

UMTRI-2004-35

AN EXAMINATION OF NATURALISTIC WINDSHIELD WIPER USAGE

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Report No. UMTRI-2004-35
December 2004

1. Report No. UMTRI-2004-35	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle An Examination of Naturalistic Windshield Wiper Usage		5. Report Date December 2004	
		6. Performing Organization Code 302753	
7. Author(s) Wetzel, J.M., Sayer, J.R., & Funkhouser, D.		8. Performing Organization Report No. UMTRI-2004-35	
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, Michigan 48109-2150 U.S.A.		10. Work Unit no. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address The University of Michigan Industry Affiliation Program for Human Factors in Transportation Safety		13. Type of Report and Period Covered	
		14. Sponsoring Agency Code	
15. Supplementary Notes The Affiliation Program currently includes AGC Automotive America, Autoliv, Automotive Lighting, Avery Dennison, Bendix, BMW, Bosch, DaimlerChrysler, DBM Reflex, Decoma Autosystems, Denso, Federal-Mogul, Ford, GE, General Motors, Gentex, Grote Industries, Guide Corporation, Hella, Honda, Ichikoh Industries, Koito Manufacturing, Lang-Mekra North America, Magna Donnelly, Mitsubishi Motors, Muth, Nichia America, Nissan, North American Lighting, OLSA, OSRAM Sylvania, Philips Lighting, PPG Industries, Reflexite, Renault, Schefenacker International, Sisecam, SL Corporation Solutia Performance Films, Stanley Electric, Toyoda Gosei North America, Toyota Technical Center USA, Truck-Lite, Valeo, Vidrio Plano, Visteon, 3M Personal Safety Products, and 3M Traffic Safety Systems. Information about the Affiliation Program is available at: http://www.umich.edu/~industry			
16. Abstract As part of a field operational test, 96 drivers were lent instrumented vehicles for approximately 26 days. During this time, a variety of measures regarding vehicle use were recorded, including windshield wiper use, wiper setting adjustments, and headway time margin to preceding vehicles. Windshield wiper activity was examined in detail in order to provide data regarding the naturalistic use of windshield wiper systems. The results have implications for the design and durability of windshield wipers, wiper motors, windshields, and glazing treatments (such as hydrophobic coatings). Overall, windshield wipers were used 8.6% of the time the vehicles were being operated. Across all conditions, the slowest intermittent setting was the most frequently used—whereas the fastest continuous setting was used the least. When ambient lighting diminished, a shift towards higher wiper speeds was observed. Average headway time margin and range increased, and speed decreased, when windshield wipers were engaged. Middle-aged drivers used wipers more often than either their younger or older counterparts. Finally, older females used their wipers the least amongst female drivers, while male drivers used wipers fairly uniformly across age groups.			
17. Key Words Age differences, driving, headway, lighting, precipitation, rain, visibility, windshield wiper		18. Distribution Statement Unlimited	
19. Security Classification (of this report) None	20. Security Classification (of this page) None	21. No. of Pages 22	22. Price

ACKNOWLEDGMENTS

Appreciation is extended to the members of the University of Michigan Industry Affiliation Program for Human Factors in Transportation Safety for support of this research. The current members of the Program are:

AGC Automotive America	Mitsubishi Motors
Autoliv	Muth
Automotive Lighting	Nichia America
Avery Dennison	Nissan
Bendix	North American Lighting
BMW	OLSA
Bosch	OSRAM Sylvania
DaimlerChrysler	Philips Lighting
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Ichikoh Industries	Vidrio Plano
Koito Manufacturing	Visteon
Lang-Mekra North America	3M Personal Safety Products
Magna Donnelly	3M Traffic Safety Systems

CONTENTS

ACKNOWLEDGMENTS	ii
INTRODUCTION	1
METHOD	3
PARTICIPANTS.....	3
APPARATUS	3
DESIGN AND ANALYSIS.....	4
RESULTS	6
WINDSHIELD WIPER USE	6
WIPER TRIPS BY DRIVER AGE AND GENDER.....	7
WIPER SETTING SELECTION AND DURATION BY DRIVER AGE AND GENDER	9
WIPER SETTING SELECTION AND DURATION DURING LIGHT AND DARK CONDITIONS.....	11
INDICES OF DRIVER BEHAVIOR AND WIPER USE.....	14
DISCUSSION AND CONCLUSIONS	16
REFERENCES	18

INTRODUCTION

This report provides information about the conditions and manner in which drivers use their windshield wiper systems via a naturalistic observation of driver behaviors. Of particular interest were potential gender and age differences that may affect overall use and wiper setting selection. In addition, the study provided an opportunity to observe how wiper use changed throughout the course of one calendar year in a region that experiences four seasons. Finally, an aim of this report was to determine what behavioral modifications, if any, drivers used in order to compensate for the reduced visibility that may have occurred because of inclement weather. Such behavioral indices included the average range, speed, and headway time margin drivers maintained relative to other vehicles while windshield wipers were in use.

Previous research regarding windshield wiper use has focused primarily on object visibility and seeing distance. Many studies have been limited by the fact that they used simulated rainfall in stationary vehicles to assess driver visibility (Kurahashi, Fukatsu, & Matsui, 1985; Morris, Mounce, Button, & Walton, 1977b). However, some work has been collected using natural rainfall. Specifically, in regard to visibility with windshield wiper use during natural rainfall, it was shown that windshield wipers do not interfere with perceiving the forward visual scene via fixation time or size and direction of saccadic movements (Cohen & Fischer, 1988). However, changes in eye movements did occur during windshield wiper activity, resulting in shorter preview distances of the roadway ahead (Zwahlen, 1979). In addition, with increased rainfall, seeing distances were significantly degraded (Bhise, Meldrum, Forbes, Rockwell, & McDowell, 1981; Ivey, Lehtipuu, & Button, 1975; Morris, Mounce, Button, & Walton, 1977a). In particular, research conducted by Bhise et al. (1981) examined driver seeing distances for a target vehicle during periods of natural rainfall. Bhise and colleagues had participants, in either moving or stationary vehicles, report when they first detected a target vehicle while their windshield wipers were engaged or recently turned off. They reported that, during rainfall, detection distances significantly decreased as ambient lighting decreased. Furthermore, as rain intensity increased, a concomitant decrease in seeing distance occurred. Finally, it was reported that drivers in moving vehicles had reduced seeing distances relative to stationary vehicles because of increased precipitation present upon the windshield. However, no known study has examined how the effects of natural rainfall influence both wiper setting

selection and driver behavior (e.g., reduced speed, increased driver range). While it is known that visibility is reduced with increasing rain intensity, it is not known to what extent driver behaviors change with changing conditions. This study therefore aimed to unobtrusively examine naturalistic driving activity to determine how people drive in inclement weather.

The naturalistic examination of wiper use was conducted as a secondary analysis of data collected as part of a field operational test of other automotive systems over a 12-month period, from March, 2003 to February, 2004. Ninety-six drivers were lent instrumented vehicles for periods of 26 days each, during which they were instructed to drive as they normally would. In total more than 13,600 trips were recorded, and 1,714 trips with wiper use were recorded across 95 of the 96 drivers (one driver did not use the windshield wipers during the experiment). During the 1,714 wiper trips, 2,625 discrete events in which the wipers were turned on were recorded. In addition to the number of discrete wiper events, the number of wiper settings drivers used was also recorded. In total, 5,344 valid wiper settings were used, resulting in approximately 2.0 settings used per wiper event and 3.1 settings used per trip in which the wipers were used. Using these events, this report addresses three main areas of interest: overall windshield wiper use, wiper setting use, and driver behavioral changes related to lead vehicles associated with windshield wiper use.

METHOD

Participants

The results were derived from the data generated as part of a large field operational test examining the use of driver assistance systems that included 96 drivers. Participants were selected in three age ranges: 20-30 years old (younger), 40-50 years old (middle-age), and 60-70 years old (older) drivers. There were 32 drivers in each age group, with approximately equal numbers of male and female drivers (see Table 1).

Table 1
Demographic breakdown of gender and age groups.

Age Group	Male	Female	Total
20-30	15	17	32
40-50	15	17	32
60-70	17	15	32
Total	47	49	96

Apparatus

Each driver was lent a 2002 four-door sedan that was to be driven exclusively by the participant for a period of 26 days. Each vehicle was equipped with a sophisticated on-board data acquisition system that continuously collected numerous data channels, including the operating state of the windshield wipers, at a sampling rate of 10 Hz whenever the vehicle engine was running. Data collection commenced once the data acquisition system “booted-up,” which typically occurred around 60 s from engine start-up. Windshield wiper use was tallied across drivers for all trips made throughout the study. The results represent wiper use for a contiguous 12-month period, representing more than 137,000 miles, or 220,000 km, of driving.

The sedans came equipped with a seven-position wiper control, providing five intermittent wiper speeds in addition to *Low* and *High* continuous speeds. Table 2 depicts the

seven wiper control settings and their cycle speeds (cycles/min). A complete wiper cycle was defined as wiper movement from the wiper’s resting state to its fullest extent, and subsequent return to the resting state.

Table 2
Wiper control settings and associated wiper speeds (cycles/min).

Wiper Setting	Wiper Cycles/Min*	
<i>High</i>	49	
<i>Low</i>	34	
Intermittent Settings	<i>Delay1</i>	22
	<i>Delay2</i>	16
	<i>Delay3</i>	10
	<i>Delay4</i>	6
	<i>Delay5</i>	2

* The number of wiper cycles was truncated to the nearest integer

To determine the use of the wiper control setting, dwell times of at least 5 s were used to operationally define wiper use at any particular speed. Durations less than 5 s were considered scrolling activity where drivers were searching amongst settings in search of their desired setting. However, to calculate the percentage of total time drivers spent using their windshield wipers, a summation of all wiper control settings was included, regardless of duration.

Design and Analysis

The current study incorporated numerous variables to examine wiper use. Gender and age group served as between-subject variables in order to detect any uniform discrepancies across driver cohorts that may occur with wiper use and subsequent driving behaviors while wipers were engaged. In addition, the seven wiper settings served as a within-subject variable, where differences in setting use were examined. Finally, changes in ambient lighting conditions (i.e., ‘light’ or ‘dark’) served as a within-subject variable to determine if drivers’ wiper behaviors altered with changing environmental conditions. For all analyses, $p < .05$ was adopted as the criterion for determining statistical significance. For all within-subject variables, Greenhouse-Geisser corrections were applied when the sphericity assumption, denoting independence amongst observations, was not met. Furthermore, Box corrections were conducted on the

degrees of freedom for both effect and error terms when corrected probability values were reported (Keppel, 1991).

For overall wiper use, the percentage of time drivers used their wipers while driving was determined. Wiper use was analyzed by month, gender, and age group. In regard to dependent measures of wiper setting use, both setting selection and setting duration calculations were made. For wiper setting selection, the number of times a driver used a particular setting was recorded and its use was normalized by distance driven. The wiper setting selection variable was designed to examine the number of different wiper settings that drivers use during inclement weather. To complement setting selection, setting duration was also used as a dependent measure. Measures of setting duration were calculated by summing the total time (hours) that each driver spent engaged in each of the seven wiper settings. Finally, various dependent measures of driver behavior were analyzed. Average speed (m/s), range (m), and headway time margin (s) were each calculated to determine drivers' behaviors during car-following scenarios when wipers were 'off' versus 'on.' All car-following scenarios were included when driver speeds were in excess of 25 mph and when the duration of wiper use was greater than 5 s.

RESULTS

Windshield Wiper Use

The overall rate of windshield wiper use for the 12-month period was 8.6%. Use was based upon the total time the wipers were on, at any wiper setting, with the vehicle's engine running. A between-subjects ANOVA performed on percent wiper use showed neither a main effect of gender nor age group. In addition, no significant interaction between age group and gender was observed. Figure 1 illustrates the trends in wiper use across age groups by gender.

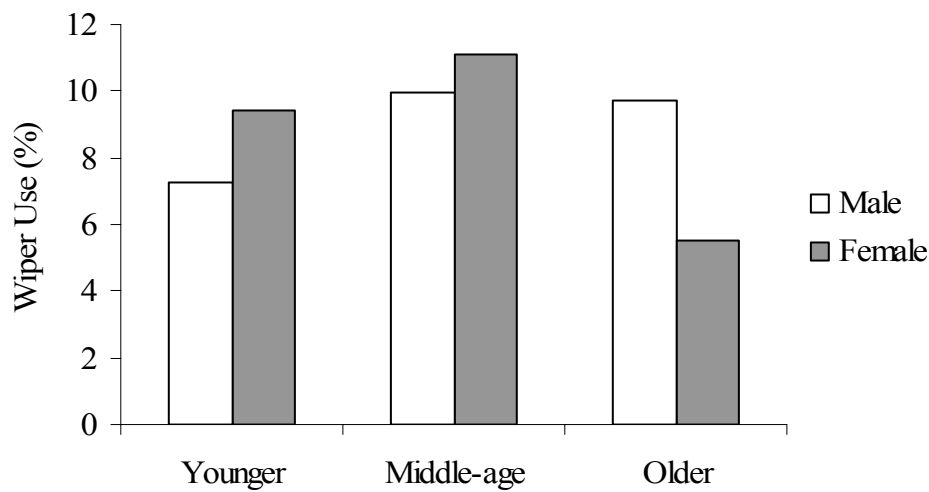


Figure 1. Wiper use by driver age group and gender.

Figure 2 illustrates the variation in wiper use by month, and the associated precipitation rates observed for the region in which drivers lived for the same period. Wiper use was highest during the month of January (12.8%) and lowest during July (3.3%). However, wiper use does not consistently track rates of precipitation. A portion of the difference between precipitation and wiper use was probably attributable to the presence of condensation on the windshield in the spring and fall, and road spray from melted snow/ice in the winter months. In other words, there may have been a considerable number of instances in which windshield wipers were used in the absence of active precipitation. Furthermore, precipitation rates reflect those of southeastern Michigan where 78.2% of the driving took place. However, drivers' travels and associated windshield wiper use were not exclusive to that area, because drivers were allowed to use the instrumented vehicle throughout the lower 48 states.

Attempts made to collect real-time precipitation were not entirely successful. Using GPS coordinates of each vehicle at any specified time, hourly precipitation data were collected from the nearest of 65 active weather reporting stations and correlated with wiper activity to approximate the amount of precipitation the driver experienced for a subset of the trips. Unfortunately precipitation rate and wiper activity had an extremely low correlation. This is most likely due to the fact that during an hour's worth of travel, a vehicle will only briefly pass through any one reporting location. Furthermore, within that hour's time, the actual rate of precipitation can vary dramatically, thereby not ensuring that the driver will encounter commensurate precipitation amounts.

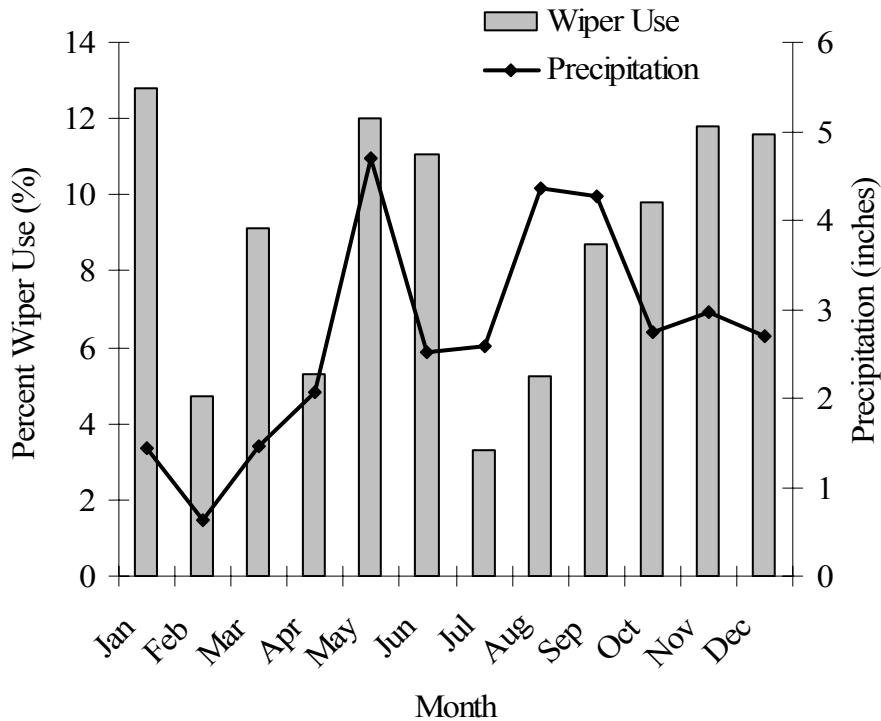


Figure 2. Wiper use and precipitation in southeastern Michigan by month.

Wiper Trips by Driver Age and Gender

A between-subjects ANOVA was conducted with the number of trips in which windshield wipers were used (wiper trips) serving as the dependent variable. Wiper trips were normalized by distance driven (wiper trips/100 miles) and were defined as any trip where wipers were used continuously for a minimum duration of 5 s. Five seconds was used as a criterion to

discriminate wiper use associated with precipitation from windshield cleaning or other discrete momentary events. Figure 3 illustrates the relationship of driver age group and gender to trips in which windshield wipers were in use. While no main effect of gender was obtained, a significant effect of age group was observed, $F(2, 90) = 3.8, p = .027$. Follow-up comparisons indicated that middle-aged drivers ($M = 2.0$) made significantly more wiper trips per 100 miles than older drivers ($M = 1.2; t(62) = 2.4, p = .021$) and younger drivers ($M = 1.4; t(62) = 2.0, p = .05$). The age group by gender interaction was not significant.

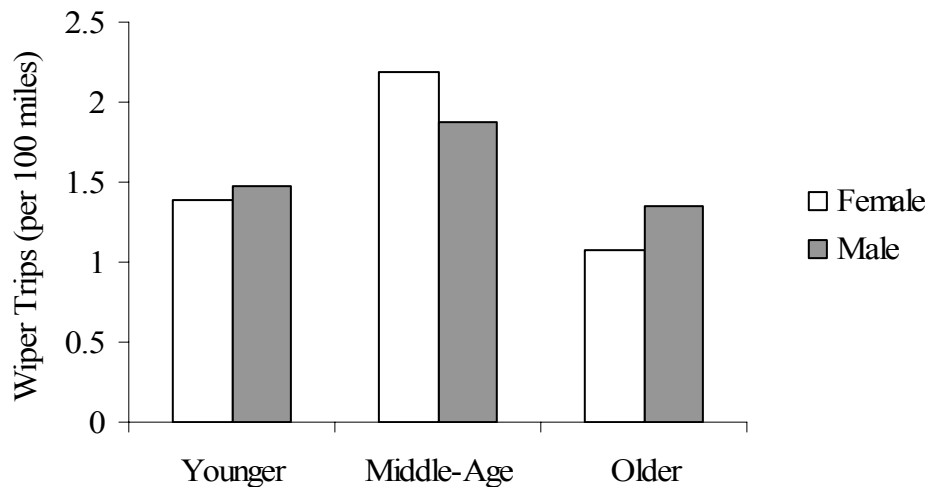


Figure 3. Wiper trips (per 100 miles) by age and gender.

An additional analysis was conducted within wiper trips. During the 1,714 wiper trips, there were 2,625 discrete wiper events. A discrete wiper event was defined as any instance in which a change in wiper state from ‘off’ to ‘on’ occurred, lasting longer than 5 s. A subsequent between-subjects ANOVA of normalized discrete wiper events (wiper events/ 100 miles) was conducted with the total number of discrete events serving as the dependent measure. Figure 4 illustrates age group and gender effects. Similar to the analysis of wiper trips, neither a main effect of gender nor a two-way gender by age group interaction was obtained. However, a marginally non-significant main effect of age group was obtained, $F(2, 96) = 3.06, p = .052$. Similar to wiper trips (see Figure 3), middle-aged drivers ($M = 2.9$) had significantly more discrete wiper events per 100 miles than older drivers ($M = 1.86; t(62) = 2.15, p = .035$) and marginally more than younger drivers ($M = 2.09; t(62) = 1.81, p = .075$).

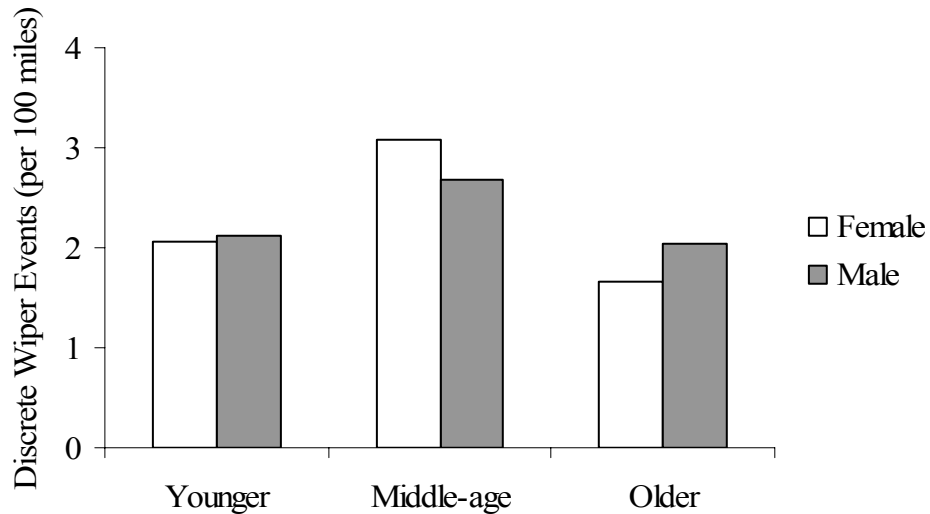


Figure 4. Discrete wiper events across age and gender.

Finally, because drivers frequently made control setting adjustments during wiper use, we also analyzed the 5,344 wiper settings drivers used within the 2,625 recorded wiper events to determine the number of wiper settings used within each wiper event. Multiple uses of any valid setting (i.e., duration > 5 s) were included in the wiper setting analysis, where wiper setting use was again normalized by distance (per 100 miles). Neither a main effect of age group or gender nor an age group by gender interaction was observed. In total, the findings suggest that the number of wiper control settings used per 100 miles during each wiper event was similar across age group and gender cohorts.

Wiper Setting Selection and Duration by Driver Age and Gender

For wiper setting duration, a simple one-way repeated-measure ANOVA was conducted across all 96 drivers with average setting duration serving as the dependent variable. Overall, a significant main effect of wiper control setting was observed, $F(3.0, 285.8) = 17.8, p < .001$. A bimodal trend emerged (see Figure 5), where *Delay5* and *Low* had, numerically, the longest mean durations amongst the seven wiper settings. Follow-up planned comparisons revealed that *Delay5* and *Low*, which did not differ, were indeed used for a significantly longer period of time than all other wiper settings (at the $p < .005$ level). Conversely, *High* was used for the shortest period of time across the seven wiper settings (at the $p < .001$ level).

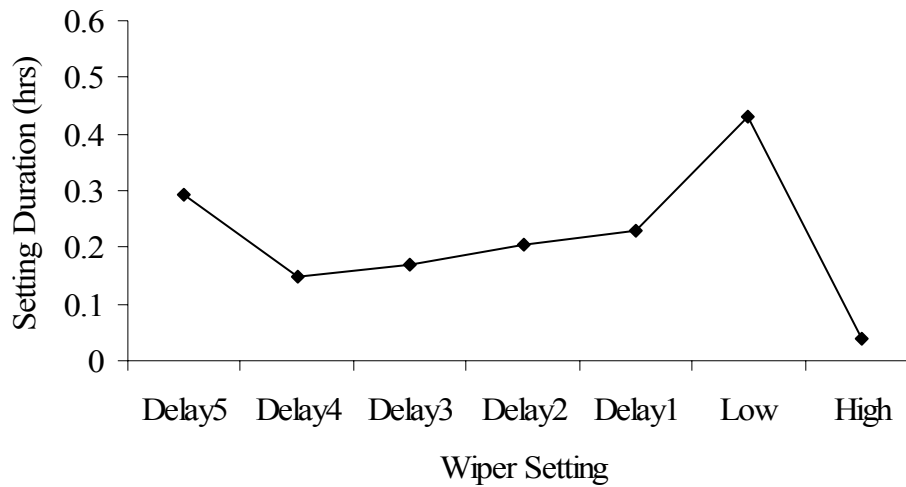


Figure 5. Mean wiper setting duration across wiper control settings.

A subsequent analysis was conducted to determine if wiper setting duration changed as a function of gender or age group. No main effects or interactions were obtained for either gender or age group; however, the main effect of wiper setting was preserved.

In regard to wiper setting selection, an inferential statistical analysis was not performed due to the fact that each driver did not use each wiper setting. However, setting selection, normalized by distance (setting selected/100 miles), is illustrated in Figure 6. *Delay5* was selected more per 100 miles than all other wiper control settings. In contrast, *High* was selected less than all other wiper control settings. Wiper setting selection was relatively uniform for the remaining settings. A subsequent descriptive examination of wiper setting selection across both gender and age groups was conducted. Across male and female drivers and across age groups, setting selection remained consistent with *Delay5* selected the most and *High* selected the least.

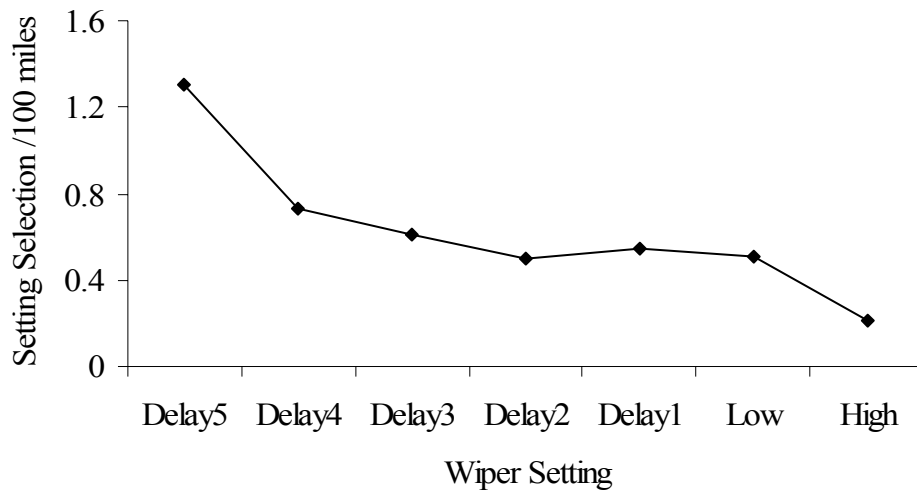


Figure 6. Mean wiper setting selection per 100 miles across wiper control settings.

Wiper Setting Selection and Duration during Light and Dark Conditions

The terms ‘light’ and ‘dark’ are used here instead of day and night and are based upon the car’s photoelectric sensor that determined when the headlamps would be automatically turned on. However, the car’s photoelectric sensor may report ‘dark’ conditions during periods of overcast skies, heavy rain, fog, tunnels, and other natural driving conditions regardless of the actual time of day. Overall, driving in ‘light’ conditions constituted 72.0% of all driving time; whereas driving in ‘dark’ conditions constituted 28.0% of all driving time. Yet only 54.6% of the time which wipers were on took place during ‘light’ conditions, whereas ‘dark’ conditions represented 45.4% of all wiper events. In fact, throughout the duration of ‘dark’ driving, wipers were in use 16.7% of the time as compared to ‘light’ conditions, where wipers use was 6.5%. Consequently, the overrepresentation of wiper events during ‘dark’ driving in relation to the amount of time spent driving during ‘dark’ conditions is likely best explained by the fact that during daytime hours, adverse weather conditions may create a sufficiently ‘dark’ ambient environment that may be more likely associated with precipitation events.

For wiper setting duration, simple one-way repeated-measure ANOVAs across the seven wiper control settings were conducted for ‘light’ and ‘dark’ driving, respectively. For ‘light’ driving, a significant main effect of wiper setting was obtained, $F(3.4, 327.1) = 13.5, p < .001$ (see Figure 7). Follow-up comparisons revealed that *Delay5* was used significantly longer than

all other settings (at the $p < .05$ level) and *High* was used for a significantly shorter period of time than all other settings. The remaining settings did not differ.

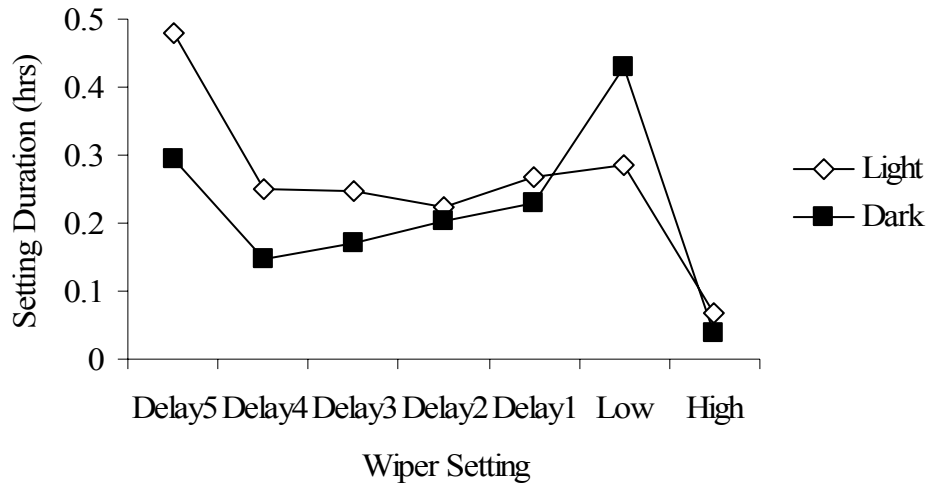


Figure 7. Mean wiper setting duration across ‘light’ and ‘dark’ driving conditions.

For ‘dark’ driving conditions (see Figure 7), a main effect of wiper setting was observed, $F(2.3, 218.4) = 12.9, p < .001$. Follow-up comparisons (at the $p < .05$ level) revealed that, unlike ‘light’ driving conditions, the longest used setting during ‘dark’ driving was *Low*, which was used significantly longer than all other settings, except *Delay5* which was not significantly different. In addition, *Delay4* was used for a shorter period than *Delay5*, *Delay2*, and *Delay1*, and *Delay5* was used longer than *Delay3*.

Lastly, a 7 (wiper setting) \times 2 (ambient condition: ‘light’/‘dark’) repeated-measure ANOVA conducted on mean setting duration revealed a significant main effect of wiper setting, $F(3.0, 285.3) = 17.8, p < .001$. While no main effect of ambient condition was observed, a significant wiper setting by ambient condition interaction was obtained, $F(3.2, 308.3) = 5.8, p < .001$. Planned simple effects tests between ‘light’ and ‘dark’ conditions across each wiper setting revealed that drivers used *Delay5*, *Delay4*, and *Delay3* significantly more during ‘light’ conditions than during ‘dark’ conditions. In contrast, a trend towards significance was obtained for *Low*, where drivers tended to use the *Low* setting more during ‘dark’ conditions ($p = .067$). The lack of significance between ‘light’ and ‘dark’ conditions for *Low* may best be attributable to the greater amount of individual variability present at that setting. Overall, however, it appears that when ambient lighting conditions darken, drivers tend to increase the wiper setting

speeds to help account for reduced visibility. The increase in wiper setting speeds in ‘dark’ conditions may be attributable to (1) an increase in precipitation during overcast conditions during daytime driving and (2) an interaction between nighttime driving and amount of precipitation.

For wiper setting selection, again because many drivers did not use all possible wiper settings, inferential statistical analyses were not performed. Setting selection was summarized across the seven wiper control settings for both ‘light’ and ‘dark’ driving. The number of settings selected in ‘light’ and ‘dark’ were normalized by the drivers’ distances in both ‘light’ and ‘dark’ ambient conditions, respectively. For ‘light’ driving, *Delay5* was selected most frequently per 100 miles than all other settings. Conversely, *High* was selected least often during ‘light’ driving (see Figure 8).

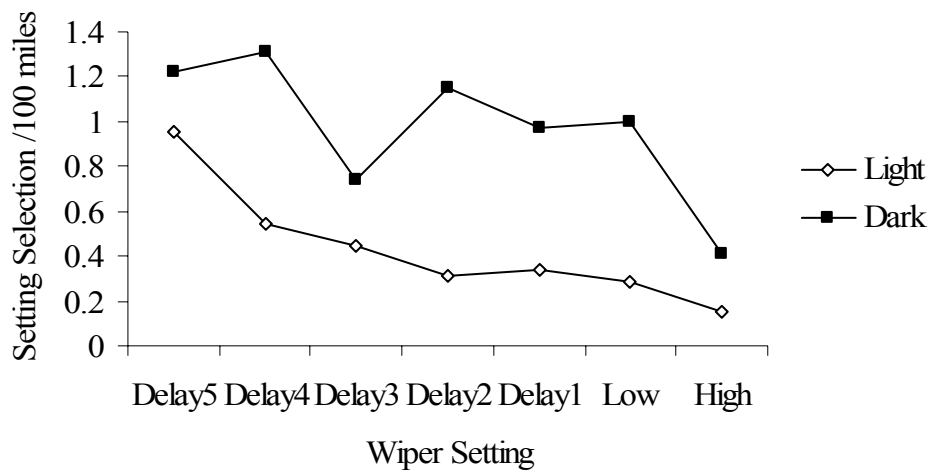


Figure 8. Wiper setting selection per 100 miles for ‘light’ and ‘dark’ driving.

In regard to ‘dark’ driving, there were greater individual differences concerning setting selection as compared to ‘light’ driving, preventing any definitive conclusion from being obtained (see Figure 8). It seems apparent that individual differences arise because some drivers tend to explore more settings during ‘dark’ driving, whereas others maintain wiper selection patterns similar to ‘light’ conditions. Lastly, when comparing the overall number of settings selected between ‘light’ and ‘dark’ conditions, drivers selected, on average, more settings during ‘dark’ driving ($M = .97$) than during ‘light’ driving ($M = .43$; see Figure 8).

Indices of Driver Behavior and Wiper Use

Wiper Control Setting and Headway Time Margin. Certain driver behaviors associated with windshield wiper use were predicted based upon the data available from prior instrumented research vehicles. Specifically, it was predicted that drivers would increase their headway time margin (HTM) from lead vehicles when the windshield wipers were engaged, because the use of the wipers would be indicative of less than ideal driving conditions in terms of environmental elements.

HTM was calculated for all instances where a lead vehicle was in the driver's path and driver speeds were in excess of 25 mph. In addition, HTM was averaged when wipers were 'off' and as well as when wipers were 'on' across all wiper settings. Figure 9 depicts HTM across age groups when wipers were 'on' and 'off.' A main effect of wiper state on HTM was found, $F(1, 88) = 39.3, p < .001$, where HTM was shorter when wipers were 'off' ($M = 2.2$ s) than when wipers were 'on' ($M = 2.5$ s). Furthermore, a main effect of age group was also obtained, $F(2, 88) = 8.8, p < .001$. Follow-up comparisons revealed that across wiper states, younger drivers maintained significantly shorter HTMs ($M = 2.1$ s) than either middle-aged ($M = 2.4$ s; $p = .011$) or older drivers ($M = 2.6$ s; $p < .001$), which did not differ. No main effect of gender was observed, nor was there a two-way wiper state by gender interaction.

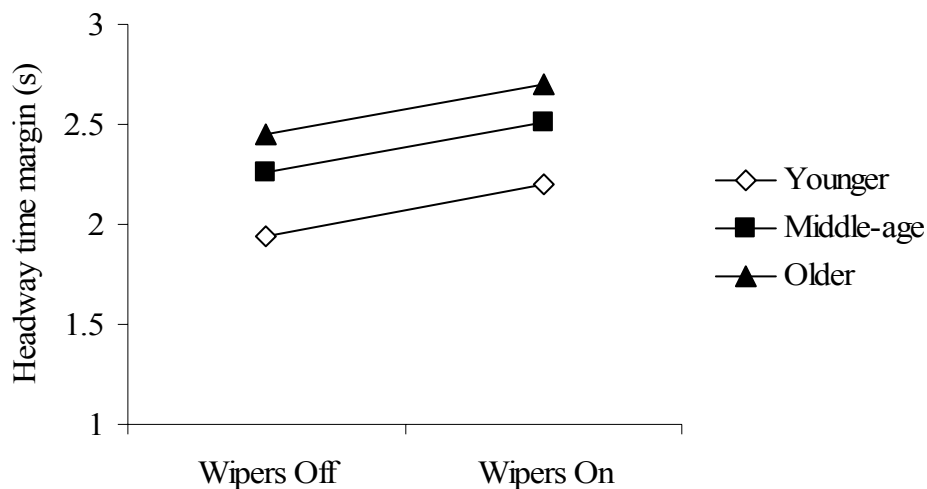


Figure 9. Headway time margin across age groups when wipers were 'off' and 'on.'

Wiper Control Setting and Range. Similar to the analysis of HTM, a subsequent analysis of range (or following distance) was calculated. A main effect of wiper state was

obtained, $F(1, 88) = 25.9, p < .001$, where drivers significantly increased their following distances when their wipers were ‘on’ ($M = 48.5$ m) as compared to when their wipers were ‘off’ ($M = 45.3$ m). Furthermore, an effect of age group was also obtained, $F(2, 88) = 10.936, p < .001$, where each age group had significantly different average ranges (at the $p < .05$ level). Follow-up comparisons revealed that younger drivers maintained the shortest average range ($M = 42.5$ m), whereas older drivers maintained the longest average range ($M = 51.4$ m). Figure 10 depicts average range across age groups when wipers were ‘on’ and ‘off.’ Finally, there were no effects of gender on average range.

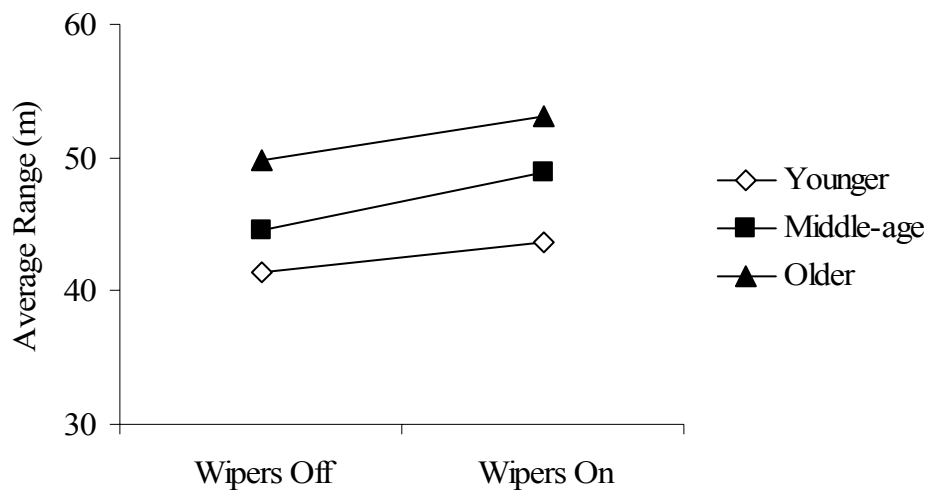


Figure 10. Average range across age groups when wipers were ‘off’ and ‘on.’

Wiper Control Setting and Driver Speed. Finally, to complement HTM and range, driver speed in car-following situations was analyzed. A main effect of wiper state was obtained, $F(1, 89) = 15.3, p < .001$, where driver speed was significantly slower when wipers were ‘on’ ($M = 19.9$ m/s) than when wipers were ‘off’ ($M = 20.8$ m/s). There were, however, no effects of age group and gender on driver speed, regardless of whether wipers were engaged.

DISCUSSION AND CONCLUSIONS

With approximately equal numbers of males and females representing younger (20-30 years of age), middle-aged (40-50), and older-drivers (60-70), a comprehensive analysis of windshield wiper use in actual traffic was performed. Overall, across driver groups, windshield wiper use was fairly uniform, with only a few significant differences between gender and age groups. Middle-aged drivers, regardless of gender, were more likely to use their wipers and wiper settings per distance driven than were younger and older drivers. Yet, when considering the distribution of wiper setting selection across age groups, results were largely consistent, with the slowest intermittent setting (*Delay5*) being selected the most and the *High* continuous wiper setting being selected the least. In contrast, when examining the duration of setting use, *Delay5* and *Low* were used for considerably longer periods of time than were all other settings. Furthermore, *High* was used the least. Therefore, it appears that while drivers may have selected *Low* significantly less than *Delay5*, the amount of time drivers spent in *Low* was comparable to *Delay5*, indicating that drivers tend to ‘stick’ with the continuous settings. However, for the intermittent *Delay5* setting, drivers may scroll amongst additional intermittent settings or frequently re-engage their wipers from ‘off’ to *Delay5* as occasions warrant (e.g., to clean spray from passing vehicles on the highway).

In addition to overall wiper setting duration and selection, ambient light was found to be a factor that influenced wiper setting duration. Specifically, when wiper use occurred during ‘light’ ambient conditions, wiper setting duration was biased towards slower wiper settings, with the slowest intermittent setting, *Delay5*, being used for the longest period of time. Conversely, when wiper use occurred during ‘dark’ ambient conditions, drivers spent less time on the slower intermittent settings (i.e., *Delay5*, *Delay4*, *Delay3*), and tended to spend more time on the *Low* setting as compared to ‘light’ conditions. This trend in wiper setting duration may perhaps reflect the visibility benefits of increased wiper speed. In addition, during daytime hours, if ‘dark’ conditions arise, heavier associated rainfalls may occur, accounting for the shift in wiper setting speeds. Unfortunately, accurate real-time precipitation readings were unavailable, making it difficult to determine if precipitation differed for ‘light’ and ‘dark’ conditions during daytime driving.

Overall, drivers collectively used their wipers approximately 8.6% of the time. When wipers are engaged, it is important to understand what behaviors, if any, drivers modify to compensate for the altered environmental conditions they are experiencing. Behaviors such as speed, range, and headway time margin were expected to change in relation to wiper use. Specifically, as hypothesized, HTM increased, range increased, and speed decreased when wipers were turned ‘on.’ In addition, differences in age groups emerged, with HTMs being significantly larger for older drivers than for middle-aged and younger drivers, and range being longest for older drivers and shortest for younger drivers. Subsequently, changes in driver behaviors with wipers in use did not differ between male and female drivers. Overall, when wipers are used, drivers seem to exhibit greater caution by increasing their headways.

In summary, examination of naturalistic driving data provided an unobtrusive approach to explore driver behaviors in regard to wiper use, where drivers were allowed to use the car as they normally would. The current study showed that drivers make adjustments, both in terms of wiper setting use and driving behaviors, when wipers are in use, such as increased HTM while following vehicles. Finally, the study provided a means to examine potential differences in driver populations as they relate to wiper use and associated behaviors. For instance, middle-aged drivers tended to use wipers the most and older drivers tended to drive with longer HTMs and ranges and slower speeds once wipers were turned ‘on.’ These findings provide naturalistic information on driver use of windshield wiper systems, and therefore, may be of particular interest to windshield wiper and automotive windshield manufacturers regarding frequency of use and life expectancy of various associated automotive components. Future research should be directed to explore additional naturalistic driving to better understand how drivers interact with their environment (e.g., inclement weather and road conditions) and make the necessary adaptations to effectively navigate through it. Specifically, real-time precipitation measurements obtained from the vehicle are needed to better infer how driver behavior (i.e., range, speed, HTM) and wiper setting selection changes with precipitation, wiper use, and ambient light conditions. In addition, such precipitation information would enable a comparison of driver speed, wiper setting, and actual rainfall to create a model of how drivers drive in inclement weather.

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