012). It stands to reason that if daytime headlight usage can give drivers the impression that a vehicle is larger or increase its contrast, this will help to correct for some of the speed underestimation experienced by drivers. Brooks and Rafat (2015) noted that lower levels of contrast in a driver’s field of view contributes to reduced accuracy in personal speed perception. The possibility exists that the greater contrast offered by the usage of headlights on vehicles in daylight conditions may assist drivers in making a more accurate judgement of speed on those vehicles.

Simulation of Driving Conditions

Numerous studies have confirmed the validity of results obtained through the presentation of driving stimuli in a simulated fashion. Evans (1970) found that subjects were able to estimate the speed of a vehicle from a film made through the windshield of a car as long as subjects were the correct perspective distance away from the screen. These results are bolstered by Cœugnet and colleagues (2013), who found that subjects were able to make estimations about vehicle speed from films made from the driver's perspective and were able to estimate both the speed they would travel if they were driving, and the speed the vehicle was traveling in the film. The use of recorded footage to act as a surrogate for putting a subject behind the wheel of a vehicle is capable of providing accurate and valid data.

Current Study

The current study seeks to analyze the impact of headlight usage during daylight conditions on the estimation of oncoming vehicle speed. As there has been little-to-no research done on this particular topic, there is no previously established model to follow. While previous studies have employed the use of two moving vehicles, this study will utilize one vehicle traveling toward a camera positioned in the roadway to simulate the point of view one might have sitting in the driver's seat of a car. The current study will employ the playback of previously recorded footage to subjects seated a standardized distance from a computer screen. The footage will consist of several clips of a vehicle approaching the camera at a variety of constant speeds during optimal daylight conditions with headlights both on and off. Subjects will be asked to estimate the speed at which the vehicle was travelling in the course of the clip. Previous research has suggested that oncoming vehicle speed is typically underestimated. It has also been noted that low contrast in the visual field results in lower accuracy of speed estimations. Therefore, it is hypothesized that subjects will make more accurate estimations of the speed of the vehicle in the clips where it has its headlights on.

Method

Participants

Sixty-four Stockton University undergraduate psychology students participated in the experiment (51 females, 13 males; *M (SD)* age = 22.44 (6.55) years old).

All participants were provided course credit as compensation for participating in the study.

Materials

Participants were asked to record their estimations of speed in miles per hour on a paper form. Participants were tested in a laboratory setting in front of a computer, where they watched 60 video clips of the experimental car without sound. The experimental car was a grey Kia Soul. The clips depicted the experimental car driving in the opposite lane on a two-lane road toward the camera. See Figure 1 for an illustration of the scenery and vehicle used in the clips. In each set of videos, the experimental car remained at a constant speed throughout the duration of the clip. There are five clips in each set of videos that differ based on the speed the vehicle is moving: 25, 30, 35, 40, and 45 miles per hour. There are four sets of clips. In Set A, the experimental car traveled 500 feet with its headlights off, and in Set B, the experimental car traveled 500 feet with its headlights on. In Set C, the experimental car traveled for 5 seconds (183.33, 220, 256.67, 293.33, and 330 feet for each speed, respectively) with its headlights off, and in Set D, the experimental car traveled for 5 seconds with its headlights on. Sets A & B comprise the distance standardization set, where Sets C & D comprise the time standardization set. The duration of the videos in the distance standardization set were 14.64, 12.36, 10.74, 9.52, and 8.58 seconds, respectively, and the duration of the videos in the time standardization set were fixed at 5 seconds. Two different constants were used in order to improve the validity of the study. The distance standardization set held distance traveled constant at the expense of changing clip times, which presented a timing confound. Conversely, the time standardization set held time constant at the expense of changing clip distances, which created a distance confound. The inclusion of both types of standardization in this experiment assisted in determining if the confounding variables of time and distance affected subjects' speed estimations.

Figure 1.

Images from the video clips. The top image depicts the headlight condition, where the bottom picture depicts the no headlight condition.

Procedure

Participants signed a consent form, and then watched 60 clips of a vehicle travelling toward the camera in the opposite lane to imitate an oncoming vehicle. Participants estimated the speed of the vehicle by recording their estimates on the computer through SuperLab, using miles per hour as the unit of measure. Participants were exposed to and estimated the speed of all 20 videos three times each. The order in which the 20 videos were presented in each of the three sets was randomized for each block. Participants viewed every video in each 20-video block before any of the videos were presented a second time.

Estimation Errors were calculated using the following formula:

$$\frac{(\text{Estimated Speed} - \text{Actual Speed})}{\text{Actual Speed}} * 100$$

This error variable quantifies error as the difference between the actual speed and the estimated speed as a percentage of the actual speed. This means that positive error values indicate overestimates of the actual vehicle speed, while negative error values indicate underestimates of the actual vehicle speed.

Data Screening

The results of 15 of the participants were excluded from data analysis due to the range of their estimations being less than 10 miles per hour across all of the trials. Thus, this analysis was based on a sample of forty-nine of these participants (38 females, 11 males; *M (SD)* age = 22.08 (4.91) years old).

Results

A 5 (speed: 25 vs. 30 vs. 35 vs. 40 vs. 45) x 2 (headlight: on vs. off) x 2 (standard: distance vs. time) repeated measures ANOVA was performed to test for effects on speed estimation errors. Table 1 displays the mean and standard deviation values of the estimation errors for each of the headlight and standardization conditions.

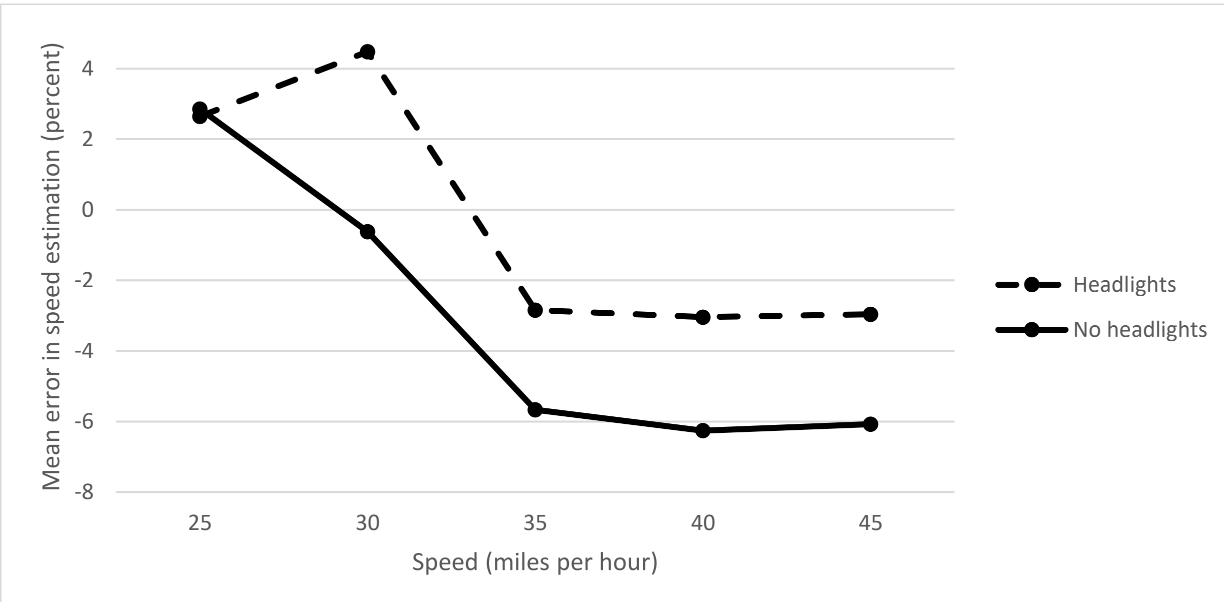
Table 1. Mean (SD) Speed Estimation Error Values

	Distance Standard		**Time Standard**	
Actual Speed	**Headlights On**	**Headlights Off**	**Headlights On**	**Headlights Off**
25	-5.55% (27.36%)	-2.79% (31.22%)	10.86% (28.87%)	8.50% (30.13%)
30	-1.55% (28.69%)	-4.86% (27.83%)	10.52% (22.29%)	3.62% (25.22%)
35	-7.04% (22.58%)	-8.21% (25.82%)	1.35% (23.46%)	-3.13% (23.69%)
40	-6.75% (22.74%)	-8.65% (19.80%)	0.68% (22.68%)	-3.88% (22.59%)
45	-2.43% (18.76%)	-7.55% (20.48%)	-3.49% (17.60%)	-4.62% (18.69%)

Analyses Pertaining to the Effects of Headlights

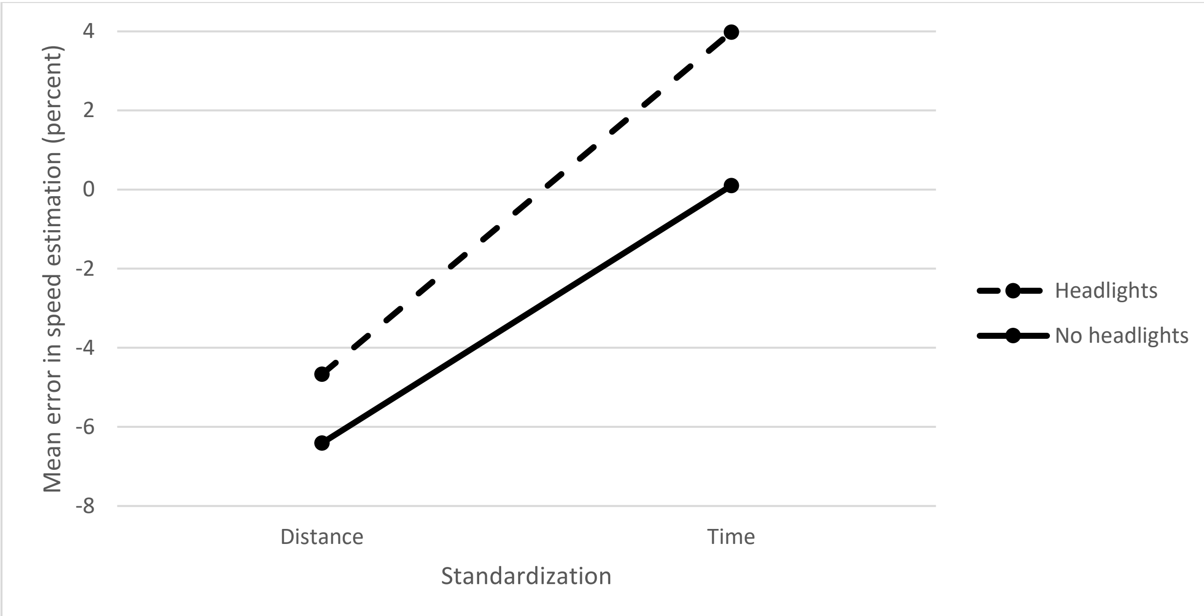
There was a significant main effect of headlight use, F (1, 48) = 9.46, $p < .01$, partial η^2 = .165. There was no significant interaction between headlight and speed, F (4, 192) = 1.49, $p >$ .05, partial η^2 = .030. Graph 1 displays the mean errors in estimation across the speed trials for both headlight conditions. At 25 and 30 miles per hour, participants overestimated speed in both headlight conditions in trials with time standardization, but underestimated speed in both headlight conditions in trials with distance standardization. For all other speeds, participants underestimated the speed of cars significantly more in the headlight off condition than in the headlight on condition.

Graph 1. Mean errors in speed estimation by speed for headlights on and headlights off.



There was also no significant interaction between headlight and standardization, F (1, 48) = 1.88, p > .05, partial η^2 = .038. Graph 2 displays the mean errors in estimation across the standardization conditions for both headlight conditions. Participants made smaller underestimations in speed for videos in which the headlights were on in distance standardization condition, but in time standardization condition, participants made overestimations in speed for videos in which the headlights were on.

Graph 2. Mean errors in speed estimation by standardization for headlights on and headlights off.

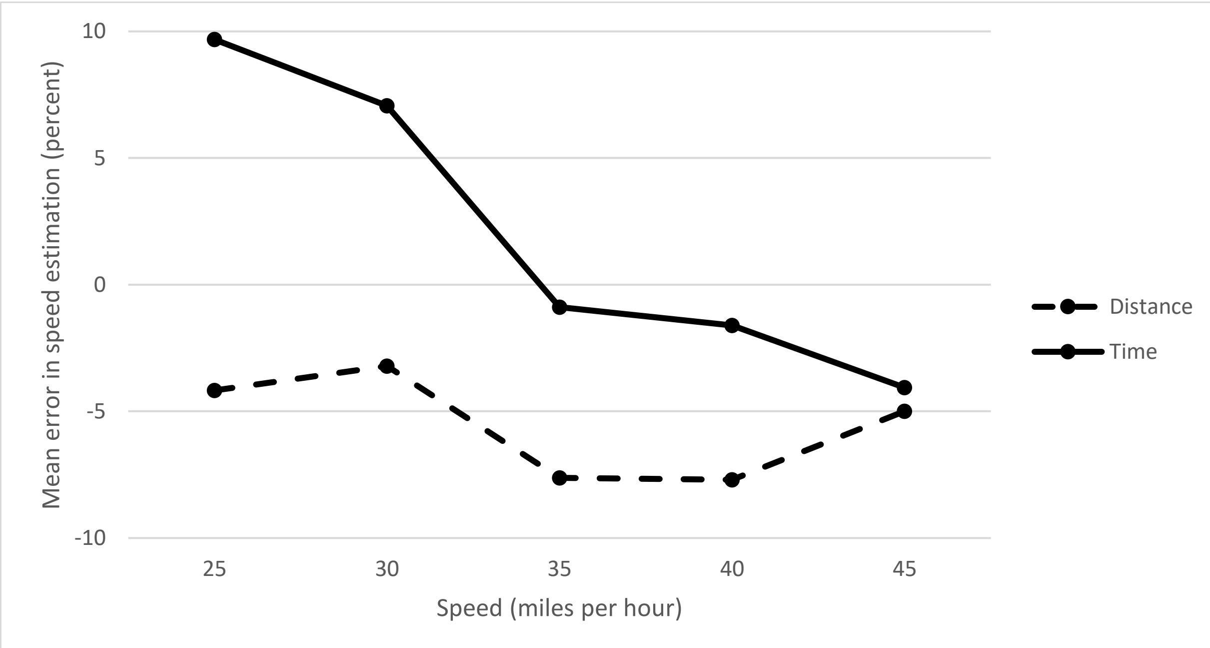


There was no significant three-way interaction between speed, headlight use, and standardization, F (3.41, 163.83) = 1.35, $p > .05$, partial $\eta^2 = .027$.

Additional Analyses

There was a significant main effect of speed, F (2, 96.31) = 12.84, $p < .01$, partial η^2 = .211. There was also a significant main effect of standardization, F (1, 48) = 55.80, $p < .01$, partial η^2 = .538. There was a significant interaction between speed and standardization, F (3.04, 145.66) = 7.64, $p < .01$, partial η^2 = .137. For the distance standardization condition, speed was underestimated at a relatively constant degree (an underestimation of roughly 5%) across all 5 actual speeds, while, in the time standardization condition, the two slowest actual speeds were largely overestimated, but became increasingly underestimated as the actual speed of the car increased. Graph 3 displays the mean errors in estimation across five speeds for both standardization conditions.

Graph 3. Mean errors in speed estimation by speed for distance standardization and time standardization.



Discussion

In summary of the results previously described, individuals estimated speed to be greater when headlights were on than when headlights were off, on average when condensing the two standardization groups. This was true for all speeds above 25 miles per hour. For all speeds above 35 miles per hour, this effect remained relatively constant in magnitude, again on average when condensing the two standardization groups.

Higher speeds tended to produce greater underestimations in speed for the two headlight conditions, while the lowest speed produced overestimations in speed. Additionally, the nature of the standardization used has an appreciable impact on individuals' errors in speed estimation, with distance standardization errors trending around 5 percent underestimation for all speeds, and time standardization starting out at a roughly 10 percent overestimation at 25 miles per hour and then decreasing at a relatively constant rate to a nearly 5 percent underestimation at 45 miles per hour. Trials where the distance the vehicle travels remains constant replicated the underestimation results found by Schutz and colleagues (2015).

The findings of this research were largely in keeping with the hypotheses presented earlier and with the conclusions of other studies. As found by Cœugnet and colleagues (2013), digital presentation of footage of a vehicle did result in underestimations of speed which were comparable to those made by subjects in the field. Speed was increasingly underestimated as the actual vehicle speed increased when headlights were off, replicating the results of Conchillo and colleagues (2006) but not Schutz and colleagues (2015), who found that estimation was increasingly accurate as actual speed increased. The reason for this discrepancy may be due to variation in the testing conditions of the two studies; while the Schutz and colleagues (2015) study ran vehicles on an airport runway, a flat and open area which typically has a minimum of extraneous visual stimuli, the Conchillo and colleagues (2006) study ran vehicles on both a closed track and a roadway, which represent more accurately driving conditions outside of the lab.

As was hypothesized, trials in which the headlights of the vehicle were on led to significantly lower errors in speed estimation. This effect can likely be attributed to an increase in contrast, a critical factor in increasing estimation accuracy as noted by Brooks and Rafat (2015). The usage of headlights would seem to provide an additional cue for individuals to incorporate into their estimations of vehicle speed, ultimately increasing the accuracy of their estimations. The findings of the present study as they pertain to headlight usage increasing contrast would be supported by an additional study in which the luminance of the headlights in the test vehicle was variable. If the contrast generated by headlights is truly a factor in increasing speed estimation accuracy, higher luminance values for the headlights should produce an increase in estimation accuracy.

There are additional questions raised by the findings of this study. One interesting effect worth noting is that of standardization. It was found that individuals made underestimation errors consistent with the results of the Conchillo and colleagues (2006) and Schutz and colleagues (2015) studies in trials where the distance the car traveled was held constant. For the trials where time was held constant, there was an inflation of estimated speed error which decreased as the speed of the vehicle increased, until it was nearly identical to the error made by individuals in the distance standardization trials. The Schutz and colleagues (2015) study did not utilize distance or time standardization, instead allowing subjects to drive for as long as necessary until they felt they had reached the instructed speed. The Conchillo and colleagues (2006) study used time standardization for their passenger-based estimations of speed, where the vehicle they were in accelerated to its target speed and then held that speed for 9 seconds before subjects made their estimate of speed. The results of the present study may reflect the unrealism of time standardization; in reality, cars do not appear five seconds away from a driver on an otherwise open road, they are typically spotted while there is still an appreciable amount of time before the driver and the oncoming vehicle meet. In the present study, speed estimation errors were more influenced by the duration the vehicle was seen; speed in the time standardization condition was overestimated at the lowest speed and underestimated at the highest speed. In the distance standardization condition, where the duration the vehicle was seen varied in accordance with its speed, speed was underestimated at a relatively consistent magnitude for all actual speeds.

Considering this, distance standardizations appear to be the most ecologically valid method for testing speed estimation errors, supported by the results of the present study as well as the findings of both Conchillo and colleagues (2006) and Horswill and colleagues (2005).

Limitations

Due to the field-based nature of this experiment, the footage collected cannot be completely standardized. There may be slight discrepancies in the angle of the camera due to traffic conditions at the time of filming, and the discontinuity in lighting between the footage itself and the lighting of the testing room may disrupt the intended immersive nature of the experiment. An additional limitation to this study is the range of speeds utilized in the study. While 5 mile per hour increments were discernable for individuals, beginning with a speed of 25 is unrealistic for typical two-lane highway conditions. A lower bound of 40 and an upper bound of 70 would have more thoroughly encompassed the range of roadway conditions typically experienced by drivers. A further limitation to consider is the fact that the camera is stationary for the footage collected in this experiment. It may be that footage from a moving vehicle increases the degree to which errors in speed estimation are made, making the differences between the groups more pronounced. There is also a question of ecological validity to be raised where stationary footage is concerned; stationary footage is not representative of the experience of passing a vehicle on a two-lane highway.

Concluding Thoughts

The effect of headlight usage on errors in speed estimation indicates that individuals are more able to accurately discern the speed of an oncoming vehicle when its headlights are on. This result answers a fundamental question of improving road safety, but it also begs further considerations. With regard to passing behaviors, one future study might attempt to examine whether headlight usage in oncoming vehicles leads to fewer passing attempts or to fewer failed passing attempts in a lab simulation, to better ascertain the possible applications of the present research.

References

Bar-Gera, H., Shinar, D. (2005). The tendency of drivers to pass other vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour, 8*, 429-439.

Brooks, R., Rafat, M. (2015). Simulation of driving in low-visibility conditions: Does stereopsis improve speed perception? *Perception, 44,* 145-156.

Cœugnet, S., Miller, H., Anceaux, F., Naveteur, J. (2013). How do time pressured drivers estimate speed and time? *Accident Analysis & Prevention, 55*, 211-218.

Conchillo, A., Recarte, M., Nunes, L., Ruiz, T. (2006). Comparing speed estimations from a moving vehicle in different traffic scenarios: Absence versus presence of traffic flow. *Spanish Journal of Psychology, 9*(1), 32-37.

Evans, L. (1970). Automobile speed estimation using movie-film simulation. *Ergonomics, 13*.

Gould, M., Poulter, D., Helman, S., Wann, J. (2012). Judgments of approach speed for motorcycles across different lighting levels and the effect of an improved tri-headlight configuration. *Accident Analysis & Prevention, 48,* 341-345.

Horswill, M., Helman, S., Ardiles, P., Wann, J. (2005). Motorcycle accident risk could be inflated by a time to arrival illusion. *Optometry and Vision Science, 82*, 740-746.

Mwesige, G., Farah, H., Koutsopoulos, H. (2016). Risk appraisal of passing zones on two-lane rural highways and policy applications. *Accident Analysis & Prevention, 90*, 1-12.

National Center for Statistics and Analysis. (2014). *Traffic safety facts: 2012 data.* Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812021

Schütz, A., Billino, J., Polin, P., Khanh, T., Gegenfurtner, K. (2015). Robust underestimation of speed during driving: A field study. *Perception*, *44*, 1356-1370.