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TREATMENT OF THE DRIVER-SIDE
WINDOW AND REARVIEW MIRROR
ON DISTANCE JUDGEMENT**

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16. Abstract <p>This study investigated the effects of hydrophobic treatment on distance estimation under conditions of simulated rain and wind when applied to the driver-side window and driver-side exterior rearview mirror. The dependent measure was the estimate of distance to a target vehicle viewed through the driver-side window and rearview mirror. The following independent variables were examined: actual distance, hydrophobic treatment of the driver-side window, hydrophobic treatment of the driver-side exterior rearview mirror, participant age, and participant sex.</p> <p>While the results of this study indicate no significant effect of hydrophobically treating driver-side windows or mirrors, one marginally nonsignificant interaction of interest was observed. Specifically, there was a tendency for older drivers to report shorter (more conservative and presumably safer) distance estimates when viewing vehicles through a driver-side window that has received hydrophobic treatment. This tendency, in combination with over-representation of older drivers in lane change/merge crashes, suggests that additional research efforts should be focused on examining the potential for safety benefits from applying hydrophobic treatment to driver-side windows.</p>					
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INTRODUCTION

Numerous products for hydrophobic treatment of motor vehicle windows are commercially available. These include products that consumers may apply and others that must be applied by trained automotive service technicians (at oil change facilities, dealerships, etc.). Hydrophobic treatments are generally liquid polymers that bind with motor vehicle glazing. These transparent coatings act as water repellents, causing rain and other accumulated moisture to bead. Aided by airflow resulting from wind and vehicle motion, beads of water are more readily shed from a vehicle's windshield. The application of hydrophobic treatment to a vehicle windshield has previously been shown to improve driver visual performance (Sayer, Mefford, Flannagan, and Sivak, 1997).

Sayer et al. reported that the application of hydrophobic treatment to the windshield of an automobile, under simulated rainy driving conditions, resulted in significantly improved visual acuity and decreased response time to recognize a simple target. The improvement in response time was, on average, greater than one second. The improvement in visual acuity was also rather large (approximately 34% in terms of the minimum visual angle resolved). By way of comparison, visual acuity improved in a treated-nighttime condition to a level that was not significantly different from performance in an untreated-daytime condition. The experimental conditions in the Sayer et al. study simulated moderate to heavy amounts of rainfall, with the windshield wipers on at all times, and simulated wind comparable to a moderate traveling speed. Sayer et al. (1997) reported that the hydrophobic treatment of windshields appeared to provide the greatest benefit for older participants.

Although the findings of Sayer et al. require validation under actual conditions of rain, and in real-world driving, the preliminary indications are that the application of hydrophobic treatment to automotive windshields can substantially improve driver visual acuity and reduce response time, particularly for older drivers.

The Objectives of the Present Study

The present study investigates the potential benefits of using hydrophobic treatment on the driver-side window and exterior rearview mirror. Unlike windshields, which are equipped with wipers, side windows and rearview mirrors must rely exclusively on wind from vehicle motion for the removal of water. Furthermore, visual acuity did not seem to be a critical variable for most tasks that involve the driver-side window and exterior rearview mirror.

In order to investigate the effects of hydrophobic treatment when applied to the driver-side window and exterior rearview mirror, a distance estimation task was used. The dependent measure was distance estimation to a target vehicle viewed through the driver-side window and exterior rearview mirror. The following independent variables were examined:

- actual distance,
- hydrophobic treatment of the driver-side window,
- hydrophobic treatment of the driver-side exterior rearview mirror,
- participant age, and
- participant sex.

Like the previous study by Sayer et al., the present study was performed under conditions of simulated rain and airflow that would result from a combination of wind and vehicle motion. Estimating the distance between vehicles is an important task in which drivers use both the side window and exterior rearview mirror. This task is often an important part of judging whether it is safe to change lanes based on the size of a gap in traffic.

This experiment did not address the durability or longevity of hydrophobic products, as the hydrophobic treatment was only tested when it was newly applied (and therefore could be expected to be near peak performance). The effects of hydrophobic treatments on driver distance estimates are likely to change with time and wear (more or less slowly, depending on product durability).

METHOD

Participants

Twenty-four paid participants took part in this study. Twelve were older (ranging from 66 to 83, mean age = 72.1 years) and twelve were younger (ranging from 20 to 28, mean age = 23.1 years). Each age group consisted of six men and six women. Participants were recruited from a list of individuals maintained by UMTRI, as well as by advertisements placed in local newspapers.

Task

The task was to make numerical estimates of the distance to a stationary target vehicle positioned to the rear of the experimental vehicle, one lane width to the driver's left. Participants had only the driver-side rearview mirror available for their use; the exterior passenger side and interior rearview mirrors were adjusted so that participants could not use them to see the target vehicle. A large rotary misting machine was visible through the windshield at all times. The distance from the participant to the rotary mister was assigned a unitless value of ten, and participants were instructed to make distance estimations using that value as an anchor. The wording of the instructions to participants was as follows:

During this study, you will be seated in the driver's seat of this car, but you will not be doing any actual driving. We will be simulating wind and rain during this experiment. Your task is to look into the driver-side exterior rearview mirror and estimate the distance of the vehicle that you see. Please note the distance to the tire on the fan in front of you. Assign a value of 10 to this distance and choose numbers to estimate the distances between you and the car that you will see in the rearview mirror, relative to this anchor. For example, if you believe that the position of the car that you see in the rearview mirror is five times the anchor distance, then assign it a value of 50. If you believe that the distance is one and one half times the anchor distance, then assign it a value of 15. You may use any positive number to describe the distances. Do not think about these measurements in terms of feet, meters or car lengths, rather assign a distance relative to the anchor distance of 10.

Each trial began when the participant was instructed by an experimenter to look up from a downward gaze, and look into the driver-side rearview mirror. After a three-second glance, the participant was instructed by the experimenter to look downward and orally report an estimate of distance to the target vehicle. Each participant was given

three practice trials. The position of the target vehicle was changed between trials while the participant was looking downward at the floor of the experimental vehicle. For each trial, the front bumper of the target vehicle could be located at one of eight possible distances from the seated participant: 10, 15, 20, 25, 30, 35, 40 or 45 m. The target vehicle was always one lane to the left of the experimental vehicle (a lateral displacement between vehicles of 3.7 m, center-to-center).

Excluding practice trials, each participant provided a total of 96 distance estimates—three trials at each of the eight distances, for each of the four experimental vehicle conditions (untreated mirror/untreated window, untreated mirror/treated window, treated mirror/untreated window, and treated mirror/treated window). Trials were blocked by experimental vehicle condition (24 trials per block), and the order of the trials within each block was randomized. The order in which each participant experienced the experimental vehicle conditions was also randomized.

Two experimenters conducted the experiment. One was positioned in the right-rear seat of the experimental vehicle to ensure participant compliance with instructions and to record distance estimates. The second experimenter drove the target vehicle, changing its position between trials.

Four virtually identical, late-model sedans were used as experimental vehicles in this study. These vehicles differed only in exterior body color (two were black, and two were dark purple). Each experimental vehicle had one of the four combinations of treatment of the driver-side window and driver-side exterior rearview mirror. Treatment consisted of applying a commercially available hydrophobic coating, following the manufacturer's directions for application. Additional treatments were applied daily in order to maintain maximum effectiveness of the coating. A fifth vehicle, also a late-model sedan, was used as the target vehicle.

Apparatus and Setup

Rain was simulated by spraying water onto the vehicle's windshield using a garden hose and spray nozzle that was approximately 0.5 m in front of the bumper of the experimental vehicle (Figure 1). The resulting coverage was not uniform, but rather concentrated on the driver-side windshield and housing of the exterior rearview mirror. The rate at which water was applied was 7 L/min; this appeared from the drivers' vantage to be comparable to driving in moderate rainfall that would require low speed windshield wiper use in actual driving.

In order to simulate wind, which normally aids in removing water from the windshield of a vehicle in motion, a rotary misting machine was used. The mister was

10 m in front of the participant's vehicle. Average wind speed produced by the mister at the exterior surface of the windshield in the participant's line of sight, as measured with a hot-wire anemometer, was 79 km/hr. However, this air speed varied slightly because of ambient winds.

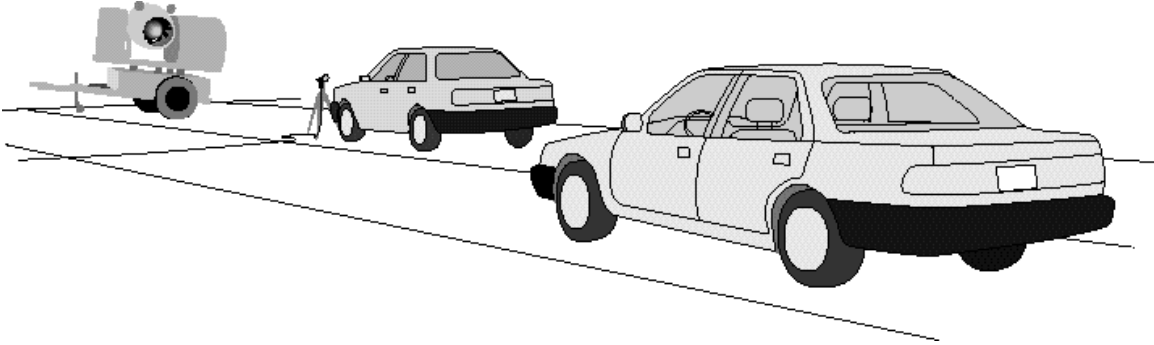


Figure 1. A diagram of the apparatus and setup.

RESULTS

Data from one participant, an older female, were excluded before any analyses were performed. This participant stated that she was unable to detect the target vehicle at several of the distances presented, under all combinations of window and mirror treatment.

A repeated-measures analysis of covariance (ANCOVA) was performed on the distance estimates provided by the remaining participants. The independent variables in the analysis were actual distance (10, 15, 20, 25, 30, 35, 40, or 45 m), participant age (younger or older), participant sex (female or male), driver-side window condition (treated or untreated), and driver-side exterior rearview mirror condition (treated or untreated). Actual distance, window treatment and mirror treatment were within-subjects variables. The covariate was the order in which individual participants received the four treatment conditions, which had been randomly assigned. The dependent measure was the log transformation of the distance estimates to the front of the target vehicle. However, the reported distance estimates have been transformed back to the range of numbers used by participants when providing their estimates (i.e., an inverse log transformation has been performed on the means after the ANCOVA).

Actual Distance

The effect of actual distance was statistically significant, $F(7, 152) = 5.34$, $p \leq .001$. A plot of the distance estimates reveals a linear relationship between actual and estimated distances (Figure 2). In general, participants overestimated the distance to the target vehicle (relative to the anchor point provided). The solid line in Figure 2 represents where the data would lie if the units used by participants in providing distance estimates were perfectly calibrated to the anchor point.

Participant Age and Sex

Neither participant age nor sex were significant effects, $F(1, 152) < 1.0$; and $F(1, 152) = 1.68$, $p \leq .33$ respectively. Although it was not statistically significant, there was a tendency for older participants to provide distance estimates that were shorter than those of younger participants. The mean distance estimate provided by older participants was 26.6, while the mean distance estimate provided by younger participants was 31.3. There was no apparent trend associated with participant sex.

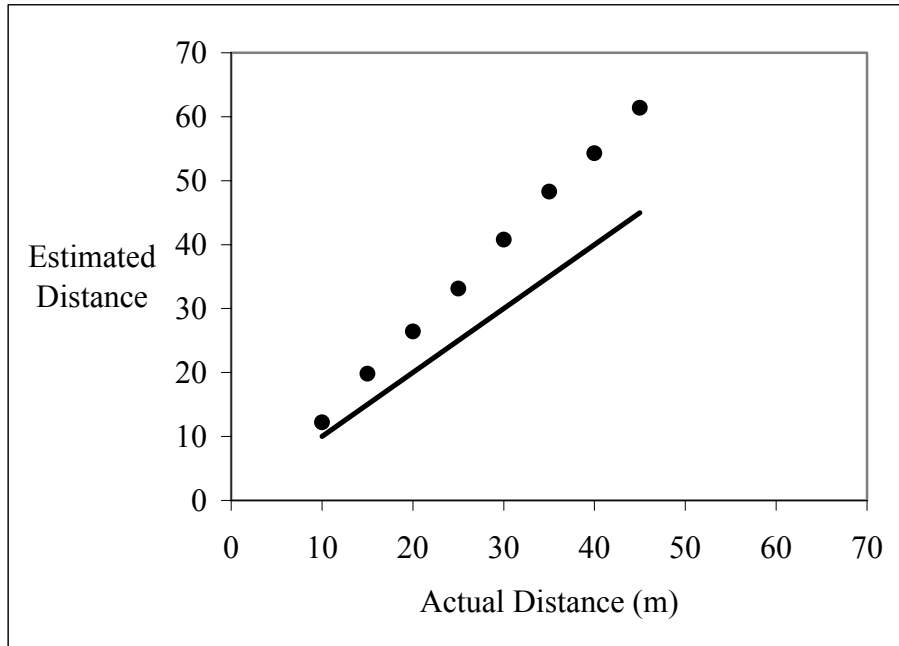


Figure 2. Distance estimates as a function of actual distance averaged across all participants. The solid line represents where the data would lie if the units used by participants in providing distance estimates were perfectly calibrated to the anchor point.

Window Treatment

Participants tended to report slightly shorter distance estimates when the driver-side window received the hydrophobic treatment. The mean distance estimate for the treated window condition was 28.6, and for the untreated window condition the mean estimate was 29.2. However, the main effect of treating the driver-side window with hydrophobic coating was not statistically significant, $F(1, 152) = 1.86, p = .19$.

Mirror Treatment

Participants again showed a nonsignificant tendency to report slightly shorter distance estimates when hydrophobic treatment was used. The mean distance estimate for the treated mirror condition was 28.6; and for the untreated mirror condition the mean estimate was 29.1. However, the main effect of treating the driver-side exterior rearview mirror with hydrophobic coating was not statistically significant, $F(1, 152) < 1.0$.

Interactions

While there were no statistically significant interactions, there was one marginally nonsignificant interaction of interest. The interaction of participant age and window

treatment, $F(1, 152) = 4.26, p = .054$ (see Figure 3), resulted in the shortest estimates being provided by the older participants in the treated window condition (mean = 25.9). The longest estimates were provided by the younger participants, also in the treated window condition (mean = 31.5). In the untreated condition, older participants still provided shorter distance estimates relative to the younger participants (mean = 27.3 for older and mean = 31.2 for younger). Thus, while not statistically significant, there appears to be a tendency for the hydrophobic treatment of the driver-side window to result in shorter distance estimates for older participants.

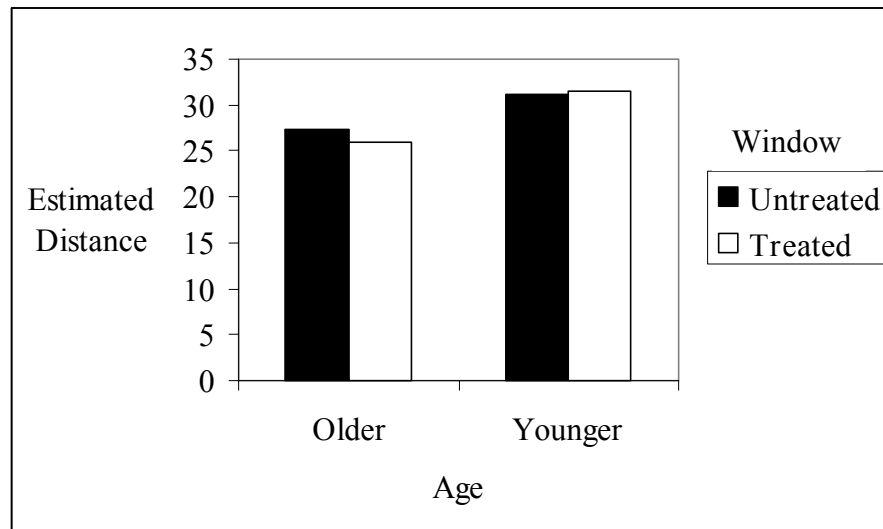


Figure 3. Distance estimates for the marginally nonsignificant interaction of participant age and window treatment condition.

DISCUSSION AND CONCLUSION

General Interpretation

For the purpose of this study, we interpret shorter (more conservative) distance estimates as erring on the side of safety. Specifically, we hypothesize that—when viewing gaps between vehicles through a driver-side window and exterior rearview mirror—drivers are less likely to attempt a lane change or merge (and are therefore safer) if they perceive gaps to be short rather than long.

Actual Distance

The effect of actual distance on distance estimation was to be expected based on previous distance perception research. The trend that estimated distance increases faster than actual distance has been reported previously (Sedgwick, 1986). In particular, this bias in judging distance is frequently observed when participants have a relatively unrestricted view of a three-dimensional object that is resting on a horizontal surface (as in the task employed in the present study). Furthermore, the maximum distance examined in the present study (45 m) was short enough to permit reasonable estimates. Previous research has shown that the farther an object is, the more difficult it is for people to estimate distance (Nasar, Valencia, Omar, Chueh, and Hwang, 1985).

Implications of the Findings

Older drivers, as a group, have one of the highest crash rates per vehicle mile traveled (Massie, Campbell, and Williams, 1995). In particular, older drivers are significantly more likely than younger or middle-aged drivers to be the responsible party in merge and lane change crashes (McGwin and Brown, 1999). The two most common causal factors in lane change crashes have been reported to be that the responsible driver either “did not see” the vehicle struck or misjudged the gap/velocity, 61% and 30% respectively (Najm, Koziol, Tijerina, and Pierrowicz, 1994).

While marginally nonsignificant, the tendency is for older drivers to report shorter (more conservative and presumably safer) distance estimates when viewing vehicles through a driver-side window that has received hydrophobic treatment. Such an effect might be expected if drivers associated clearer images with shorter distances. Under inclement weather it is generally true that closer vehicles will be seen through less veiling precipitation. It may be that a clearer image provided by the application of hydrophobic coatings thus appears similar to the effect of shorter actual distance. This possible age-related safety benefit, specific to older drivers, is similar to that reported for

the hydrophobic treatment of windshields by Sayer et al. (1997). Given that this age group is significantly more likely to be involved in lane change/merge crashes, it appears that additional research efforts should be focused on examining the potential for a safety benefit specifically for older drivers. Application of hydrophobic treatment to the driver-side window for younger participants, or to the rearview mirror for either age group, resulted in essentially no change in distance estimates.

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