Driving Performance in the Presence and Absence of Billboards

FINAL REPORT

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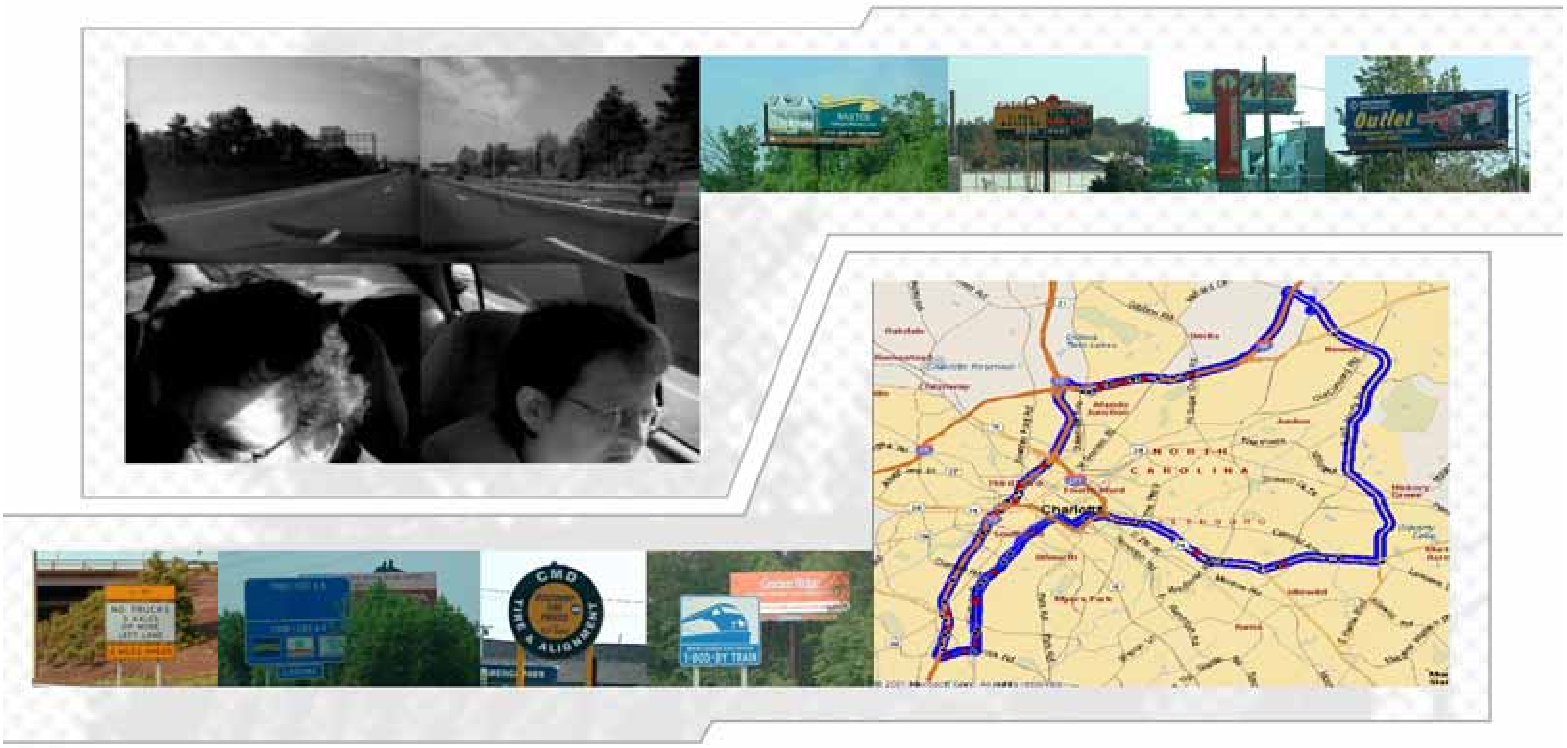

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ABSTRACT

The current project was undertaken to determine whether there is any change in driving behavior in the presence or absence of billboards. Several measures of eyeglance location were used as primary measures of driver visual performance. Additional measures were included to provide further insight into driving performance--these included speed variation and lane deviation. The overall conclusion from this study is that there is no measurable evidence that billboards cause changes in driver behavior, in terms of visual behavior, speed maintenance, and lane keeping. A rigorous examination of individual billboards that could be considered to be the most visually attention-getting demonstrated no measurable relationship between glance location and billboard location. Driving performance measures in the presence of these specific billboards generally showed less speed variation and lane deviation. Thus, even in the presence of the most visually attention-getting billboards, neither visual performance nor driving performance changes measurably.

Participants in this study drove a vehicle equipped with cameras in order to capture the forward view and two views of the driver's face and eyes. The vehicle was also equipped with a data collection system that would capture vehicle information such as speed, lane deviation, GPS location, and other measures of driving performance. Thirty-six drivers participated in the study, driving a 35-mile loop route in Charlotte, North Carolina. A total of 30 billboard sites along the route were selected, along with six comparison sites and six baseline sites. Several measures were used to examine driving performance during the 7-seconds preceding the billboard or other type of site. These included measures of driver visual performance (forward, left, and right glances) and measures of driving performance (lane deviation and speed variation).

With 36 participants and 42 sites, there were 1,512 events available for analysis. A small amount of data was lost due to sensor outages, sun angle, and lane changes, leaving 1,481 events for eyeglance analysis and 1,394 events for speed and lane position analysis. Altogether, 103,670 video frames were analyzed and 10,895 glances were identified. There were 97,580 data points in the speed and lane position data set.

The visual performance results indicate that billboards do not differ measurably from comparison sites such as logo boards, on-premises advertisements, and other roadside items. No measurable differences were found for visual behavior in terms of side of road, age, or familiarity, while there was one difference for gender. Not surprisingly, there were significant differences for road type, with surface streets showing a more active glance pattern than interstates. There were also no measurable differences in speed variability or lane deviation in the presence of billboards as compared to baseline or comparison sites. An analysis of specific, high attention-getting billboards showed that some sites show a more active glance pattern than other sites, but the glance locations did not necessarily correspond to the side of the road where the billboards were situated. The active glance patterns are probably due more to the road type than to the billboard itself. One major finding was that significantly more time was spent with the eyes looking forward (eyes on road) for billboard and comparison sites as compared to baseline sites, providing a clue that billboards may actually improve driver visual behavior. Taken as a whole, these analyses support the overall conclusion that driving performance does not change measurably in the presence or absence of billboards.

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Introduction

The current project was undertaken to determine whether there is any change in driving behavior in the presence or absence of billboards. Several measures of eyeglance location were used as primary measures of driver visual behavior. Additional measures were included to provide further insight into driving performance--these included speed variation and lane deviation. The overall conclusion from this study is that the presence of billboards does not cause a measurable change in driver behavior in terms of visual behavior, speed maintenance, or lane keeping. A rigorous examination of individual billboards that could be considered to be the most visually attention-getting demonstrated no relationship between glance location and billboard location. Driving performance measures in the presence of these specific billboards generally showed less speed variation and lane deviation. Thus, even in the presence of the most visually attention-getting billboards, neither visual behavior nor driving performance changed measurably.

Methods

Participants in this study drove a vehicle equipped with cameras in order to capture the forward view and two views of the driver's face and eyes. The vehicle was also equipped with a data collection system that would capture vehicle information such as speed, lane deviation, GPS location, and other measures of driving behavior. The video and other data were linked by use of a common time numbering system, and all data were collected at the rate of 10 times per second.

Thirty-six drivers participated in the study. Participants were unaware of the focus of the study on billboards; they were told that the purpose of the study was to examine natural driving behavior, which was also true. The drivers were a diverse group in terms of age, gender, income, education, and ethnicity. They were all familiar with at least some segments of the test route, which was a 35-mile loop route in Charlotte, North Carolina. The route included both interstate and surface streets, and it was mostly urban and suburban in nature. A total of 30 billboard sites along the route were selected with assistance from a Charlotte, North Carolina outdoor advertising company and representatives from the Outdoor Advertising Association of America (OAAA). The route included billboards of various sizes, on both sides of the road, and on both interstates and surface streets. In addition, six comparison sites (e.g., logo signs, on-premises signs, etc.) and six baseline sites (i.e., no visual elements such as buildings or signs present) were included for comparison purposes.

Participants were oriented to the study and the experimental vehicle before they began driving the route. After a short practice route with the experimenter, each participant drove the route unaccompanied and with the assistance of route directions mounted on the dashboard. Data were collected unobtrusively by using hidden sensors. The data were then stored on compact disks for later analysis. After returning to the starting point, drivers completed a demographic and driving questionnaire and were then paid a token amount in appreciation for their time.

The experiment was designed so that the elements of participant age (younger/older), participant gender (male/female), side of road (left/right), and type of site (billboard, comparison, or baseline) were equally represented. Several measures were used to determine whether driver behavior varied during the 7-seconds preceding the billboard site (as compared to other types of sites). These included measures of visual behavior (eyeglance locations of forward, left, and right) and driving performance (lane deviation and speed variation). The measures were statistically analyzed in terms of the controlled elements of site type, age, gender, and route, as well as by road type and familiarity. An additional analysis examined visual and driving performance in the presence of certain high-profile billboards that might be expected to be the most attention-getting along the route.

The eyeglance data were analyzed by four trained data analysts who used a customized software package. The software used GPS location data for site, route, and vehicle identification on an electronic road map. Glances were analyzed down to a tenth of a second, in terms of both length of glance and glance locations. Analysis of vehicle speed and lane position variability was accomplished with a computerized post-processing procedure on the raw data file. Each analyzed event was 7 seconds long.

With 36 participants and 42 sites, there were 1,512 events available for analysis from approximately 54 hours of data collection. A small amount of data was lost due to sensor outages, sun angle, and lane changes, leaving 1,481 events for eyeglance analysis and 1,394 events for speed and lane position analysis. Altogether, 103,670 video frames were analyzed and 10,895 glances were identified. There were 97,580 data points in the speed and lane position data set.

Questionnaire Results

The average participant age was 25 years for younger drivers and 56 years for older drivers. On average, drivers had completed 14 years of education (high school plus two years of college). For marital status, 78% of participants were single or married, while 14% were divorced and 8% widowed. Over 61% of drivers were European (Caucasian) and 39% of drivers had an African American, Native American, or Multi-racial background. Seventy-two percent of drivers reported an annual income of less than $49K. All drivers were familiar with the roadway system in Charlotte, North Carolina and most drivers both lived and worked there.

Analysis of the questionnaire results revealed that the most common items that caught drivers' attention during the route were traffic, other drivers, road signs, and highway signs, as well as construction, landmarks, landscaping, and buildings. Only 25% of drivers indicated that billboards caught their attention during the drive. Upon further discreet inquiry, these drivers indicated that they either tended to look at billboards in general or at specific billboards that caught their attention.

Other questions asked drivers to indicate what was memorable about the drive or what they noticed about other drivers. Most comments involved traffic, construction, the weather, or aggressive driving by other drivers. Many drivers indicated that they typically also performed other activities while driving, such as listening to music, talking on a cell phone, eating, drinking, smoking cigarettes, or talking to passengers. The last question asked drivers to reiterate the purpose of the study; all of the drivers indicated that the study was designed to examine natural driving behavior, which is what they had been told at the beginning.

Forward Visual Scanning Behavior Results

The visual behavior results indicate that billboards are not measurably different from comparison sites such as logo boards, on-premises advertisements, and other roadside items. The analysis of eyeglance patterns provided insight as to whether drivers displayed more active glance performance when passing billboards. Glances were analyzed in terms of number of glances, average duration of glances, and total duration of glances for each of three site types: billboard, baseline, and comparison sites. Billboard sites did not differ significantly from the comparison sites for left-forward glances, but did differ from baseline sites. There were also a difference in terms of left-forward total glance duration; billboard and comparison sites had significantly longer left-forward total glance durations than baseline sites, but did not differ from one another. There were no differences for the average glance durations in any direction between three site types. Out of nine visual performance measures, there were no cases for which the billboard site type differed significantly from the comparison site type, and only two cases for which both billboard and comparison sites differed from baseline sites.

In terms of side of road, age, or familiarity, no differences were found for eyeglance behaviors, and there was only one difference for gender. Females displayed longer average and total right-forward glance durations across all site types; this difference, although significant, was relatively small in terms of magnitude and does not appear to have any practical significance.

Not surprisingly, there were significant differences for road type, with surface streets showing a more active glance pattern than interstates. More glances were observed in all directions on surface segments, as compared to interstate segments. The average and total center forward glance durations were longer for the interstate segments; in most cases, the right- and left-forward average and total glance durations were shorter on the interstate than on surface streets. In most cases, surface road sites have more signs, buildings, and other features closer to the side of the road, so it is not surprising that drivers would look at locations other than center forward while driving in these areas.

Speed Variability Behavior Results

Speed maintenance behavior was not measurably different in the presence of billboards as compared to comparison and baseline sites. Significant differences were found for side of road, familiarity, and road type; however, from a practical perspective, differences were small. Sites on the right were associated with less speed variation than those on the left. Drivers also exhibited less speed variation for sites rated as familiar. The largest difference was in terms of road type--sites on the interstate had less speed variability than did sites on the surface streets.

Lane Deviation Behavior Results

Lane maintenance behavior was not measurably different in the presence of billboards as compared to comparison and baseline sites. Lane position analysis revealed differences only for side of road. For sites on the left side of the road, lane position varied by 10 inches during the 7-second segment, as compared to 7.5 inches for sites on the right side. These differences, although significant, are within the expected range of deviation.

Specific Board Analysis Results

An analysis of specific boards was performed to determine: 1) how specific billboards compared to other billboards as well as specific baseline and comparison sites in terms of eyeglance and driving performance measures, and 2) how the eyeglance measures corresponded to the placement of the billboards (left or right) in relation to the road. By choosing the four billboards that might be expected to draw the most glances, as well as two more ordinary boards, and comparing their results to all other sites, it became obvious that the selected billboards did not change visual performance. Some billboard sites seemed to have a more active glance pattern than others, but this was most likely due to road type differences, since the glance directions at these sites did not correspond to the side of the road where the billboards were situated.

Eyes-Off-Road Analysis Results

Eyes-off-road percentage was significantly greater for baseline sites than for billboard and comparison sites, providing some indication of potential improvement in driver visual performance in the presence of billboards. However, there was no measurable difference in the direction of these non-forward glances for baseline, comparison, and billboard sites.

Study Parameters

This study was conducted in a specific city chosen to be representative of mid-sized U.S. cities. The route was chosen to include both urban and suburban sections (and some sections were close to rural in nature). The billboards in Charlotte, North Carolina are generally situated close to the side of the road, therefore placing the boards within the forward-view of the participants for a longer period of time than if they were further offset from the road. Both the setting (urban/suburban/rural) and the billboard offsets were typical of most billboard locations found in the U.S. For each of the above-mentioned parameters, every attempt was made to conduct a balanced, representative study for which the results could be generalized to other cities and routes.

One limitation of this study was that there were few electronic boards along the route, so no conclusions can be drawn regarding driver behavior in the presence of this type of billboard. All three of the electronic billboards available on the route were included, however, for a total of 10% of the sampled billboards. Future research into this topic should focus on routes with a greater number of available electronic billboards so that an electronic/non-electronic analysis can be conducted.

Conclusions

The overall conclusion from this study is that the presence of billboards does not cause a measurable change in driver behavior, in terms of visual behavior, speed maintenance, or lane keeping. A rigorous examination of individual billboards that could be considered to be the most visually attention-getting demonstrated no measurable relationship between glance location and billboard location. Driving performance measures in the presence of these specific billboards generally showed less speed variation and lane deviation. Thus, neither visual behavior nor driving behavior changes measurably, even in the presence of the most visually attention-getting billboards. One major finding was that significantly more time was spent with the eyes looking forward (eyes on road) for billboard and comparison sites as compared to baseline sites, providing a clue that billboards may actually improve driver visual behavior.

INTRODUCTION

There is a long history of studying billboards in the context of traffic safety, but although the research record covers a many years (1951 until the present), it is lacking in volume. There were a few early epidemiological studies in the early 1950's examining traffic accidents in the presence and absence of billboards. As will be seen, much of this early work was methodologically flawed. After a long gap in research, there were a few other studies in the 1960's through the 1980's, none of which demonstrated that billboards are unsafe. Traffic accident analysis techniques have improved in recent years with the creation and maintenance of national crash databases. A careful examination of these databases shows that billboard distraction fails to show up in any of the accident databases as an accident cause. Likewise, an examination of numerous driver distraction studies demonstrates that billboards fail to show up as a cause of driver distraction. The lead author of this report recently participated on an expert panel charged with providing recommendations for a minimal data set to be included on police accident reports; billboards were never raised as a possible distraction or as an item that should be included on these accident reports.

Yet the argument continues to be raised that billboards may pose a traffic safety hazard. The safety argument follows this train of logic: billboards are designed to capture attention and are therefore designed to divert the driver's eyes from the forward view. Therefore, if billboards perform the job they are designed to do, they affect driver behavior and are thus a safety hazard. A search of the literature revealed that no research has been conducted inside the vehicle in a naturalistic manner to determine if billboards somehow affect driver behavior. The current project was therefore undertaken to fill this research gap and to determine whether billboards do in fact cause a change in driver behavior as he/she passes a billboard location. Several measures of eyeglance location were used as primary measures of driver visual behavior. Additional measures of driver performance were included to provide further insight--these included speed variation and lane deviation. Drivers in this study used an instrumented vehicle and were uninformed as to the underlying purpose of the study itself.

The report is organized as follows: a literature review, covering topics such as early accident analysis studies, sign conspicuity studies, and later safety and driver distraction studies; a methods section; a results section; conclusions; references; and supporting material contained in appendices.

REVIEW OF PREVIOUS RESEARCH

Early Epidemiological Studies

Early studies from the 1950's attempted to correlate the occurrence and frequency of accidents with the location of billboards or other roadway or roadside features. For example, a series of studies by the Minnesota Highway Department (Rykken, 1951) analyzed accident features in order to determine whether there was any direct relationship between accident frequency and type and several elements of roadway and road-side design, including advertising sign type and location. Accident reports from a 500-mile portion of US highway were analyzed from 1947 to 1949 in conjunction with information regarding geometric design, access points, and advertising signs. While a relationship between frequency of access points and accident occurrence was evident, no apparent relationship was found between accident occurrence and advertising sign type or location.

Rykken (1951) added that more accurate accident reports may reveal an unexpected relationship between signs and accidents: the absence of signs when no other roadside objects are present may increase the likelihood of accidents by decreasing the driver's sense of a need for caution. Immediately after 45 miles of highway with no billboards or advertising sings in viewable distance, a roadside interviewing station investigated driver response. Because drivers expressed a feeling of fatigue and unease after having driven the section, the author postulated that the combination of a small number of detracting features and the complete absence of billboards produced a feeling of security, which tends to result in higher average driving speed. Several severe accidents that occurred over that stretch were attributed to excessive speed.

McMonagle, a researcher with the Michigan State Highway Department, analyzed 2,675 accidents on a 70-mile strip of highway from 1947 to 1948 in order to measure the relationship between accidents and highway design and roadside features (McMonagle, 1951). The strip of road included a variety of roadside features and design characteristics, including the number of lanes and traffic volume. Findings showed that the highest incidence of crashes occurred near intersections, particularly when gas stations, restaurants and other establishments were clustered nearby. Only a slight association (correlation coefficient .11) existed between large advertising signs and accidents. While total advertising signs correlated with accident frequency to a greater degree (correlation coefficient .41), advertising signs still contributed less to accident frequency than did groupings of design features or roadside features such as gas stations.

In an attempt to correlate accident frequency with density of advertising and roadside business, Rusch (1951) analyzed crash reports originating in 1947 and 1948 that examined sections of highway distributed across Iowa. Stretches of road approaching 24 representative cities with a 1947 population of 5,000 or more were included in the study. The position of an accident was classified by density of advertising and business on the adjacent roadside, and the accident itself was assigned one of three causes: 1) roadside business, 2) inattention or misdirected attention, or 3) an "other causes" category. Roadside business was listed as the cause of an accident only if the business was specifically named in the accident report, as in the case of a vehicle exiting a gas station and being struck by oncoming traffic. Results showed that twice as many collisions occurred on the portions of road in the high-density category than occurred on the other parts of the test stretches put together. More accidents were attributed to inattention than to any other cause in the high-density category. In the low-density category, more accidents were attributable to miscellaneous causes than to business and inattention combined. Sections of highway in the low-density category showed lower accident rates than those in the high-density category, even when traffic volume was held constant. Also, accidents on low-density stretches occurred more sporadically with less of a tendency to recur in the same locations the following year. In reference to this study, Andreassen (1985) later claimed that “greatest number of inattention accidents occurred on the sections where business and advertising predominated as the roadside property usage, but this does not prove anything about the effect of advertising signs on accident occurrence.”

Overall, these early studies provided some initial insight into accident causation, but did not demonstrate that billboards or other advertising signs were a possible cause of accidents. In fact, intersections and high density roadways combined with inattention were most commonly associated with increased number of accidents. As a matter of fact, later analysts using modern statistical techniques critiqued these early studies as being methodologically flawed (e.g., Wachtel and Netherton, 1980; Andreassen, 1985).

Research Related to Attention and Perception of Signs and Billboards

After these early studies, there was approximately a 15-year gap before researchers once again began to study signs (in some cases including billboards) in a scientific manner. In these next studies, the focus was more on the transmittal of sign information and visual performance in the presence of signs. Johansson and Rumar (1966) conducted a two-part study to investigate the amount of information traffic signs imparted to drivers on a 105-mile stretch of road in Sweden. In the first part of the study, five participants were driven past the 424 road signs on the route and asked to record each one by pressing a button as they passed it. The participants recorded an average of 90% of the signs. In the second part, one of five temporary signs was set up on the road, and about 200 drivers were stopped just after they passed it and asked whether they had noticed its presence or what it said. A total of 47% of drivers noticed having just passed a sign, with significant differences depending on the meaning of the sign. For example, a sign warning a change in speed limit was remembered the most often, followed by a sign for police control. The authors concluded that traffic signs usually fail to catch drivers’ attention, and the level of efficacy depends on the amount of personal risk implied by the message.

Tachistoscopy, the study of visual perception via a machine that flashes images on a screen for a set fraction of a second, was used by Gutman (1972) to investigate the efficacy of illustration and copy placement in outdoor advertisements. Ads were manipulated photographically before being shown to 96 different participants. Each participant was asked to identify the advertiser and repeat the words seen in the advertisement, specifically reporting which aspect was seen first. Four layouts, two horizontal and two vertical, were tested. Horizontally, the copy was on one side and the illustration on the other; if the illustration was on the left, the copy was on the right, and vice versa. Vertically, either the illustration was on top with the copy underneath it or the copy was on top with the illustration on bottom. Findings showed that illustrations are usually the first focus of attention, regardless of their placement in the layout. Because the eye tends to scan from left to right, words were most effective when placed to the right of the illustration. Both vertical layouts were ineffective, most likely because the eye's preference for horizontal movement slows perception on a vertical plane.

An article by Johnston and Cole (1976) summarized five experiments that investigated the distracting impact of irrelevant information. Johnston and Cole hypothesized that a multiplicity of contributing factors may be involved in any collision, and establishing their relevance is often complicated by driver motivation when making police and insurance reports. For these same reasons it is difficult to unequivocally claim that outdoor advertising plays no role whatsoever in accident occurrence. However, Johnston and Cole put forward three hypotheses concerning the impact roadside advertising has on drivers, as follows:

1. A driver may visually sample the traffic environment at an appropriate rate, responding to cues by accelerating, steering etc. In the intervals between these samples, the driver may attend to information irrelevant to the driving task in such a way that advertising displays do not interfere with driving performance.
2. *The Distraction Hypothesis.* The driver's visual sampling of the traffic environment while driving may be spent in part on looking at roadside advertising. If the driver's sampling rate is inappropriate for the surrounding events, the driver may be unable to avoid potentially dangerous situations. This is mitigated by the fact that the driver can ignore information judged to be irrelevant to the driving task.
3. *The Confusion Hypothesis.* The background luminance, color or movement of advertising signs may camouflage critical information in the driving environment.

Laboratory investigation of distraction as summarized by Johnston and Cole (1976) shows that primary task performance tends to show only a small decrement in the presence of manifold distractions. The distracting stimuli used in these studies were characterized by their irrelevance to the participants' main activity. Human performance on sensory-motor tasks follows a U-shaped curve so that the optimum performance can be found when stimulation is fairly high. If a driver is "under-aroused," listening to a car radio has been shown to improve performance by increasing the level of stimulation. In short, laboratory knowledge concerning distraction shows that the effect of irrelevant stimuli is complex and depends on four things: 1) the nature of the primary task, 2) the level of arousal, 3) the type of distraction, and 4) the psychological 'set' of the observer at the time.

Johnston and Cole (1976) performed five experiments, each building on the previous one, to investigate the potential distraction (rather than the confusion) aspect of advertising displays. All five experiments used a rig similar to a driving simulator, in which the participant sat in the middle of a hemi-cylindrical screen. The primary tracking task required the participant to move a joystick in the direction indicated by a small, changing arrow in the middle of the screen. A small monetary reward for correct responses was used in the first three experiments to ascertain that this task was given priority. For experiments 3, 4, and 5, a second task was added to amplify any distraction effects from the advertisements. The secondary detection task involved pressing a button in response to infrequent spots of light in the periphery of the visual field. Distractor images, selected from advertisements in magazines by virtue of their content and their similarity to typical billboard imagery, were displayed while the participant performed these two tasks. Eight product groups (such as food and baby products) provided 30 to 40 ads each, which were then redistributed randomly into 20 groups of 12. Each group was shown sequentially to each participant so that no distractor slide was presented more than once. In the first experiment, the ads moved from 5° off center to 45° in the left visual field. In the following experiments, the ads remained stationary directly above the arrow in the center of the screen. In later experiments the ads also flashed to increase their distractive qualities.

The findings of the five experiments performed by Johnston and Cole (1976) were as follows:

1. Differences in tracking performance were not the result of distraction stimuli in the first experiment, but were a function of the frequency of tracking arrow presentation because of the increase in perceptual load.
2. Temporal uncertainty in the presentation of the tracking arrow reduced tracking performance by increasing perceptual load heavily. The presence of distraction was associated with a significant fall in mean tracking score when the participant's perceptual load was this high. The magnitude of the fall, though significant, was very small.
3. When the perceptual load was greatest, an interaction between the secondary task and the distracting images actually caused an increase in performance on the tracking task, possibly due to an arousal effect. Distraction caused a significant, though very small, decrement in performance on the secondary detection task.
4. When distraction advertisements were presented at high visual contrast, tracking task performance increased if the secondary detection task was being performed at the same time. As in experiment 3, an arousal effect was hypothesized to explain the improvement. Performance on the secondary detection task itself was significantly worse when distractions were presented, even though primary task performance increased.
5. The findings of the previous experiments were corroborated. Only at the highest perceptual load did distraction have an effect (a negative one) on tracking performance.

To summarize, distracting advertisements had no significant effect on task performance until the perceptual load became high, whether by speed or temporal uncertainty of stimulus presentation. When the secondary detection task was added, distracting advertisements had the opposite effect: they improved performance on the main task, although performance on the secondary task suffered. The arousal effect hypothesized by Johnston and Cole (1976) to explain this improvement asserts that stress on the participants increased to a level nearer their optimum, raising vigilance according to priority. Andreassen (1985) later summarized the Johnston and Cole research by giving the following pointers for billboard design: control glare; make the message simple; allow no signs in places where drivers will be "highly loaded;" and control novel, sensuous, or moving displays.

A study by Boersema and Zwaga (1985) investigated the degree to which the physical environment of a target affects its conspicuity. Visual conspicuity of any object is determined by its physical properties, its relation to what surrounds it (contrast), and the cognitive set of the observer. Participants were asked to locate routing signs in pictures of a train station, and the number of advertising signs competing for attention was varied systematically in the pictures. The results indicated that it took longer to locate the routing signs when there were advertisements in the immediate vicinity.

Luoma (1988) performed a study to investigate the degree to which conscious perception and eye fixation while driving are interdependent. Drivers wore a machine on their heads that calculated the direction and duration of their eye fixations while they drove a 50 km route. Glances toward five types of objects (traffic signs, lane markings, crosswalks, roadside advertisements, and houses) were specifically monitored. Findings showed that fixation did not necessarily indicate perception. Rather, the length of time necessary for a fixation to become a perception depended on the nature of the object being seen. Roadside advertisements required a very long fixation time, about four times as long as any other category tested.

According to Luoma (1986), the roadside advertisement is recessive in the visual field if there are numerous targets relevant to the driving task. This was the finding of a study designed to investigate eye movement, fixation, and perception of billboards and traffic signs, whether billboards disturb perception of signs, and how well billboards and traffic signs remain in memory. Participants were shown daylight images in succession, some of just a road, some of the same scene with a traffic sign or a billboard, and some with both. Questionnaires were administered at irregular intervals in order to check the participant's memory of recent images. The perception of a billboard was found to be dependent upon the simplicity of its pictures, internal contrast, and easy outlining. The presence of billboards in a picture was found to decrease the perception of traffic signs by an average of 34%. Perception of traffic signs was disturbed most seriously by billboards that were difficult to perceive correctly or that communicated their message poorly. The presence of billboards slightly improved recall of the meaning of perceived traffic signs. Billboards did not significantly affect the perception of oncoming traffic.

A second experiment in the same study by Luoma (1986) used the same protocol with similar images taken at night. Under these conditions, billboards disturbed the perception of traffic signs an average of 39%. They just barely disturbed the perception of oncoming traffic, and even less for billboards that had a traffic sign included with the image.

Across both tests, billboards were found to remain in a person's memory longer than traffic signs. A third study using similar methodology investigated eye movement and fixation with perception. In daylight, the presence of a billboard did not alter eye fixation patterns but did decrease perception. At night, billboards both changed fixation patterns and decreased perception. The authors concluded that billboards are disturbing primarily when the driver feels capable of perceiving everything necessary while spending attention on billboards as well. When there are numerous stimuli in a complex driving environment, drivers can seek out what is important without being negatively affected by billboards.

Donthu, Cherian, and Bhargava (1993) attempted to identify and quantify the factors that influence how well outdoor advertising is recalled in a naturalistic setting. Ten new billboards were erected on a 30-mile stretch between a suburb and a downtown exit, between 45 and 60 days prior to the beginning the study. Telephone interviews were conducted with 142 adults who commuted past these signs every day. The interview regarded their ability to recall ads, what aspects they recalled, and their attitude towards the ads. Factors found to influence recall included the following:

- Location: highway or surface street.
    - Highway produced superior recall.
- Position: right or left side of the road.
    - Right side was superior.
- Number of words.
    - Seven or less was superior to 8 or more.
- Color: black and white or color.
    - Black and white was superior.
- Respondent involvement with the product.
    - The more involved the observer was with the product, the better the recall.
- Attitude toward outdoor advertisements in general.
    - The more positive the respondent's attitude, the better the recall.

The authors postulated that black and white advertisements were more effective than color because black and white was very rare in the strip of billboards investigated. Based on these findings, Donthu et al. (1993) advised using uncommon execution as in this coloration example, placing the advertisements on the right hand side of highways, and using few words.

A study by Boersema, Zwaga, and Adams (1989) identified two types of conspicuity that describe the attention-getting properties of an object in the visual field, such as a billboard on the side of the road. The ease with which an object can be seen once the observer is specifically searching for it is called search conspicuity. The ease with which an object is seen when it is not being searched for is called attention conspicuity. Both of these types of conspicuity have traditionally been measured by laboratory search and response tasks, in which a participant presses a button or otherwise verifies identification once the object has been located in his or her visual field.

The time it takes a participant to do this task, the reaction time, is composed of two parts: first the participant must correctly identify the object (search time), then the participant must decide what to do about it (processing time). Boersema, Zwaga, and Adams (1989) devised an experiment to eliminate processing time in the measurement of an object's conspicuity characteristics, since processing demands change between participants, making it a source of error variance. Absolute search time was measured by eye fixations alone, erasing the variation in responses. Eye movement data was shown to be a sensitive measure of the conspicuity of visual targets in realistic scenes. The details of this experiment were very similar to a prior study by Boersema and Zwaga (1985) in which 54 participants were asked to identify routing signs in slides of train stations. The slides were photographically manipulated to show exactly the same scene with 0, 1, or 3 advertisements. The number of eye fixations was found to increase significantly with the number of advertisements in the scene. The increase in fixations resulted in increased search time, showing that the presence of advertisements in an environment can decrease the efficiency with which information can be found. Once identified, the time it took to process and react to the information did not change with variation in the number of advertisements in the scene. It should be noted that these types of experiments, which do not involve driving, do not take into account the fact that drivers generally allocate most of their attention to the primary task of driving, and only allocate attention to other tasks as excess attention becomes available.

Distraction is difficult to measure, partially because it is difficult to quantify the distribution of attention. Eye movement recordings and verbal report techniques were used by Hughes and Cole (1986) and Luoma (1988) to determine where the drivers' attention was directed, but the expensive nature of these measures, along with uncertainty regarding the underlying attentional processes, can present problems. Hoger (2001) measured attention through response time to flashes of light located on varying images in a simulated driving scene. This Signal Location Task (SLT) was designed so that the time it took to locate the light signal depended on its proximity to the place the attention had been resting originally. This allowed the researchers to record what objects drivers were directing their attention toward, without the cumbersome problems associated with distraction measurement.

Hoger (2001) used SLT to measure the amount of attention that drivers directed to outdoor advertising compared to other cars on the road (traffic), traffic signs (information), and irrelevant locations in the periphery (e.g., clouds and trees). Reaction times were significantly shorter when the targets were located on task-relevant images (i.e., traffic or traffic signs). Reaction times were also shorter for billboards than for meaningless items in the periphery, which reveals that billboards do attract more attention than entirely task-irrelevant objects do.

Jones (2001) provides engineering guidelines for design and placement of effective information and guide signs along major roads by summarizing current standards. The Manual on Uniform Traffic Control Devices (*MUTCD*), from which current standards are drawn, addresses the use of changeable message signs (CMSs), specifying font size (from 11 to 18 in.) and minimum legibility distance (650 ft. if portable, but 1000 ft if in high-speed locations). The point of *MUTCD* recommendations on CMSs is to maximize the ease with which a driver can understand and process the information.

The initiation of billboard regulation sparked a need for formal signage along freeways to direct motorists to service facilities such as restaurants and gas stations. Specific service signs (logo placards) are also addressed by *MUTCD*, as reported in Jones (2001). These signs advertise services at nearby exits and are used primarily on freeways. GAS, FOOD, and LODGING are examples of headings on the signs; each sign, commonly referred to as a logo placard, has up to six standardized logos showing what facilities can be accessed at the next crossroad. Limitations to this program are that only "qualifying" facilities or attractions can be advertised on these signs, and their use was originally intended to be limited to rural areas. Tourist-oriented directional signs (TODS) on conventional highways are also used to advertise small businesses such as potteries and fruit stands.

Compact urban areas mandate the prioritization of signs to prevent driver overload, while higher speeds dictate placement of signs well in advance to allow the driver time to process and react appropriately. Because guide signing is an integral part of the system, it needs to be incorporated into the early stage of highway planning and design (Jones, 2001). A highway with an optimal physical design will not operate safely if it does not have a good signing system.

The complexity of the visual field has been said to affect a driver's abilities to detect a specific stimulus. Researchers Akagi, Takuya, and Motoda (1996) of the Japanese Ministry of Construction performed an experiment to investigate whether the visual noise ratio (defined as the area of cluttering signs compared to the total field of view) is correlated with eye fixation patterns and sign detection distance. They also examined the effectiveness of the visual noise ratio as an index to express the degree of visual complexity in the driving environment.

Fixation pattern results showed that fixation time decreased as clutter increased, but fixation velocity increased at the same time. This means that drivers look at a greater number of objects more quickly when surrounded by a complex visual field. Akagi et al. (1996) postulated that an increase in the visual noise ratio creates greater stress for drivers and may contribute to an increase in accident frequency.

The detection distance decreased as the visual noise ratio increased, but this effect differed in its intensity according to the age and gender of the subject. The detection distance of males was longer than that of females, but visual noise interfered with male detection distance more than with female detection distance. As the age of participants increased, detection distance decreased. Akagi et al. (1996) considered older drivers more susceptible to visual noise. The visual noise ratio was found to be a very useful index in investigating the effects of visual complexity in Japan, and it revealed that female and younger drivers are comparatively unaffected by visual noise.

Garvey, Thompson-Kuhn, and Pietrucha (1995) performed a synthesis of past and present research knowledge in the field of sign visibility. They found that visibility research tended to fall into one of two categories: sign detection (a function of sign conspicuity) or sign legibility. Sign placement, which is described as the sign's height, offset, and surround (or immediate environment), most strongly affect detectability. Lateral and vertical offset from the side of the roadway can be used to maximize detection distance, especially when far from hills, curves, and intervening visual targets. Much research has shown that conspicuity is greatest when signs are erected as close to the driver's line of sight as possible--the larger the eccentricity (degrees off center), the smaller the chance the sign will be noticed. The visual complexity of the sign's surround also has a high impact on its conspicuity, meaning that the more items there are for the driver to look at, the less likely he or she is to notice the sign in question. Night vision of retroreflective signs is even more strongly influenced by these factors, so the eccentricity needs to be carefully tailored to the manufacturer's specifications and the surround needs to be as simple as possible. A sign's external contrast ratio is the luminance of the sign compared to the area immediately surrounding it. As that ratio increases, whether during the day or night, so does the sign's conspicuity. Size, shape, internal contrast (the colors of letters or illustration compared to the color of the background on the sign), and edge definition (heightened by borders around the outside of the sign) of the sign all play a role in detectability as well.

Legibility can be impacted strongly by many of the same factors, primarily because they lengthen the available time for the driver to notice and read the sign (Garvey et al., 1995). Familiar copy can be recognized and read at much greater distances than novel copy can, so one of the most successful advertising strategies, rather than manipulating font and presentation, is to make the target audience as familiar with the slogan as possible. Symbols create a much longer legibility distance, but are not comprehensible to as many drivers as alphanumeric messages are. Copy presentation issues that impact legibility include letter case, font, stroke-width, abbreviations, letter height, color, and contrast.

More Recent Epidemiological and Driver Distraction Studies

A critical research review sponsored by the Federal Highway Administration (Wachtel and Netherton, 1980) summarized knowledge concerning commercial electronic variable-message signage (CEVMS) in an effort to recommend national standards for their regulation. The review focused on their potential impact on the three areas of public interest that the Highway Beautification Act was drafted by Congress to protect: promotion of highway safety, preservation and enhancement of natural beauty along highways, and protection of highway investment. Only the portions of their report relating to safety will be addressed here.

Literature regarding safety issues was found to concern two types of studies: accident analyses and human factors studies. Wachtel and Netherton (1980) opined that roadside advertising research based on accident studies has had limited value owing to either insufficient information concerning location and traffic or problems with statistical analysis and sampling error. While some studies have found positive relationships between outdoor advertising and accident frequency, others have arrived at the opposite conclusion.

According to Wachtel and Netherton (1980), human factors laboratory research techniques are capable of gathering much more precise, reliable, and valid data in the attempt to measure and explain the effect of outdoor advertising on driver behavior. Literature from several related fields indicated that outdoor advertising probably does not hurt driving performance notably when driving conditions are favorable (in terms of weather, traffic, road, vehicle, etc.). This is because the driver has sufficient spare processing capacity to pay attention to the signs without compromising the primary task. When stimulation is extremely low, as when there is very little traffic and very little to look at or to decide, unusual environmental features such as road signs may *increase* the driver's arousal and *improve* driving performance. When the driving task becomes highly demanding, the outdoor advertising must compete with more vital information sources such as traffic, weather, and official signage. Because the driver's attentional capacity is finite, CEVMS could pose a threat, particularly due to their technological advantage over conventional billboard advertising. Variable-messages can attract attention at greater distances, hold the attention longer, and portray more images and information, all of which may contribute to an overloading of driver capacity.

Courts have preferred the logic that legislatures should try to minimize the risk of distraction when high driving concentration is needed, assuming that a driver cannot give sufficient attention to vehicle control if he is reading a billboard (Wachtel and Netherton, 1980). Even with expert witness to the contrary, this has been the trend; when expert witnesses have disagreed about the impact of outdoor advertising, legislatures have tended to restrict outdoor advertising using the safety argument as a fallback position.

In a review of published literature relating accidents to advertising signs, Andreassen (1985) brought attention to weaknesses in the small amount of research that has been conducted in this area. Almost all studies have relied on correlations and/or subjectively assigned “inattention” factors, which can only produce very tenuous evidence for a causal link between advertising and accident frequency.

Garvey et al. (1995) reviewed the studies that attempted to directly evaluate the relationship between traffic accidents and advertising signs. The common problem with these studies is attributing accident causation; high-advertising and low-advertising sites may have different accident frequencies because of differing traffic densities, pedestrian activity, and roadway geometry. Although most evidence argues against a strong causative link, it is still not possible to ascertain the existence or nature of the relationship between advertising and accidents.

Dynamic and high-resolution imaging, such as that seen on electronic billboards (EBBs) and tri-panel signs, have raised questions about safety implications with regard to driver distraction. A literature review sponsored by the Federal Highway Administration (Farbry, Wochinger, Shafer, Owens, and Nedzesky, 2001) summarized current knowledge in this research field, assessed areas needing exploration, and developed a research plan to address them. While some EBBs display motion and color with fine detail, others just show a short sequence of words in which each letter is composed of a matrix of light emitting diodes (LEDs) (Farbry et al., 2001). This type of display is used by governmental agencies to present information to drivers and is known by several different acronyms: variable message sign (VMS); dynamic message sign (DMS); and changeable message sign (CMS), which will be used in this report. A tri-panel sign, also known as a tri-vision sign, is composed of triangular cylinders that rotate periodically, showing a different composite image in between each rotation. The only movement is that of the images in transition.

Studies attempting to draw causality from correlation between dynamic billboards and accident frequency run into the same difficulties found by studies investigating static billboards and accidents (Farbry et al., 2001). Common obstacles include consistently confounding traffic conditions in areas with heavy advertising, incomplete or inaccurate accident reports, and driver motivation to omit distraction when reporting crash causality. Even given these stumbling blocks, the correlation is still statistically clear: after a dynamic, illuminated billboard is installed, crash rates go up. A common trend was exemplified when a 35% increase in sideswipe and rear-end accidents on an interstate occurred after a variable message advertising sign was put up on the side of a sports stadium. The correlation, while rarely this dramatic, is a consistent one. However, even a correlation this strong is not sufficient evidence to assume causality. Enough other variables were held to be confounding the situation that the sports stadium sign was not deemed a traffic hazard in and of itself, and it remained in place for 16 years.

Correlations alone provide little fodder for the development of countermeasures. Researchers hypothesize that a safety hazard is posed by dynamic advertising because it may cause greater distraction, which can be measured in several formal ways. One common method is to ask the driver to perform another task while driving, then to measure the degree to which the safe operation or control of the vehicle is affected. Lack of control is typically quantified by one of three measures: lateral deviation, maintenance of appropriate speed, and/or braking for emergencies. Lateral deviation is defined as either the degree to which the vehicle swerves away from the center of the appropriate lane or a measure of the variability in steering wheel position. Maintenance of appropriate speed refers to the headway between the vehicle and the vehicle ahead; if the lead vehicle slows down, the participant vehicle should also slow down and maintain an appropriate speed to keep the headway constant. Some experiments present an emergency and measure distraction by the amount of time it takes the participant to respond appropriately.

The literature review by Farbry et al. (2001) revealed that the two demographic groups most susceptible to the dangers of distraction while driving are drivers over the age of 65 or under the age of 24. Older drivers' visual processing speed and attention degrade with age, resulting in little to no spare resources with which to encode and process anything but the most important information in the driving environment. Younger drivers usually have faster processing speeds, but they are less experienced and less efficient at resource allocation. Among other weaknesses, younger drivers take more risks, may not recognize hazards, and have poor focus on the driving task itself. Because of this, they may be more vulnerable to having their attention drawn by irrelevant but attention-getting stimuli.

Other than age, a variable that may influence the degree to which a sign distracts a driver is route familiarity (Farbry et al., 2001). A driver who is new to a road may be looking for navigational or service cues, and this task may be take longer in a more complex visual environment containing numerous advertising signs. On the same road, a familiar driver may not look around much since he has all the information he needs already. Familiar signs may be less likely to attract the attention of a driver who knows the roadway well and whose primary navigational interests may be traffic conditions and incidents. According to this theory, a visitor would be more likely to be distracted by an advertising sign than would a commuter.

Research regarding distraction, conspicuity, and legibility revealed that an increase in distraction, a decrease in conspicuity, or a decrease in the legibility of a sign may cause an increase in the crash rate (Farbry et al., 2001). The review shows that, at this point, there is no effective technique for evaluating safety effects of EBBs on driver attention or distraction. Crash studies may show a positive correlation between dynamic signs and crash rates, but driver age and route familiarity are examples of confounding variables whose interference may hide the fact that very little causality can be proven.

Recently, much attention has been focused on the causes and effects of distraction on driving, especially in the area of cellular phones and other in-vehicle technology. A review of the recent driver distraction literature failed to reveal any studies in which outdoor advertising was mentioned as a cause for driver distraction. As further proof of this, the principal investigator for this project recently served on the advisory panel for the revised Model Minimum Uniform Crash Criteria in which transportation safety experts recommended revisions to the minimum set of data to be collected as part of every crash report. There were lengthy discussions over which distraction variables should be recommended, and the words “billboard” or “advertising” were never mentioned.

The national crash databases do not mention billboards in their list of driver distractions. The tow most prominent databases are the General Estimates System (GES) which estimates the number of all crashes based on a representative sample and the Fatal Accident reporting System (FARS) which is a true census of every fatal crash. The only mention of billboards in the 216 page user's manual for the GES database is in the Driver's Vision Obscured By variable, which has a category of Building, Billboard, or Other Design Features (GES, 2002). In other words, if an accident was caused by a driver's vision being obscured, billboards would be lumped together with buildings and other design features, both of which are much more common than billboards. The same holds true for the FARS user's manual of 458 pages – billboards are only mentioned in the Driver's Vision Obscured By variable, and are lumped together with buildings (Tessmer, 2002).

One very recent study of driver distraction (Glaze and Ellis, 2003) reported one mention of the word "billboard" in the context of an accident caused by driver distraction. Glaze and Ellis performed a study to determine the nature of distraction/inattention crashes in the state of Virginia. A complex system of accident report sampling was administered via surveys sent to all seven Virginia state police divisions, four selected counties, and 14 independent cities. Roughly 2,800 crash scenes were reported, involving a total of almost 4,500 drivers. At least one distracted driver was involved in 98% of those crashes. Every accident report had a space to write an open-ended description of the main distracting factor in the accident, and over 1,400 responses were recorded. One response included a billboard being repaired as a causal factor for driver distraction leading to a crash. No mention of outdoor advertising was made in any other place in the study, despite the fact that 35% of distracters were outside of the vehicle in question (62% were in-vehicle and 3% were unknown). The same study reported 25 cases of drivers being distracted by traffic signs or signals.

Conclusions from Literature Review

Historical correlation studies tried to draw relationships between outdoor advertising and accident frequency, but those studies, whose findings were inconclusive at best, have been discredited because of flawed methodology. Data gathering and analysis techniques have greatly improved in recent years, but billboards still fail to show up in any of the accident databases as an accident cause or in any of the driver distraction studies as a distraction cause.

Research Questions

The current project was undertaken to determine whether billboards do in fact change driver behavior as they pass a billboard location. Several dependent measures were selected to serve to provide insight into driver behavior and performance. Past research has indicated that eyeglance position, speed variation, and lane deviation provide excellent measures of driver performance. The following six research questions were developed to answer the overall question of whether billboards change driver behavior:

1. Does a driver’s forward scanning behavior (glances through the windshield—center forward, left forward, and right forward) change in the presence of billboards as compared to baseline and comparison sites?
2. Does a driver’s speed maintenance behavior (standard deviation of speed) change in the presence of billboards as compared to baseline and comparison sites?
3. Does a driver’s lane keeping behavior (standard deviation of lane position) change in the presence of billboards as compared to baseline and comparison sites?
4. Does a driver’s forward scanning behavior, speed maintenance behavior, or lane keeping behavior change in the presence of certain highly-attention getting billboards as compared to standard billboards?
5. Does a driver’s eyes off road percentage (sum of all glance times except center forward, left forward, and right forward divided by sum of all glance times) change in the presence of billboards as compared to baseline and comparison sites?
6. If a driver’s eyes off road percentage changes in the presence of billboards as compared to baseline and comparison sites, are there then corresponding differences in off road glance allocations (i.e., other exterior locations, rear view mirror, and other interior locations)?

METHOD

Experimental Design

This study was conducted as a mixed factors research design (a 2 x 2 x 2 x 3 design, with 4 between-subjects cells). There were five independent variables: gender, age, route familiarity, event type, and road type. The between-subjects independent variables were gender (male or female) and age (younger or older). The original within-subject independent variables were route familiarity (unfamiliar or familiar) and event type (billboard, baseline, or comparison). An additional within-subject independent variable of road type was added post-hoc (interstate or surface road). All of the participants drove each of the segments and were exposed to all of the billboards and comparison events.

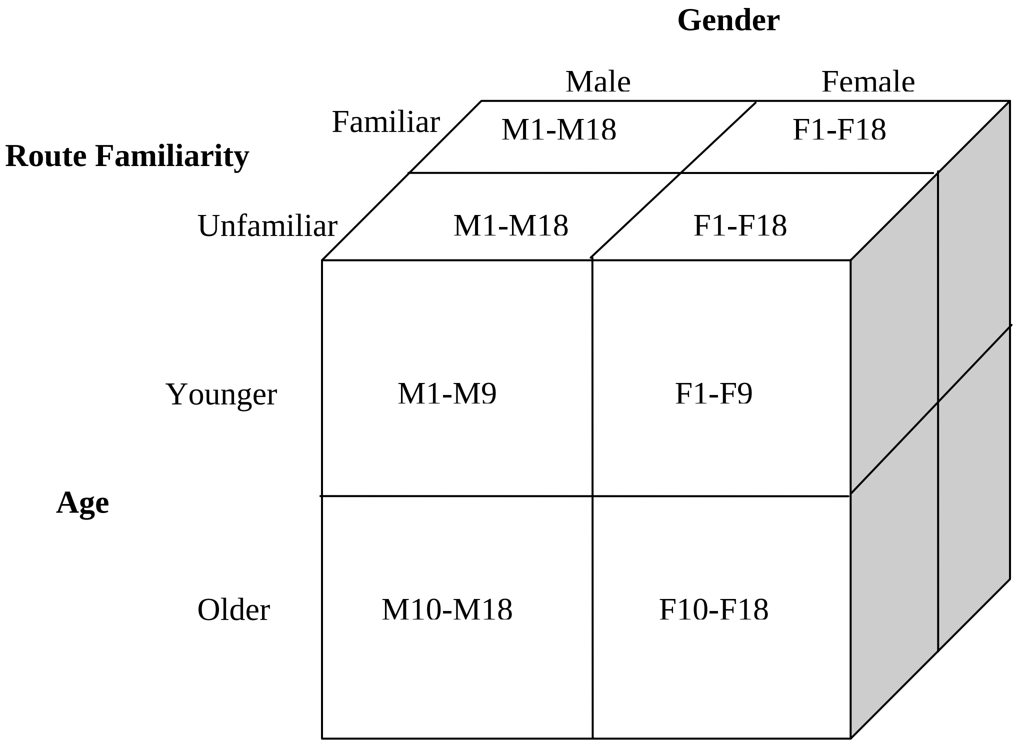

Figure 1. Assignment of Participants to Experimental Conditions.

Independent Variables

The five independent variables are listed in Table 1.

Table 1. Independent Variables

Independent Variable	**Levels**
Age	Younger (18-35) or Older (50-75)
Gender	Male or Female
Route Familiarity	Unfamiliar or Familiar (familiarity with 4 segments determined for each subject)
Event Type	Billboard, Baseline (no billboards) or Comparison (other distracters)
Road Type	Interstate or Surface Street

Age and Gender. Of the 36 participants, eighteen were younger drivers (18 to 35 years old) and eighteen were older drivers (50 to 75 years old). Eighteen of the participants were male and eighteen were female. Age was equally balanced across gender, as is illustrated by Figure 1 (e.g., of the 18 younger participants, 9 were male and 9 were female).

Route Familiarity. Route familiarity referred to how often a section was normally driven by the participant per week (e.g., unfamiliar = drove section less than once per week; familiar = drove section at least once per week). Route familiarity was ascertained after the drive by asking participants how familiar they were with the various segments they had just driven.

Event Type. The three event types included billboard, comparison, and baseline. All of the participants were exposed to all three event types. Events were 7 seconds long. The end of an event was the point at which the experimental vehicle passed the object, and the start of the event was then defined as 7 seconds before the end point.

Road Type. The two road types were interstates and surface roads. All of the participants were exposed to both road types. Approximately 40% of the route consisted of interstate segments, with the remainder being classified as surface streets.

<u>Billboards.</u> Billboard events were defined as areas in which designated billboards were visible. These were identified by GPS (latitude and longitude) coordinates associated with their exact location near the roadway. There were 5 billboard types, resulting in a total of 84 available billboards (see Table 2).

Table 2. Billboard Type, Description, Number of Available Billboards

Media Type	Description	Number of Boards
14’ x 48’ Bulletin (14x48)	Large billboard, 14 feet (h) by 48 feet (w)	47
10'6” x 36' Bulletin (10x36)	Large billboard, 10 feet 6 inches (h) by 36 feet (w)	15
Standard Poster (SP)(12’x 25’)	Medium billboard, 12 feet (h) by 25 feet (w)	15
Junior Paint (Jr P) (<10’6” x <36’)	Various billboard sizes smaller than 10’6” by 36’	5
Permanent Paint (PP) (10’6 x 36’ or 14’ x 48’)	Billboard, 10'6” by 36' or 14' by 48', “permanent” in that only one company’s advertisements are displayed on this board	2
Total		**84**

<u>Billboard Selection.</u> Of the total set of billboards available on the route, a sample of 30 billboards was selected for efficiency of data reduction and to ensure a balanced sample. The sample was selected so that it was balanced in terms of side of the road, media type, road type, and where possible, varying degrees of “visual clutter.” None of the selected boards were located directly prior to or after a road exit or entry. Preliminary review of the video indicated that drivers were likely to be changing lanes or monitoring items such as road signs during these times, which could confound the results of the analysis. Side of the road was equally represented, and 57% of boards were 14’ x 48’ bulletins. The remaining 43% were a mixture of smaller boards, including standard poster (20%), junior paint (13%), and 10’6” x 36’bulletins (10%). Table 3 lists the selected billboards, while the locations of the selected billboards are indicated by aqua blue dots (🔵) in Figure 2.

<u>Comparison sites</u>. Comparison events were areas with other potential roadside distracters. Examples include other forms of outdoor advertising such as “on-premise signs,” logo placards, and variable message signs. These are shown as yellow dots (🟡) in Figure 2.

<u>Baseline events.</u> The baseline event type referred to areas with no billboards or other distracters visible. These areas served as locations with which to compare velocity, lane position, and glance patterns and are indicated by red dots (🔴) in Figure 2.

Table 3. Billboard Sample Indicating Name (billboard #), Side of the Road, Media Type, Latitude, Longitude, and Specific Site Location Information

Name	Side	Media type	Latitude	Longitude	Site
8441	R	14X48	35.27865	-80.79637	4827 I-85 NORTH S/O SUGAR CREEK ROAD WS
8489	R	JR. P	35.27728	-80.81391	4031 I-85 NORTH S/O DERITA ROAD WS
12209	L	14X48	35.27642	-80.81382	I-85 0.2 mi S/O GRAHAM STREET ES
13052	L	14X48	35.27513	-80.82055	I-85 0.3 mi S/O GRAHAM ST ES
8537	R	14X48	35.27559	-80.82232	3639 I-85 NORTH WS
8532	L	14X48	35.27421	-80.82535	3340 I-85 NORTH ES
8568	R	14X48	35.27446	-80.82939	3399 I-85 NORTH N/O STATESVILLE AVE/RD WS
8574	L	14X48	35.27273	-80.83054	3210 I-85 NORTH N/O STATESVILLE AVE/RD ES
13346	R	14X48	35.24167	-80.85136	I-77 0.1 mi S/O HWY 16 (BROOKSHIRE) WS
8960	R	14X48	35.23256	-80.86009	I-77 SOUTH @ SECOND STREET WS
8998	L	14X48	35.22705	-80.86136	I-77 SOUTH 0.2 mi N/O INDEPENDENCE BLVD ES
9027	R	JR. P	35.22245	-80.86828	I-77 SOUTH @ W. INDEPENDENCE BLVD WS
9034	L	14X48	35.21395	-80.87255	I-77 SOUTH 0.3 mi N/O REMOUNT RD ES
9071	R	14X48	35.21271	-80.8744	I-77 SOUTH 0.1 mi N/O REMOUNT RD WS
9106	L	JR. P	35.18121	-80.88652	I-77 SOUTH @ WOODLAWN ROAD ES
9128	L	14X48	35.17475	-80.88614	I-77 SOUTH @ SOUTHERN RAILROAD ES
9159	R	14X48	35.17378	-80.88711	I-77 SOUTH S/O SOUTHERN RAILROAD WS
7716	L	14X48	35.16352	-80.88649	511 TYVOLA RD NS
7723	R	10X36	35.16536	-80.88029	900 TYVOLA RD SS
3240	L	SP	35.16852	-80.87622	5100 SOUTH BLVD N/O TYVOLA RD WS
3197	R	SP	35.17213	-80.87553	4837 SOUTH BLVD S/O INWOOD DR ES
3130	L	SP	35.18526	-80.87628	4230 SOUTH BLVD S/O SCALEYBARK RD WS
13351	R	10X36	35.18681	-80.87557	4127 SOUTH BLVD ES
3068	L	SP	35.19762	-80.86968	3040 SOUTH BLVD N/O GREYSTONE RD WS
13353	R	JR. P	35.19774	-80.86876	3033 SOUTH BLVD ES
13200	L	10X36	35.20568	-80.79402	2801 E INDEPENDENCE 0.4 mi W/O EASTWAY NS
7194	R	14X48	35.20232	-80.78991	3200 E INDEPENDENCE BLVD 0.1 mi W/O EASTWAY DRIVE SS
1856	R	SP	35.20015	-80.76359	4932 ALBEMARLE RD @ PUTT PUTT SS
7245	L	14X48	35.20156	-80.7621	5101 ALBEMARLE RD E/O GREENBROOK DR NS
1895	L	SP	35.20336	-80.74105	6115 ALBEMARLE RD W/O FARM POND LN NS

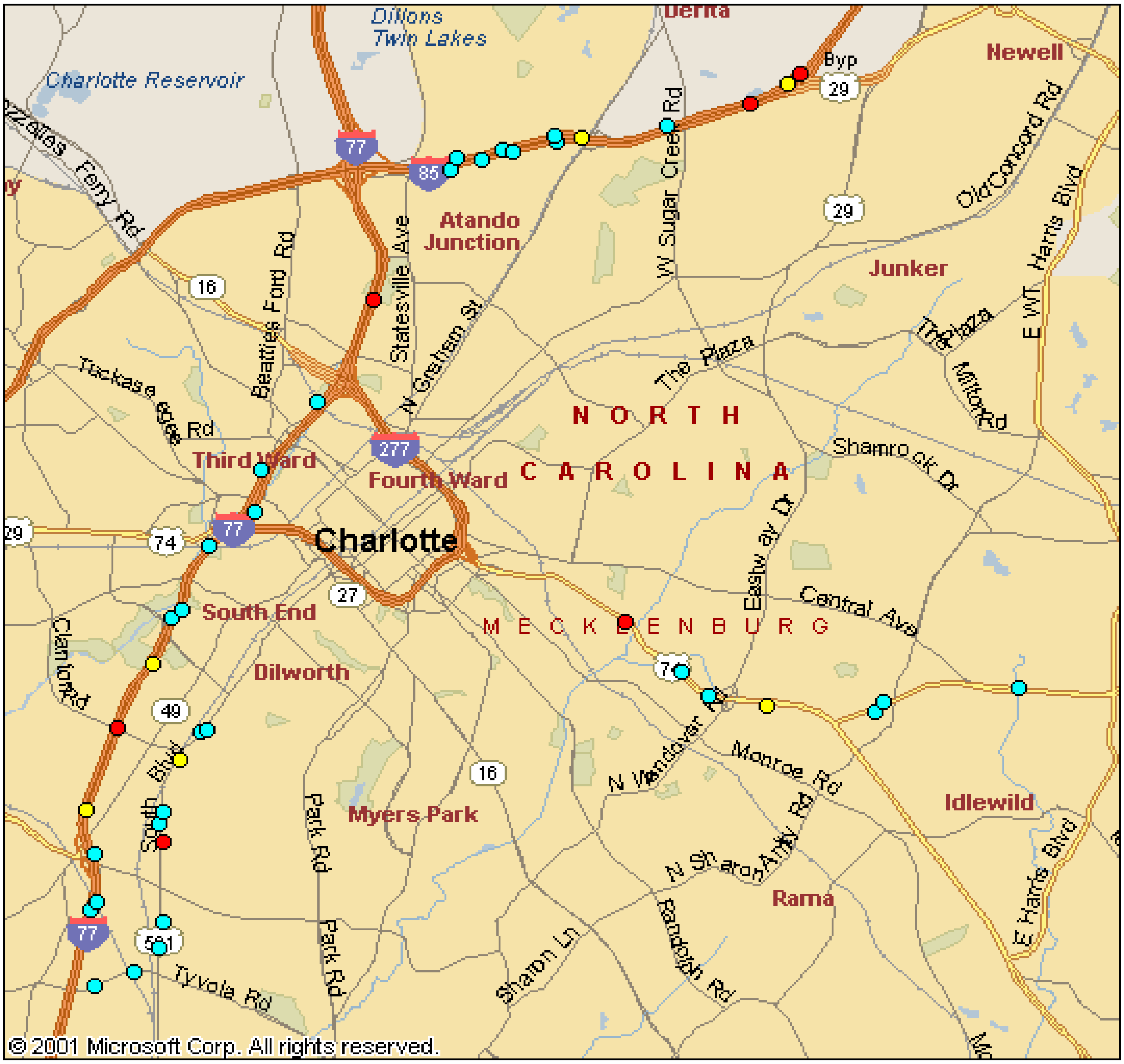

Figure 2. Map Illustrating Billboards (aqua blue), Comparison Sites (yellow), and Baseline Sites (red).

Dependent Variables

The dependent variables are discussed in more detail in the results section, but they are reviewed briefly here. The purpose of the study was to determine if there are changes in driver behavior in the presence of billboards. Eleven dependent measures were used as indicators of driver behavior: nine eyeglance measures and two driving performance measures. The nine eyeglance measures included: total number of glances for center forward, left forward, and right forward; total glance duration for center forward, left forward, and right forward; and average glance duration for center forward, left forward, and right forward. Keep in mind that all glance locations reported here were out of the front windshield, but varied in location within the forward view. The two driving performance measures were speed deviation and lane deviation. Additional analyses examined driver glance behavior to certain other locations, including interior locations and exterior locations other than forward. The next section lays the groundwork for the selection of these dependent variables, which are similar to those typically used in transportation safety research.

Selection of Dependent Variables Based on Previous Driving Studies

Measures of Visual Demand

According to Farber, Blanco, Foley, Curry, Greenburg, and Serafin (2000), typical measures of visual demand include: (1) glance frequency, (2) glance duration, (3) average duration per glance, and (4) total eyes-off-road time; such measures are time-consuming to record and analyze but are typically used as forms of visual distraction measures. For example, driving research has been conducted on the performance of completing in-car tasks such as adjusting the radio, viewing in-car displays (e.g., speedometer) or interacting with a navigation system (Dingus, Antin, Hulse, & Wierwille, 1988; Gellatly & Kleiss, 2000; Kurokawa & Wierwille, 1990; Tijerina, Palmer, & Goodman, 1999). Visual glance duration and the number of glances per task were investigated while performing conventional in-vehicle tasks and navigation tasks (Wierwille, Antin, Dingus, & Hulse, 1988). Findings indicated that glance frequency varied depending upon the task, and that glance duration for a single glance ranged from 0.62 s to 1.63 s. The mean number of glances across all tasks was between 1.26 and 6.52 glances. Zwahlen, Adams, and DeBald (1988) reported that “out of view” glance times (rear view mirror, speedometer, etc.) ranged from 0.5 s to 2.0 s during straight driving. Another example was an experiment by Parkes, Ward, and Vaughan (2001) who measured glance frequency, glance duration, and average duration per glance to evaluate two in-vehicle audio systems, in terms of total “eyes off road” time.

Mirror Glance Duration

Based on available literature discussed in this section, mirror glance times range from 0.8 s to 1.6 s (M = 1.1 s). Searches to the rear (blind spot) appeared to require a minimum value of 0.8 s. Nagata and Kuriyama (1985) investigated the influence of driver glance behavior in obtaining information through door and fender mirror systems. For door mirror systems, they reported that the average glance duration to the near-side (i.e., right side in this case) mirror was 0.69 s. Rockwell (1988) reported that the average glance duration to the left mirror was 1.10 s (SD = 0.33 s). This finding was consistent across different participants in three different experiments over a six-year period using the same data gathering and reduction technique. Taoka (1990) modeled eye glance distributions of Rockwell and found they could be well represented by means of a lognormal distribution. Taoka reported that the average time for viewing the left-side mirror was also 1.10s (SD = 0.3 s). The 5th percentile value was 0.68 s and the 95th percentile was 1.65 s. For right side mirror glances, Nagata and Kuriyama (1985) reported that average glance duration for the far-side mirror was 1.38 s (angle difference from the vertical axis of 70 degrees), while Rockwell reported an average glance duration of 1.21 s (10% larger than left glances), with an approximate standard deviation of 0.36 s. For the rear view mirror, Taoka (1990) reported that the average glance time was 0.75 s (SD = 0.36 s). The 5th percentile value was 0.32 s and the 95th percentile was 1.43 s.

Search and Scan Patterns

Early research included the investigation of visual search and scan patterns while driving (Mourant, Rockwell, & Rackoff, 1969; Mourant & Rockwell, 1970; 1972). It was found that as drivers became familiar with a route, they spent more time looking ahead, they confined their sampling to a smaller area ahead, and they were better able to detect potential traffic threats (e.g., movement in the periphery). Mourant and Rockwell (1970) found that peripheral vision was used to monitor other vehicles and lane line markers, that novice and experienced drivers differed in their visual acquisition process, and that novice drivers may be considered to drive less safely.

A recent field study investigated the influence of fatigue on critical incidents involving local short haul truck drivers (Hanowski et al., 2000). Fatigued drivers involved in critical incidents when making lane changes spent more time looking in irrelevant locations (i.e., locations other than out-the-windshield, out-the-windows, at the mirrors, or at the instrument panel). The mean proportion of time spent looking at irrelevant locations was 0.08. However, during normal lane changes (not a critical event), the mean proportion of time that drivers spent looking at irrelevant locations was 0.03, a significant difference. In terms of eye behavior, it appears that fatigued drivers involved in critical incidents pay less attention to relevant locations such as the road ahead and appropriate mirrors.

Velocity

Velocity (traveling speed) has been used as a measure of driving performance for several decades. For example, Brown, Tickner, and Simmonds (1969) found that driving while telephoning had a 6.6% reduction in speed as compared to driving alone, in an early closed-circuit driving experiment. They also concluded that telephoning while driving may impair perception and decision-making skills. More recently Alm and Nilsson (1994) concluded that a mobile telephone task while driving led to a reduction in speed level. In another effort, Tijerina, Kiger, Rockwell, and Tornow (1995) assessed driver workload for commercial vehicle operators in conjunction with using an in-vehicle device. Various measures were monitored including speed variance, which was highest for activities involving radio tuning and 10-digit cell-phone dialing tasks. Another study monitored speed for a driving study involving talking on a cell phone or talking to a passenger (Waugh, Glumm, Kilduff, Tauson, Smyth, & Pillalamarri, 2000). Results indicated that driving speeds were lower when talking on the phone as compared to talking to the passenger.

Lateral Position

Lateral lane position or deviation is one of the most common measures of driver performance and distraction (Salvucci, 2002). Lane position can be measured in terms of lane exceedances (i.e., drift across the line between the current lane and the next lane) or in the absence of actual lane crossings, lateral position in terms of distance from the center of the lane or the side lane line markings. Various researchers have used lateral position. For example, Serafin, Wen, Paelke, and Green (1993) conducted an experiment involving a driving simulator and car phone tasks. Greater lane deviation was observed for dialing while driving as compared to tasks involving listening, talking, or mental processing. In another study, Alm and Nilsson (1994) reported that for difficult driving tasks, a mobile telephone task had an effect on the drivers' lateral position during various 500 meter driving segments. Results indicated that the mobile-telephone task made drivers drive closer to the right lane line, especially for complex tracking tasks. In another study, Tijerina, Kiger, Rockwell, and Tornow (1995) evaluated various measures including lane position variance and lane exceedances. They concluded that lane keeping was degraded when performing message reading tasks.

Participants

Thirty-six participants who were familiar with the Charlotte, North Carolina freeway system and downtown area were recruited. Participants were recruited via newspaper advertisement (Figure 3) and flyers. Participant selection was determined after a telephone screening and selection process. All participants were between the ages of 18 and 73, with equal gender representation (18 female, 18 male). Figure 4 illustrates an example of a participant (actually an experimenter) seated in the experimental vehicle.

```
Car Drvrs Wanted 4 Study:
18-35 or 50-75 yrs old, 2 hrs
@$20/hr: 800-XXX-XXXX or
firstname.lastname@vt.edu
```

Figure 3. Example of 4-line Straight-Text Newspaper Advertisement.

Figure 4. Participant Seated in Experimental Vehicle.

Route and Equipment

Route

The pre-planned loop route was approximately 35 miles long and consisted of sections on Interstates 77 and 85, as well as surface streets through downtown Charlotte, NC and extending into more rural/suburban areas. Prior to collecting any data, experimenters from the Virginia Tech Transportation Institute (VTTI) visited the area several times in order to determine the final route by verifying the presence of suitable billboards. A potential 65-mile route was originally recommended by associates from Adams Outdoor Advertising, a local company located in Charlotte, North Carolina. After personal examination of the suggested route, the final 35-mile route was selected so that it could be completed in a timely manner, while still allowing participants to be exposed to a mixture of interstate, downtown, and residential road segments. This loop contained a variety of billboards and other outdoor advertisements (e.g., on-premise signs, logo placards) as well as standard DOT roadway signs. Adams Outdoor Advertising also provided GPS locations for each billboard of interest. Figure 5 illustrates the final route used for data collection. Table 4 lists the directions used for the experiment. The directions were mounted on the dashboard as illustrated by Figure 6.

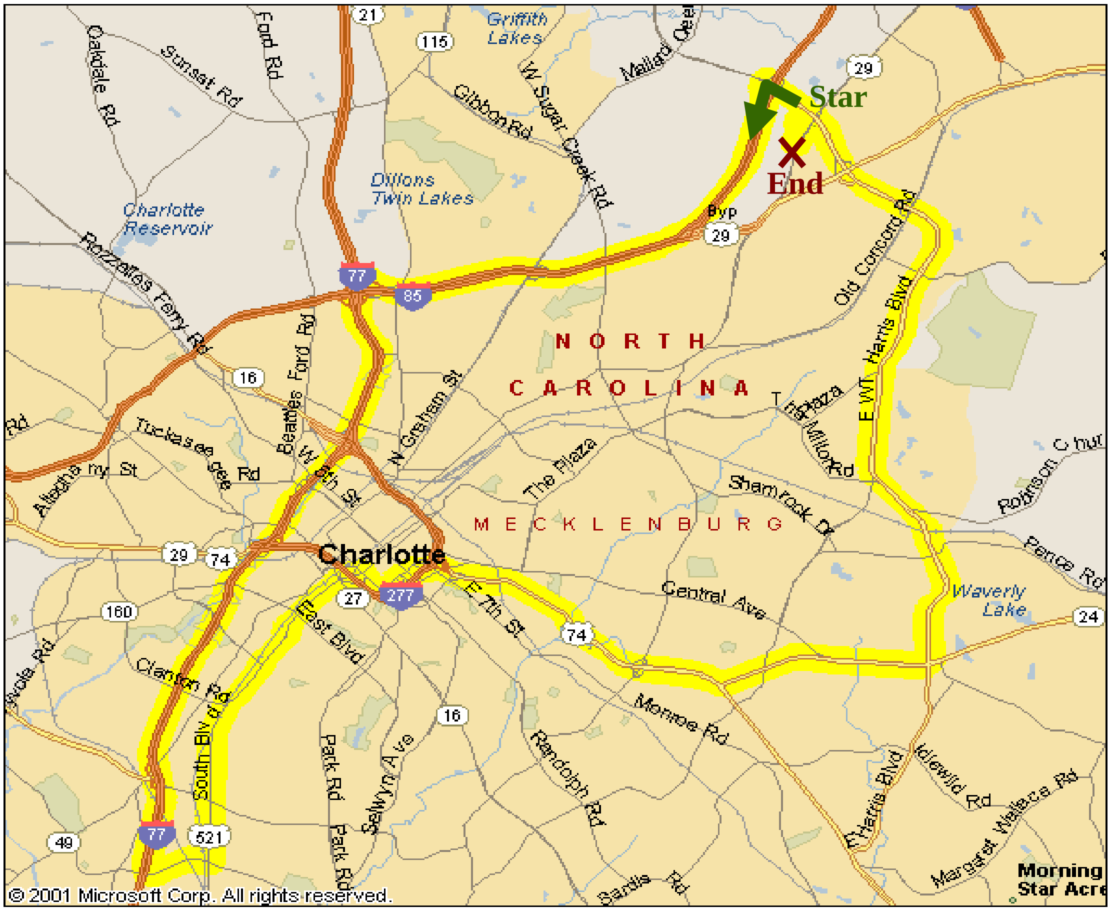

Figure 5. Map of 35-mile Loop Route in Charlotte, North Carolina.

Table 4. Directions for 35-mile Loop Route in Charlotte, North Carolina

Directions	Distance	Notes
Take W.T. Harris Blvd to I-85 SOUTH (LEFT LANE)	0.5 miles	STAY LEFT
Take I-85 to I-77 SOUTH	5.3 mi.	
Take I-77 to Tyvola Rd. (Exit 5)	8.6 mi.	
Go LEFT onto Tyvola Rd. to South Blvd.	0.8 mi.	
Go LEFT onto South Blvd to Stonewall St.	4.5 mi.	Go under 277
Go RIGHT onto Stonewall St. to McDowell St	0.4 mi.	
Go LEFT onto McDowell St. to 5th St.	0.4 mi.	
Go RIGHT onto 5th St.		Past Trade St.
5th St. turns into Independence Blvd (Highway 74/27)	0.3 mi.	
Take Independence Blvd to Albemarle Rd.	3.9 mi.	
Go LEFT onto Albemarle Rd/24/27 to W.T. Harris	2.5 mi.	1st light past Varnadore (large white bldg on left)
Go LEFT onto W.T. Harris Blvd to Tryon St.	8.1 mi	Past University City Blvd
Go LEFT onto Tryon St. to Residence Inn Hotel	350 yards	On RIGHT side

Figure 6. Directions Mounted on Dashboard of Vehicle.

Practice Route. A short, 1-mile practice route was also included. This route was driven prior to data collection on the 35-mile loop route. During the practice route, the experimenter rode as a passenger with the participant to make sure that the participant was familiar with the directions and the vehicle's displays and controls. Figure 7 illustrates the practice route used for data collection and Table 5 lists the directions.

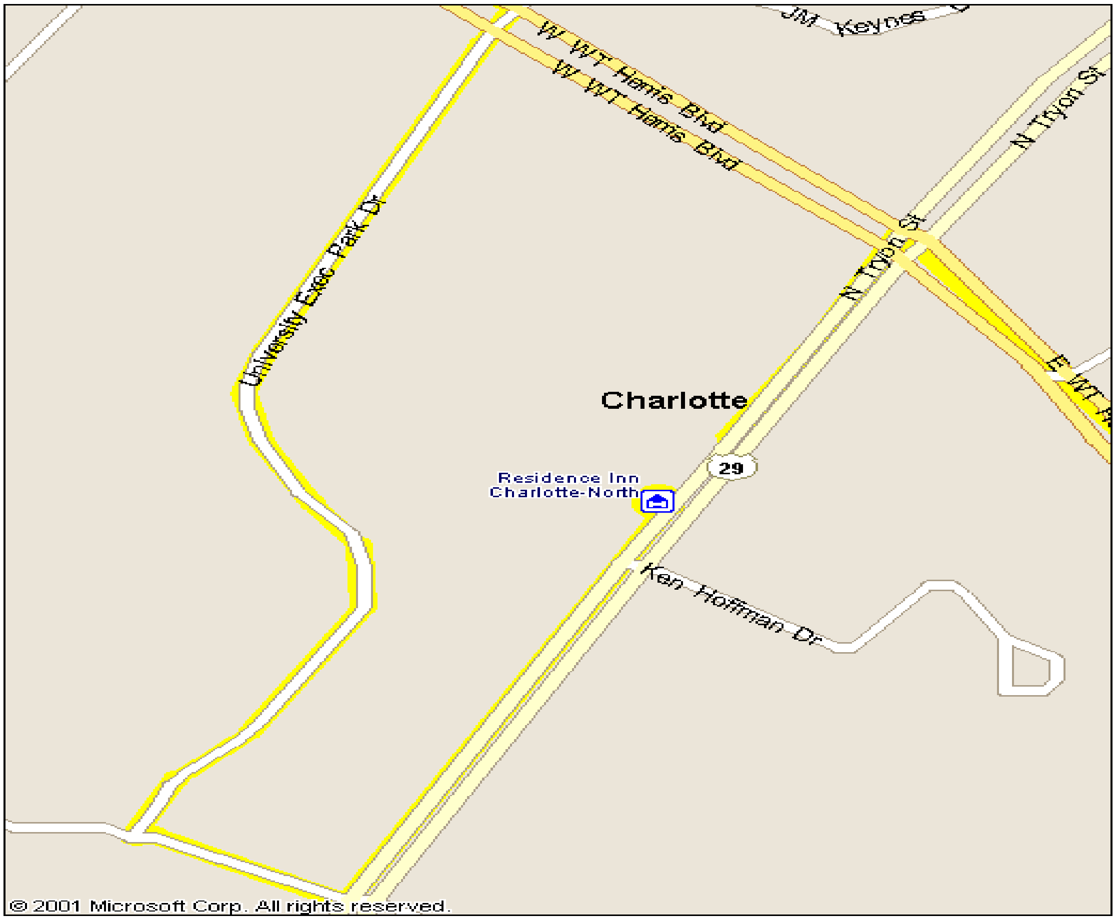

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Figure 7. Map of Practice Loop in Charlotte, North Carolina.

Table 5. Directions for 1-mile Practice Route in Charlotte, North Carolina.

Directions	**Distance**	**Notes**
Turn right onto the North Tryon Street		
Go to McCullough and turn RIGHT	350 yards	
Go to University Exec Park Dr. and turn RIGHT	125 yards	
Go to W.T. Harris Blvd. and go through light	0.5 miles	

Vehicle

A 2002 Chevrolet Malibu was used in this study and is shown in Figure 8. The vehicle had an automatic transmission, an adjustable steering wheel, and other standard features.

Figure 8. Experimental Vehicle, 2002 Chevrolet Malibu.

Data Collection System

The vehicle was instrumented with a data collection system, including cameras, a computer, and sensors that continuously collected data. The system was activated approximately 2 minutes after the ignition was turned on and was deactivated when the driver turned it off. A video system with four cameras was used. Two cameras were mounted on the back side of the rear-view mirror--one facing forward left and the other facing forward right (Figure 9). This captured the forward views of the roadway as well as the sides where billboards and other objects were visible. The other two cameras captured the driver's face from two perspectives. One camera was mounted on the top left corner of the windshield near the A-pillar (Figure 10). The other camera was mounted just above rear view mirror (Figure 11). Both faced the driver and captured head and eye movements. Figure 12 depicts these camera views. Since data reductionists needed to review all four video channels simultaneously, a quad-splitter was used to fuse the images. This produced a single, compartmentalized image such that each camera was presented in one of four locations (Figure 13). The quad splitter, computer, monitor, and keyboard were located in the trunk of the vehicle as shown in Figure 12. Finally, Figure 14 illustrates these components and how they interacted with sensors.

Figure 9. Forward Facing Cameras Mounted Behind the Center Rear View Mirror.

Figure 10. Driver Face Camera, Mounted on the Top Left Corner of the Windshield near the A-Pillar.

Figure 11. Driver Face Camera Mounted Above Rear View Mirror.

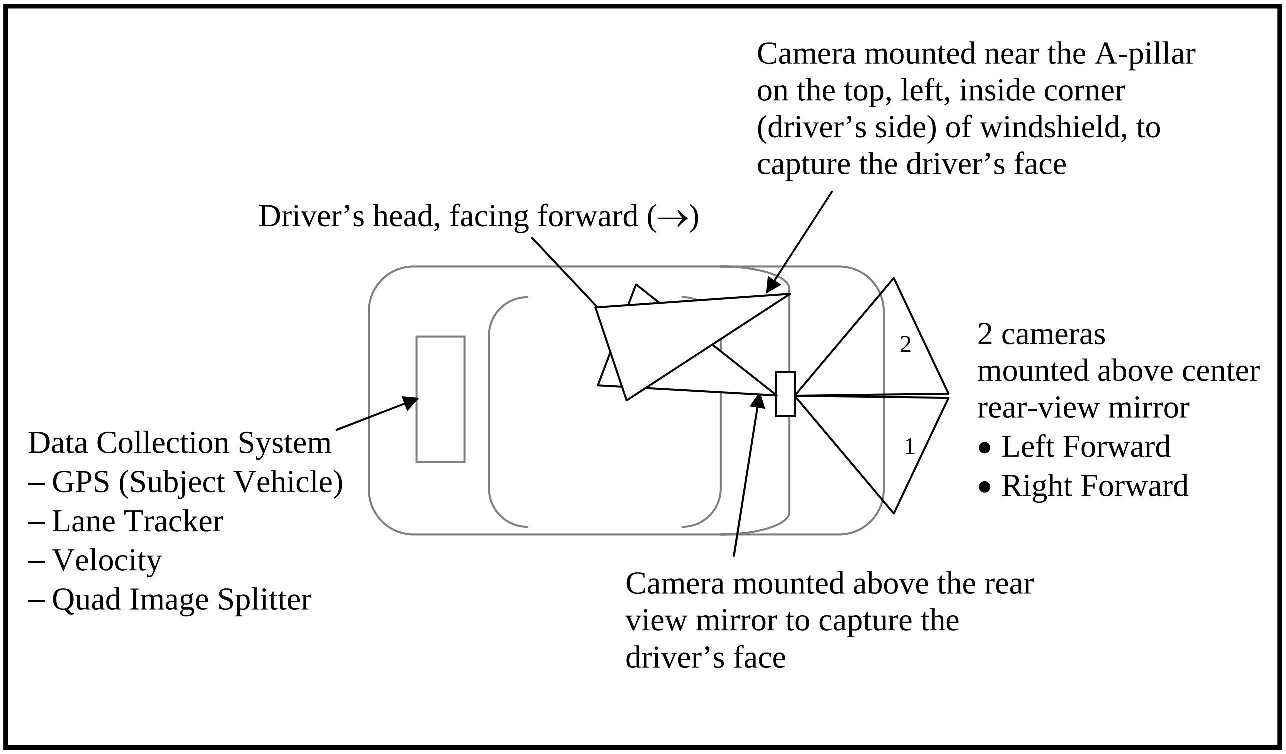


Figure 12. The four camera views recorded in the instrumented vehicle: (1) right forward view, (2) left forward view, (3) right side of driver's face, (4) left side of driver's face, and Data Collection System.

Left Forward View	Right Forward View
Driver's Face, Left Side	Driver's Face, Right Side

Figure 13. Diagram of Simultaneous Presentation of Four Camera Views.

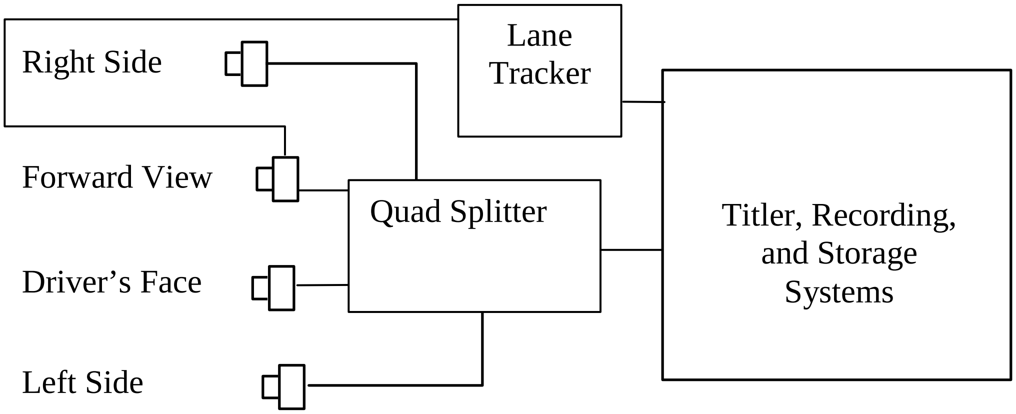


Figure 14. Components of the Data Collection System.

All video data were recorded at 30 Hz (30 frames per second), using MPEG 1 compression algorithms at a rate of 4 MB per minute. Driving performance data, including lane position and velocity, were collected at 10 Hz (10 times per second). The lane tracking system used fuzzy logic and statistical probabilities to detect lane edges in the forward camera view. Lane position was collected with a resolution of ±2 inches from the center of the lane. Raw performance data, including lane position, velocity, and video data, were saved on the hard drive of a laptop computer and then backed up onto individual CD ROMs for each participant. After each trial, the experimenter reviewed the data to assure that the data collection system performed to specification.

Procedure

Participant Recruitment and Screening

Straight-text newspaper advertisements were placed in the *Charlotte Observer* (Figure 3) and flyers were posted in strategic locations in Charlotte, North Carolina to solicit volunteer participants for the study. Respondents were instructed to contact the experimenter via email or by telephone. A telephone/email screening form (Appendix A) was used to collect general information on age, gender, medical, and driving history, familiarity with the route(s), and use of corrective lenses or sunglasses. A list of potential participants was compiled as screenings were completed, and participants who met all of the required criteria were then contacted to set up an appointment for participation. The participant met the experimenter on the appropriate date and time in the hotel lobby of the Residence Inn on North Tryon Street, in Charlotte, North Carolina.

Experimental Protocol

Upon arrival, each participant presented a valid driver’s license for the experimenter’s inspection. Each participant then completed a health screening questionnaire, an informed consent form (Appendix B), and payment forms. Participants then received an orientation (including the practice route), drove the 35-mile experimental route, completed a post-drive questionnaire (Appendix C), and received $20/hour for their time. Most participants completed the experiment in 2 hours. All procedures for recruitment and data collection were approved by the Virginia Tech Institutional Review Board, as required by federal and state law.

Before testing began, four pilot participants were recruited to test the route directions and provide additional feedback as a final check of the route and experimental set-up. For the first two pilot participants, the experimenter accompanied the participant by sitting in either the front passenger seat or in the rear seat. The second two pilot drivers completed the entire experiment without an experimenter in the vehicle, in order to simulate actual data-collection conditions.

A total of 38 drivers were recruited for the full experiment. One of the older drivers chose not to participate after completing the orientation because he was uncomfortable with freeway driving. Another participant completed the experiment, but the data were not used because it rained during most of the session. Of the 36 drivers who completed the experiment, three repeated the experiment on a later date due to rain or heat-related equipment problems (which were later resolved). That is, their initial data were not used and were replaced with the second driving session.

The order in which participants took part in the experiment was counterbalanced for age and gender to the degree possible, as illustrated by Table 6. This was done to eliminate any effects of unusual traffic or road construction conditions across participants. For example, if all of the older females had participated at the beginning of the study, and there had been some unusual conditions during that time, the data for these participants might differ from that of other participants.

Table 6. Counterbalancing of the Participants' Order of Participation (Age by Gender).

	Gender	
Age	**Male**	**Female**
Younger	M1	F1
Older	M10	F10
Younger	M2	F2
Older	M11	F11
Younger	M3	F3
Older	M12	F12
Younger	M4	F4
Older	M13	F13
Younger	M5	F5
Older	M14	F14
Younger	M6	F6
Older	M15	F15
Younger	M7	F7
Older	M16	F16
Younger	M8	F8
Older	M17	F17
Younger	M9	F9
Older	M18	F18

The informed consent form explained the general purpose of the experiment to the driver and obtained his/her permission to participate in the study. After the required paperwork was completed, the following script describing the experiment was read aloud to the participant:

> Today we will have you drive a pre-determined loop route along major freeways and highways. The vehicle that you will be operating is specially equipped with instruments that collect information about your driving habits. The purpose of this study is to collect information about the way people drive under normal circumstances, in order to improve driver safety. We want you to drive as you would if you were in your own vehicle and were driving, for example, to visit a friend, do an errand, or go to work. With this in mind, we will also want you to obey all typical traffic regulations as you normally would, including, but not limited to, posted speed limits, lane markings, and traffic control devices (such as stoplights).
>
> I will be riding in the passenger seat during a 5-minute orientation drive. You are welcome to ask questions if necessary, as this orientation will help you become familiar with the vehicle and its controls. As always, our first priority is your safety. If at any time you feel uncomfortable please inform me and we can make any necessary adjustments or end the study early.

> After the 5-minute orientation, I will exit the vehicle and have you drive the pre-determined route, which will bring you back to this location. This route will take about 1.5 hours. A map and written instructions will be provided for your reference, and I will also review the route with you before you depart. After the route is completed, I will debrief you and the session will be complete.
>
> Do you have any questions I can answer at this time?

The experimenter then reviewed the map (Figure 5) and directions (Table 4) in detail. A laminated copy of the map was stored in the glove compartment for easy reference. A laminated copy of the directions was prominently displayed on the dashboard (Figure 6). A cellular telephone was also stored in the glove compartment for emergency use only.

The experimenter then oriented the participant to the vehicle, including adjustment of the seat, seat belt, mirrors, and steering wheel. Displays and controls were also reviewed, including a review of the map, directions, and cell phone operation instructions. The participant then drove the 5-minute orientation route, with verbal reminders provided by the experimenter when required. After the orientation route was completed, the experimenter checked the data, reminded the participant to drive as they normally would, and then returned to the hotel. The participant drove the 35-mile loop route, which eventually brought them back to the hotel.

After the experiment, in-vehicle eyeglance calibration was completed in the hotel parking lot. With the vehicle parked, the experimenter sat in the passenger seat and provided verbal instructions. The protocol included having the participant sit as if driving, while alternating 3-second glances to various locations with a default forward glance location. The glances included left blind spot, left window, left mirror, left forward, forward, right forward, right mirror, right window, right blind spot, rear view mirror, instrument panel (speedometer), and climate and radio controls.

After the eyeglance calibration, the participant and the experimenter returned to the hotel lobby, where the post-drive questionnaire was completed (Appendix C). The experimenter then reviewed the questionnaire to make sure that all of the answers were legible. Item #3, “Please check the top five items that most caught your attention during your drive,” included a “Billboards” option (among a list of 18 possible items). If the experimenter noticed that “Billboards” had been marked, he asked about every checked item in an attempt to discover the details as to what caught their attention. For the billboard item specifically, the experimenter noted what aspect of the billboard caught the participant’s attention, without conveying the importance of that particular topic. Payment was then issued to the driver at a rate of $20 per hour, (2 hours in most cases, for a total of $40) and a payment log was signed to verify that funds were received. At no time was the participant made aware that this experiment was related to driving behavior regarding billboards or other roadside items.

Data for each participant were briefly reviewed to verify that all the cameras were operating correctly and that data had been recorded. Data and video files were then transferred from the data collection system's computer to a portable laptop computer. Each participant's data were copied onto a separate CD ROM as a second back-up measure. The results from the post-drive questionnaire were then entered into an Excel spreadsheet for later processing.

Data Reduction

Analyst Training

Four data analysts worked on this project under the supervision of the principal investigator. All analysts were experienced in video data reduction prior to this project. Training began with a 2-hour session in which the user manual was reviewed and the analysis software was demonstrated by the experimenter. Relevant functions were shown, and the process of how to load the map and associated GPS coordinates was explained. Prior to actual data analysis, each analyst spent an additional eight hours mastering eyeglance direction determination and spreadsheet use. This period included time with an experienced analyst present. A large part of that time was dedicated to establishing inter-analyst reliability by comparing judgments and modifying techniques until all analysts' independent determinations matched. Throughout the entire analysis effort, at least one experienced analyst was available at all times to answer any questions or review particular cases as needed. "Spot checks" were performed throughout the data reduction process, with input provided as needed to maintain a high level of consistency. Robust reliability was further assured by ascertaining that each analyst recorded a portion of the data from each participant (i.e., a portion of the data for each of the 36 participants was analyzed by each analyst). As a rule, no more than 50% of the data for any participant was analyzed by a single analyst. As events were completed, a written record was created with the analyst's initials and date of completion.

Software

This section outlines the data reduction software program developed to analyze billboard, comparison, and baseline events. The software, called the 100-Car Analyzer or HundredCarLite, was originally developed by software engineers at the Virginia Tech Transportation Institute for a large-scale naturalistic driving study known as the 100 Car Study (Neale, Klauer, Dingus, Holbrook, & Peterson, 2001). This program integrates Microsoft MapPoint 2003 using GPS data for billboard, comparison, and baseline site locations with the data obtained from the multiple sensors in the test vehicle via a graphical interface. A total of 36 files (representing the route driven for each participant) were analyzed. After a file was opened, the software presented the analyst with the relevant windows required for data identification and reduction. The MapPoint application allowed the analyst to view a map of the Charlotte, NC area, showing the relationship between the site and the roads, so that video could be compared with GPS data during site identification and eyeglance analysis. The map illustrated the route and the location of the vehicle, which was represented by a green vehicle icon that moved as the event was played. This map served solely as a visual display and could not be manipulated. The analyst training manual (Appendix D) provides more detail on the methods used by the data analysts, including screen captures of the software program.

The vehicle video and data files were manipulated with the windows displaying a basic map called MapPlotForm. This represented the GPS data, showing the complete path of the vehicle, and allowed the represented data to be selected by means of GPS coordinates. This window also allowed for the analyst to move the vehicle along the route simply by a drag-and-drop action.

The VideoForm window showed four channels of video (Figure 13). Starting from the upper-left corner of Figure 13, the four channels were: (i) left forward view, (ii) right forward view, (iii) drivers' left face view, and (iv) drivers' right face view. This video was reviewed in conjunction with the GPS data in order to identify and analyze events. In addition, analysts referred to the video while performing the eyeglance analysis. The VideoForm window showed digital video corresponding to the same tenth of a second in time as the other data being examined (in other words, the video and other data were synchronized with a common time stamp). The video and matching data files could be changed one sync number (i.e., one tenth of a second) at a time, at a real-time play speed, in fast forward, or fast reverse via the VideoForm controls.

When the video was changing, HundredCarLite fed the continually updated vehicle GPS coordinates into the MapPoint software. A small moving vehicle icon used the changing coordinates to trace the appropriate path on a map of Charlotte.

Microsoft Excel was used to enter data as the analysts reviewed each event. Each participant had a workbook with 10 worksheets--three for site identification, six for eye glance analysis, and one summary sheet for that participant's complete set of results. The summary data from each participant was amassed via a separate workbook and put into a format compatible with the statistical analysis software.

Procedure

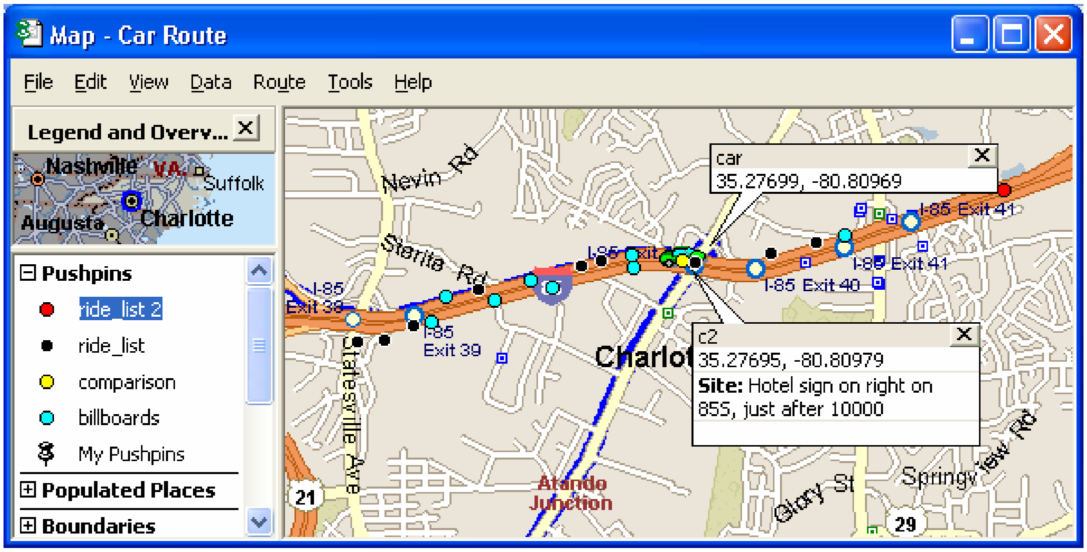
Data reduction was performed by the four analysts for each of the 36 data files. This occurred in three steps: software preparation, event identification, and eyeglance analysis. A detailed procedural instruction manual outlining each step was prepared for analyst training purposes (see Appendix D).

Software Preparation

The analyst used HundredCarLite to open the video and data files for the participant being analyzed. Once the files were completely loaded, the option to open a MapPoint display of Charlotte became available. After opening MapPoint, the analyst imported data so that every site to be identified would appear as a colored dot. Billboards in the same vicinity that were not analyzed were also displayed (as black dots) for reference to facilitate proper board identification. The site colors were labeled by category as either billboard, comparison, baseline, or other. The appropriate Excel spreadsheet for that participant was also opened.

Event Identification

The analyst used the MapPlot window of HundredCarLite to locate the vehicle icon in the immediate vicinity of the site's dot in MapPoint. The end of an event was defined as the sync number at which the test vehicle passed the site, and the event's beginning was calculated to be at seven seconds before the end point. Identification of the end point combined two methods: the GPS data was used to align the vehicle directly in conjunction with the site, and then the video was used to visually confirm accurate GPS positioning (Figure 15)



car
35.27699, -80.80969

c2
35.27695, -80.80979
Site: Hotel sign on right on 85S, just after 10000

Figure 15. MapPoint Map Showing Vehicle Icon Centered on Comparison Site (#c2) in Preparation for Event Identification.

Eyeglance Analysis

The first step in eyeglance analysis was familiarization with the participant's individual glance patterns by means of an glance location calibration video, during which participants looked at specific places according to a set script. As described in the procedures section, eye calibration was conducted *after* data collection was complete, in order to serve as a record of where drivers typically look. Analysts reviewed these records so that they could become familiar with the participant's particular glance style. The analyst was thus able to conduct the glance analysis according to each participant's particular glance styles. Glances were coded according to the following abbreviations:

F - Forward
RF - Right Forward
LF - Left Forward
RVM - Rear View Mirror
OX - Outer eXterior, including side mirrors, side windows, blind spot etc.
DIR – glances toward the experimental route DIRections
OINT - Other INTerior, including speedometer, sun visor, cell phone etc.

Analysts reviewed events from beginning to end, one tenth of a second at a time, determining the direction of glance for every 10th of a second for the seven-second duration of the event. New glances were recorded as the sync number at which the participant's glance *rested* in a new location. Transition time to the new location was included in the glance location the driver was moving *away* from. Spreadsheets automatically calculated the duration of each glance. Summary information for each event included the number of glances, average glance duration, number of glances in each direction, and the average duration of glances in each direction.

Final Reduced Data Set

With 36 participants and 42 sites, there were 1,512 events available for analysis from approximately 54 hours of data collection. A small amount of data was lost due to sensor outages, sun angle, and lane changes, leaving 1,481 events for eyeglance analysis and 1,394 events for speed and lane position analysis. Altogether, 103,670 video frames were analyzed and 10,895 glances were identified. There were 97,580 data points in the speed and lane position data set.

Statistical Analysis

Descriptive statistics were calculated using an Excel spreadsheet and the Pivot Table tool. All other statistical analyses were conducted using SAS statistical software. The analysis of variance (ANOVA) statistical technique was used; in SAS this was accomplished by means of the general linear model (GLM) procedure. Where significant differences were found, and there were more than two levels of the independent variable, a post-hoc analysis was run using the Least Squares Difference procedure in SAS to determine which levels were significantly different from which other levels. (For independent variables with just two levels that differ significantly, a simple examination of the means will demonstrate which level is significantly greater than the other.)

RESULTS

Post-Drive Questionnaire

The post-drive questionnaire (Appendix C) was completed after the route was driven. It gathered information such as route familiarity and items noticed while driving; it also collected demographic and personal information, including education level, marital status, ethnicity, and income. The questionnaire was designed by VTTI driving researchers, with input from OAAA representatives. It was also reviewed by Dr. Charles R. Taylor, Professor of Marketing at Villanova University in Pennsylvania, who has worked extensively with surveys and is considered an expert in the marketing and data collection field.

Demographics Overview

In terms of demographics, the average age was 25 years for younger drivers and 56 years for older drivers. The sample of drivers was quite diverse in terms of education level, marital status, ethnicity, and income. Most drivers lived or worked in Charlotte, North Carolina and were familiar with most of the route. The following sections provide details for relevant information about the sample of drivers. Table 7 presents these findings as well.

Age

The sample of 36 drivers ranged in age from 18 to 73 years old. The mean age of all participants was 40.5 years (*SD* = 17.2). The younger drivers ranged in age from 18 to 33 years old, with a mean of 24.6 years (*SD* = 4.7). The older drivers ranged in age from 50 to 73 years old, with a mean of 56.3 years (*SD* = 7.3).

Education Level

Participants were surveyed regarding the highest education level they had completed. The number of responses and equivalent number of years were used to calculate the product. This was used to calculate the mean education level for the sample by dividing the total number of years completed by the number of participants (500/36). The average was 13.9 years of education completed (equivalent to high school plus two years of college).

Marital Status

Most drivers were either single or married, while 14% of participants reported they were divorced and 8% (all older females) reported that they were widowed.

Ethnicity

Participants came from a variety of ethnicities. Over 60% were European (Caucasian). Almost 40% of drivers were of African American, Native American, or Multi-racial background.

Income

Of the 35 participants who reported their annual household incomes on the questionnaire, the largest number (15 participants or 43%) were in the $25,000 to $49,000 range.

Table 7. Summary of Demographic Results.

CATEGORY	**LEVELS**				
Age (mean)	**Younger Drivers**	**Older Drivers**	**All Drivers**		
	24.6 years	56.3 years	40.5 years		
Education Level	**Jr. High**	**High Sch.**	**2-Yr Deg.**	**B.A./B.S.**	**M.A./M.S.**
	3%	39%	25%	25%	8%
Marital Status	**Single**	**Married**	**Divorced**	**Widowed**	
	39%	39%	14%	8%	
Ethnicity	**European**	**African-American**	**Native American**	**Multi-Racial**	
	61%	17%	14%	8%	
Income Level	**$0-24K**	**$25-49K**	**$50-74K**	**$75-99K**	
	29%	43%	23%	6%	

Route Familiarity

Route familiarity was assessed by three items in the questionnaire. Specific topics addressed were: location of work, location of home, and frequency of driving on roads in the experimental route (defined as familiarity). Table 8 presents the route familiarity findings.

<u>Living and Working Location.</u> All drivers reported that they were familiar with the Charlotte, North Carolina area and had driven on the interstates and surface roads included in the route. Over 70% of drivers reported that they lived and worked in Charlotte, North Carolina. Two drivers (6%) reported that, although they were familiar with Charlotte, they no longer lived or worked in the area.

<u>Familiarity.</u> Route familiarity was also evaluated in terms of 6 route segments that represented various types of driving (i.e., interstate vs. downtown Charlotte). Drivers were asked to indicate if they were either “familiar” (driven at least once a week) or “not familiar” (driven less than one time a week) with each segment. In some cases, participants inquired about this question item, indicating (verbally) that, although they were quite familiar with certain areas, they may not drive on them every week. Nonetheless, the results indicated that overall, drivers were familiar with the route, particularly Independence Boulevard which was a major roadway segment (81% were familiar with this segment).

Table 8. Route Familiarity Data – Percentage Reported.

Route Familiarity	72% work & live in Charlotte	11% work in Charlotte, live elsewhere	11% live in Charlotte, work elsewhere	6% work & live elsewhere		
Route Segment	69% familiar with I-85 section	64% familiar with I-77 section	61% familiar with Tyvola Rd, South Blvd., and downtown	81% familiar with Independence Blvd. (74/27) section	44% familiar with Albemarle Road (24/27) section	69% familiar with Harris Blvd. section

Overview of What Drivers Noticed

Drivers primarily noticed items such as traffic and other drivers, road or highway signs, and construction taking place along the road. Nine of 36 drivers (25%) marked “billboards” as one of the top five items (out of 18 items) that caught their attention during the drive. Two drivers mentioned specific billboards that they remembered. Aggressive driving seemed to be the most prevalent comment regarding other drivers. Participants engaged in a variety of activities while driving--listening to the radio or CD player and using the cell phone were the most prevalent. At no point was it apparent that any participant knew the specific purpose of the study; all responses indicated that drivers believed the study was related to observing drivers in a natural driving situation, which was also true. The following sub-sections describe findings in more detail, with tables illustrating drivers’ responses.

Attention Getters. Participants were asked to indicate “the top five items that most caught your attention during your drive.” Over 50% of drivers indicated that they paid attention to traffic, other drivers, road signs, and highway signs. For those drivers that indicated “billboard” as one of the items that caught their attention, the experimenter asked them to verbally expand upon all items. For billboards in particular, five drivers made noteworthy comments. A female driver indicated that she “just notices them in general.” One male driver indicated that he worked in marketing and had a habit of viewing all billboards. Comments were made by two female drivers in reference to “gentlemen’s club” billboards. One of these same participants said that they noticed “the woman in a suit getting out of a swimming pool.” Another female driver indicated that she paid particular attention to billboards that were for gas stations or restaurants. Table 9 lists the number of responses and the percentage of drivers marking each item for this item on the questionnaire.

Table 9. Items That Caught Attention during Route: Number of Responses and Percent of Drivers Marking Item.

Questionnaire Item	Number of Responses	Percent of Drivers
Traffic	31	86.1%
Other Drivers	24	66.7%
Road Signs	21	58.3%
Highway Signs	18	50.0%
Construction	16	44.4%
Landmarks	15	41.7%
Landscaping	12	33.3%
Buildings	10	27.8%
Billboards	9	25.0%
Emergency Vehicles	8	22.2%
Gas Stations	7	19.4%
Restaurants	6	16.7%
Apartments/housing	5	13.9%
Motels/Hotels	3	8.3%
Pedestrians	1	2.8%
Walls	1	2.8%
Total	**187**	

Most Memorable. Participants were asked “What was most memorable about the drive?” This was an open-ended question, so the comments varied. For ease of categorization, similar comments were grouped where possible. A total of 35 comments were made. Over 68% of the comments were related to construction, weather/view, the experimental vehicle, or traffic, as presented in Table 10. Note that no one mentioned billboards as being most memorable.

Table 10. Most Memorable Items: Number and Percent of Comments.

Comment Category	Number of Comments	Percent of Comments
Construction	7	20.0%
Weather/view	7	20.0%
Vehicle	6	17.1%
Traffic	4	11.4%
New route	3	8.6%
Cut off/near accident	2	5.7%
Emergency vehicle(s)	2	5.7%
Aware of being monitored	1	2.9%
Bumper sticker	1	2.9%
Convertible with kids	1	2.9%
Speed limit changes	1	2.9%

What Bothers You?

Participants were asked, “What bothers you about other drivers?” This was an open-ended question, so the comments varied. For ease of categorization, similar comments were grouped where possible. A total of 30 comments were made. The large majority of the comments were related to aggressive maneuvers or questionable driving behavior such as tailgating, being cut off, not using turn signals, or driving slowly in the fast lane (Table 11).

Table 11. “What Bothers You?” : Number and Percent of Comments.

Comment Category	Number of Comments	Percent of Comments
Tailgating	7	23.3%
Cut off	6	20.0%
No signal	5	16.7%
Speeding	3	10.0%
Aggressive	3	10.0%
Slow in fast lane	3	10.0%
Cell phone talking	1	3.3%
Drivers who don't pay attention	1	3.3%
Inability to adjust to conditions	1	3.3%

<u>Other Activities.</u> Participants were asked, “What other activities do you engage in while driving?” This was an open-ended question, so the comments varied. For ease of categorization, similar comments were grouped where possible. A total of 72 comments were made. Listening to the radio or CDs was the largest single activity, making up over 26% of the comments. Using the cell phone was also common (15%). Other activities included singing or talking, drinking, smoking cigarettes, and eating, as presented in Table 12.

Table 12. Other Activities Engaged in While Driving: Number of Responses, Percentage of Responses, and Cumulative Percentage.

Comment Category	Number of Comments	Percent of Comments
Listen to radio/CDs	19	26.4%
Cell phone	11	15.3%
Sing/talk w/self	7	9.7%
Drinking	6	8.3%
Smoking	5	6.9%
Eating	4	5.6%
Adjust radio/CDs	4	5.6%
Driving/steering	3	4.2%
Talk w/others	3	4.2%
Adjust AC/windows	2	2.8%
Watching	2	2.8%
Fix hair/lipstick	2	2.8%
Reading billboards	1	1.4%
Reach into purse	1	1.4%
Chewing gum	1	1.4%
Flash cards at stop lights	1	1.4%

Other questions asked participants for additional input about the written directions and the purpose of the study. Substantively relevant participant responses included three separate suggestions relating to conducting a driving study with passengers or children, the effect of video cameras on driving behavior, and the statement that "driving in my own car would be more 'normal.' " While no one reported problems with the directions, three drivers did get off-route at one point during their trip; however, very few data points were missed. Drivers were also queried as to their recollection of the purpose of the study; all responses were within the scope of what they had been told verbally and in the informed consent form.

Forward Scanning Behavior: Site Type

This set of analyses was undertaken to answer the following research question:

1. Does a driver's forward scanning behavior (glances through the windshield—center forward, left forward, and right forward) change in the presence of billboards as compared to baseline and comparison sites?

There were three site types studied in this experiment: baseline sites, comparison sites, and billboard sites. Baseline sites were areas with no billboards, on-premises signs, or buildings close to the road, while comparison sites were selected sites including logo signs, on-premises signs, and unique architecture. For site type, two of the nine eyeglance dependent variables showed significant differences. These were observed for only left-forward glances for both the number of glances and total glance duration, as illustrated by Table 13. For the number of left-forward glances, billboard sites had significantly more glances than baseline sites, but comparison sites did not differ significantly from either billboard or comparison sites. For total glance duration, participants looked left forward for exactly the same amount of time for both billboard and comparison sites (no significant difference). However, a significantly shorter time was noted when passing baseline sites. Figures 16-17 illustrate the significant differences graphically. Appendix E contains descriptive statistics for all eyeglance measures by individual site type (i.e., individual baseline, comparison, and billboard sites).

Table 13. Average Glance Statistics and Probabilities for Site Type.

	Site Type			
	Baseline	**Billboard**	**Comparison**	**Probability**
Number of Glances				
Center Forward	3.46	3.58	3.32	n.s.
Left Forward	0.70	1.00	0.82	0.0021
Right Forward	1.32	1.44	1.31	n.s.
Average Glance Duration (seconds)				
Center Forward	1.88	1.87	2.07	n.s.
Left Forward	0.23	0.32	0.37	n.s.
Right Forward	0.38	0.45	0.42	n.s.
Total Glance Duration (seconds)				
Center Forward	4.62	4.50	4.64	n.s.
Left Forward	0.38	0.57	0.57	0.0245
Right Forward	0.74	0.91	0.86	n.s.

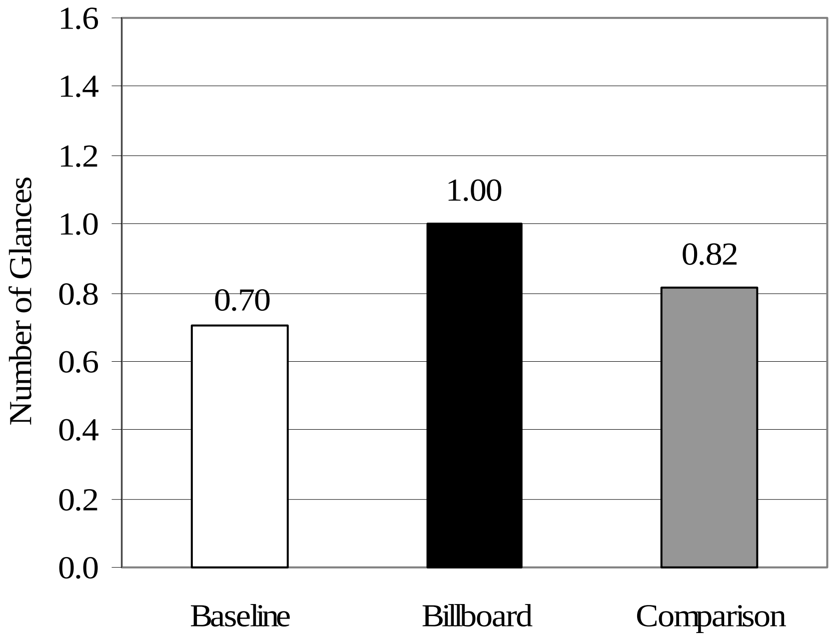


Figure 16. Number of Left Forward Glances by Site Type (significant at *p* = 0.0021). Billboard sites differ significantly from baseline sites, but comparison sites do not differ significantly from either billboard sites or baselines sites.

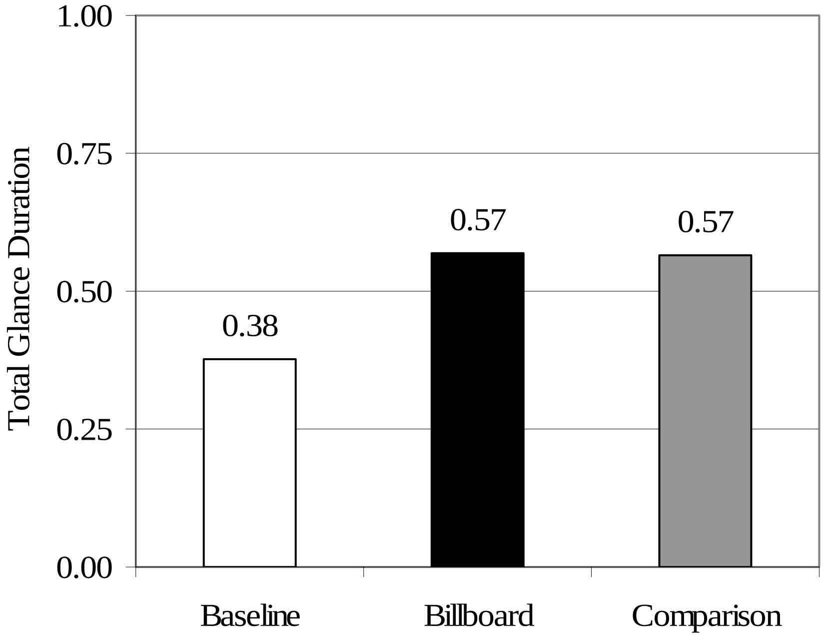


Figure 17. Total Left Forward Glance Duration in Seconds by Site Type (significant at *p* = 0.0245). Billboard sites did not differ significantly from comparison sites, but both billboard and comparison sites differed significantly from baselines sites.

Forward Scanning Behavior: Side of Road, Age, Familiarity, Gender, and Road Type

This set of analyses was undertaken to answer auxiliary research questions about other factors that may influence forward scanning behavior. For side of road (right, left), age (younger, older), and familiarity (familiar, not familiar), there were no significant differences revealed in terms of any of the eyeglance dependent measures. However, in terms of both average glance duration and total glance duration, differences were observed for gender in right-forward glances, as illustrated by Table 14 and Figures 18-19. While there was no significant difference in the number of glances to the right-forward, females had significantly longer total and average glance durations to the right-forward than did males.

Table 14. Average Glance Statistics and Probabilities for Gender

	Gender		
	Female	**Male**	**Probability**
Average Glance Duration (seconds)			
Right Forward	0.49	0.39	0.0383
Total Glance Duration			
Right Forward	0.98	0.78	0.0451

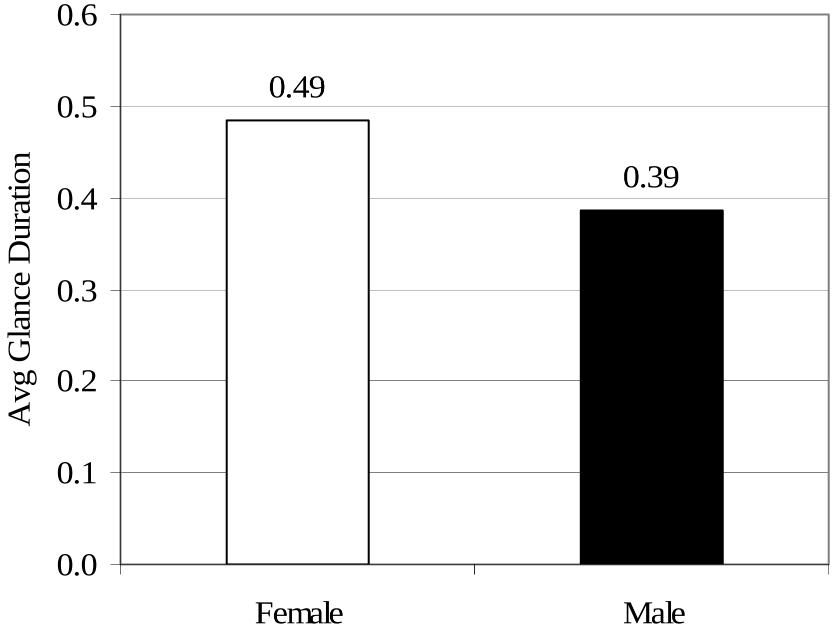


Figure 18. Average Right Forward Glance Duration in Seconds for Gender (significant at *p* = 0.0383).

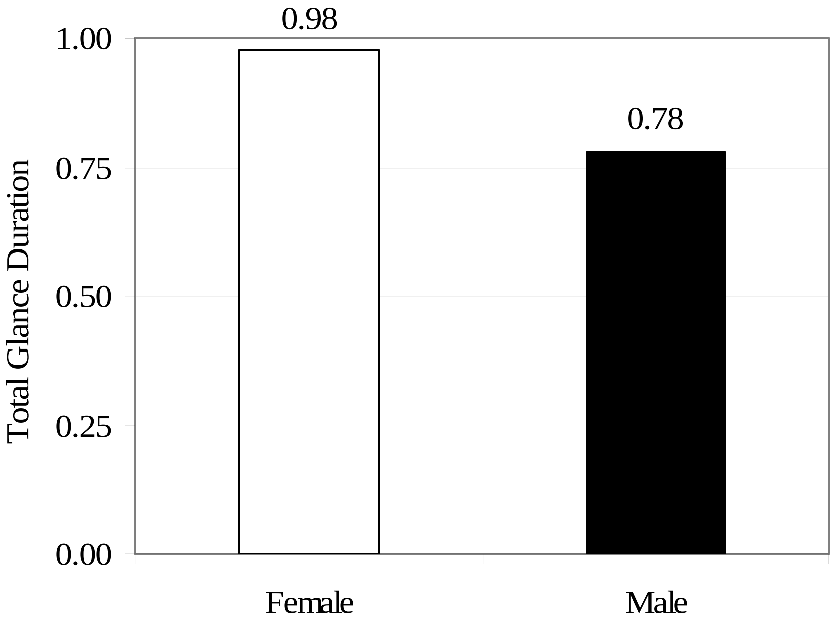


Figure 19. Total Right Forward Glance Duration in Seconds for Gender (significant at *p* = 0.0451).

Road type yielded the largest number of significant findings--far more than the site type analysis. Analysis of interstate versus surface roads found differences for almost all glance measures, in terms of number of glances, average glance duration, and total glance duration, as illustrated by Table 15. Figures 20-27 illustrate these differences graphically. As a reminder, interstate refers to Interstate 85 and Interstate 77, while surface refers to roads such as Tyvola Road, South Blvd, Independence Blvd, and Albemarle Road. Observed differences were systematic, almost without exception--surface roads scored significantly higher on nearly all counts, whether it referred to higher numbers of glances or longer durations (averages or totals). Forward-glance durations, average and total, were significantly longer for interstate than for surface roads.

Table 15. Average Glance Statistics and Probabilities for Road Type.

	Road Type		
	Surface	**Interstate**	**Probability**
Number of Glances			
Center Forward	3.75	3.37	0.0003
Left Forward	1.12	0.81	< 0.0001
Right Forward	1.65	1.24	< 0.0001
Average Glance Duration			
Center Forward	1.71	2.03	0.0012
Left Forward	0.33	0.30	n.s.
Right Forward	0.51	0.39	< 0.0001
Total Glance Duration			
Center Forward	4.43	4.61	0.0160
Left Forward	0.61	0.49	0.0027
Right Forward	1.08	0.75	< 0.0001

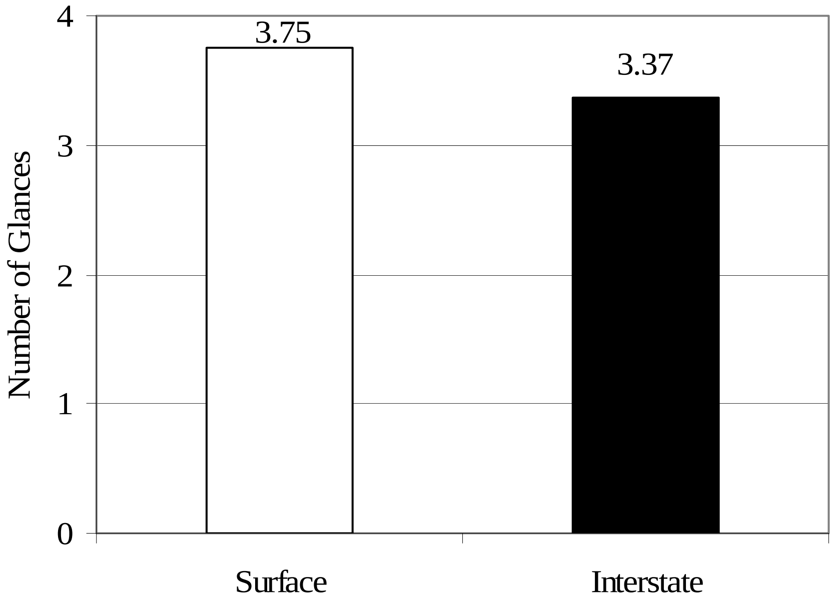


Figure 20. Number of Center Forward Glances by Road Type (significant at *p* = 0.0003).

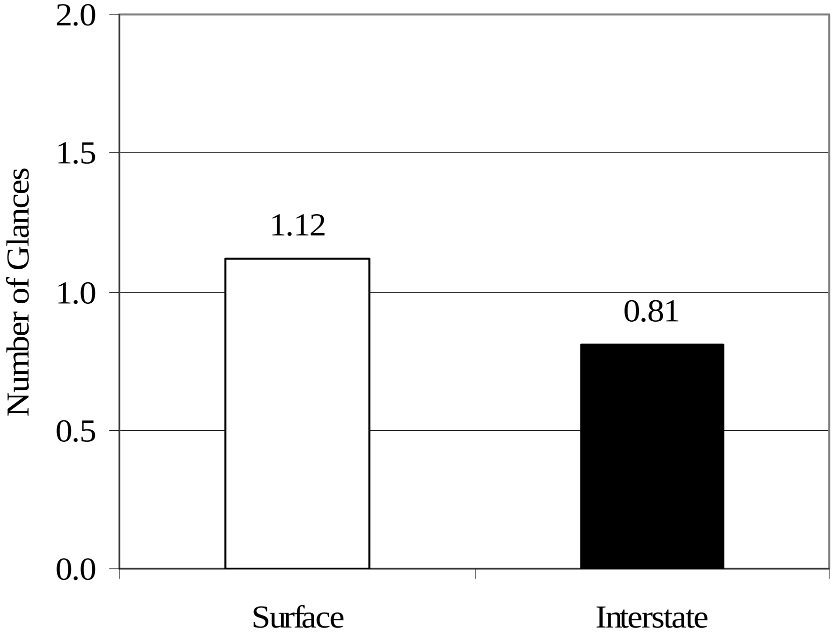


Figure 21. Number of Left Forward Glances by Road Type (significant at *p* < 0.0001).

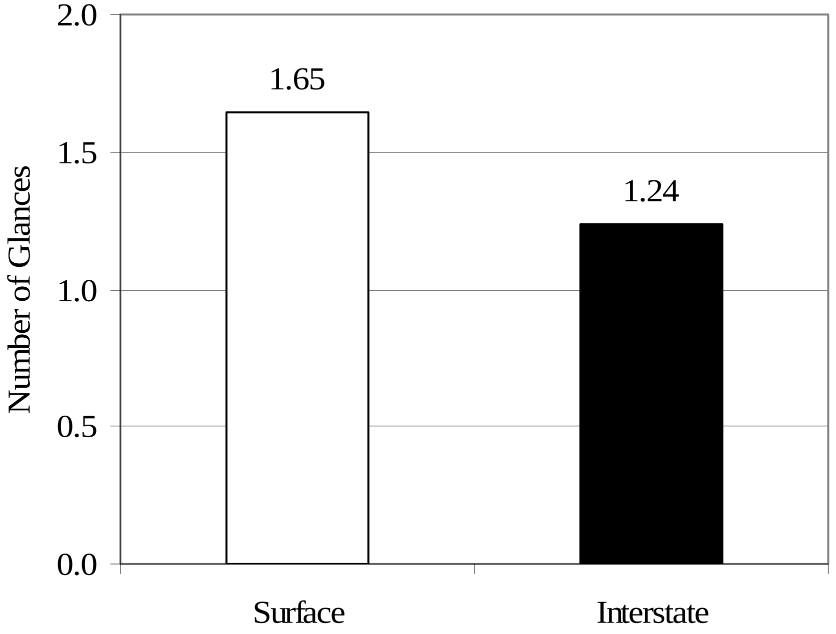


Figure 22. Number of Right Forward Glances by Road Type (significant at *p* < 0.0001).

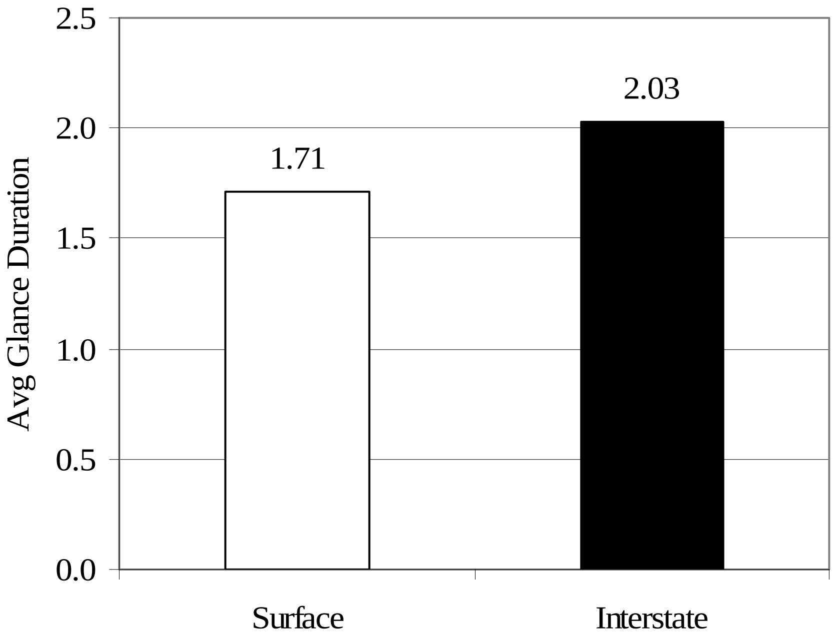


Figure 23. Average Forward Glance Duration in Seconds by Road Type (significant at *p* = 0.0012).

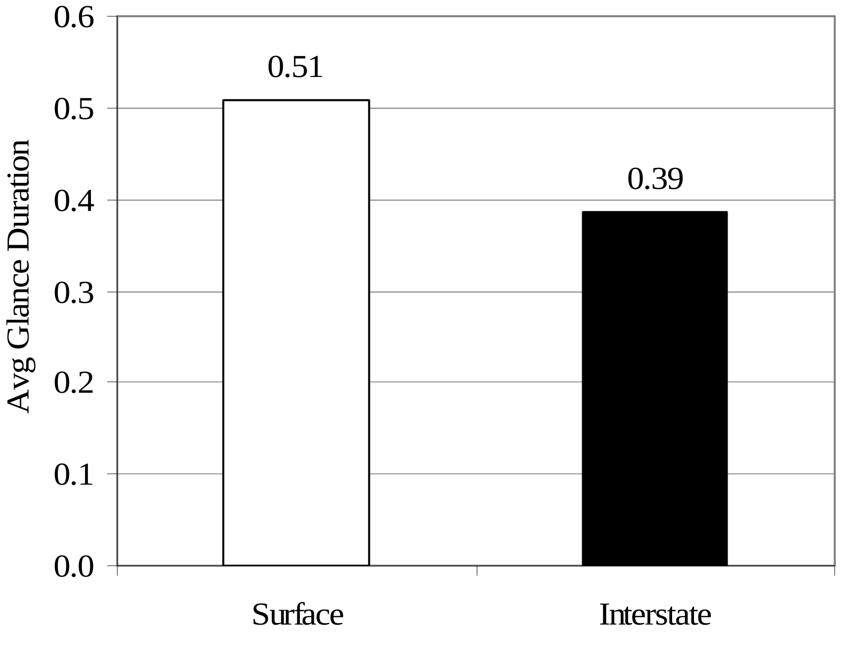


Figure 24. Average Right Forward Glance Duration in Seconds by Road Type (significant at *p* < 0.0001).

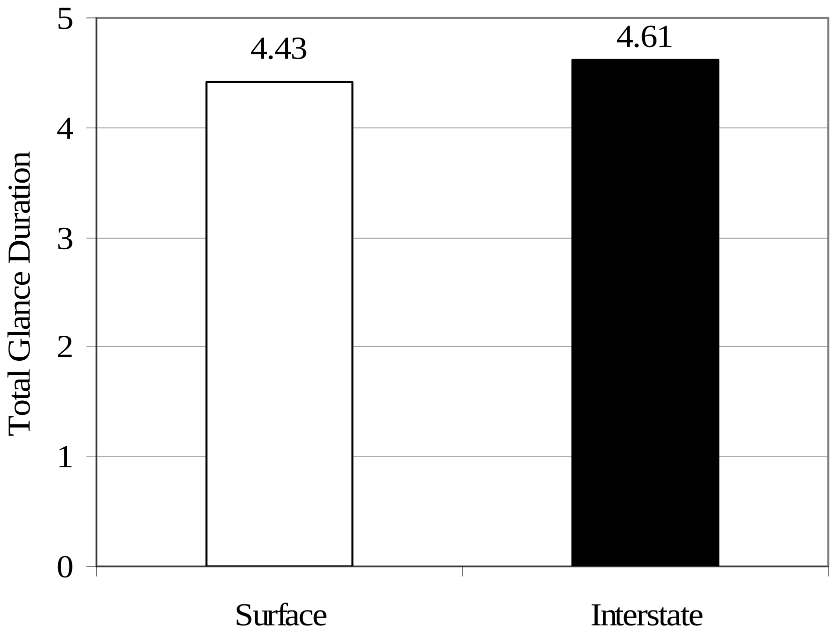


Figure 25. Total Forward Glance Duration in Seconds by Road Type (significant at *p* = 0.0160).

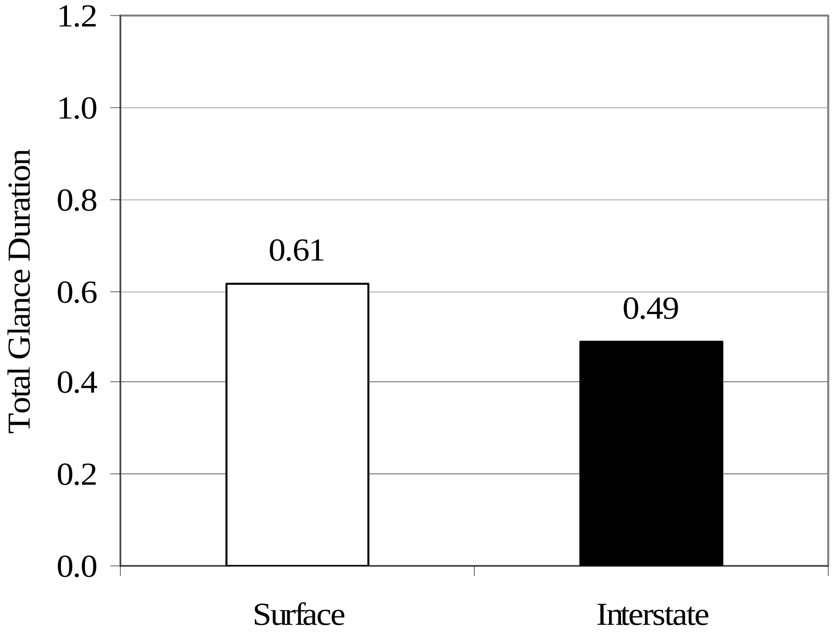


Figure 26. Total Left Forward Glance Duration in Seconds by Road Type (significant at *p* = 0.0027).

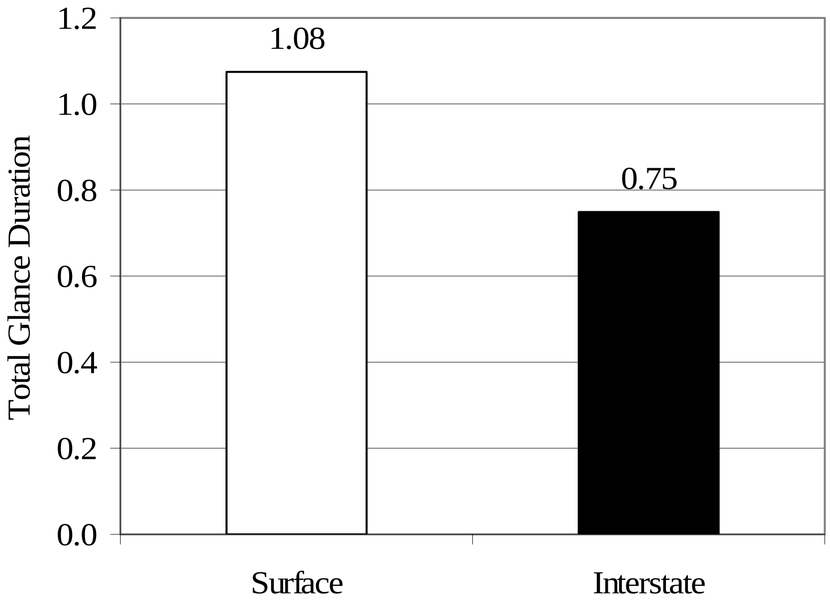


Figure 27. Total Right Forward Glance Duration in Seconds by Road Type (significant at *p* < 0.0001).

Speed Maintenance Behavior

This set of analyses was designed to answer the following research question:

2. Does a driver's speed maintenance behavior (standard deviation of speed) change in the presence of billboards as compared to baseline and comparison sites?

In terms of speed variation, as measured by the standard deviation of speed over the 7 seconds of interest for each event, there was no significant difference between billboard, comparison, and baseline sites. Sites of all types on the left were associated with significantly greater speed variation as compared to sites on the right ($p = 0.0005$). In terms of route familiarity, segments that were rated as familiar had significantly less speed variation as compared to route segments that were not familiar ($p = 0.0343$). Speed variation was greatest for road type--sites on the interstate had less speed variation as compared to surface roads ($p < 0.0001$). Table 16 presents the descriptive statistics for speed and Figures 28-30 illustrate the significant differences graphically.

Table 16. Standard Deviation Statistics for Speed.

Mean Standard Deviation of Speed (mph)				
Site Type	**Baseline**	**Billboard**	**Comparison**	**Probability**
	0.61	0.99	0.82	n.s.
Side	**Left**	**Right**		**Probability**
	1.18	0.81		0.0005
Age	**Older**	**Younger**		**Probability**
	0.87	0.95		n.s.
Gender	**Female**	**Male**		**Probability**
	0.96	0.86		n.s.
Familiarity	**Familiar**	**Not-Familiar**		**Probability**
	0.86	1.00		0.0343
Road Type	**Surface**	**Interstate**		**Probability**
	1.31	0.65		< 0.0001

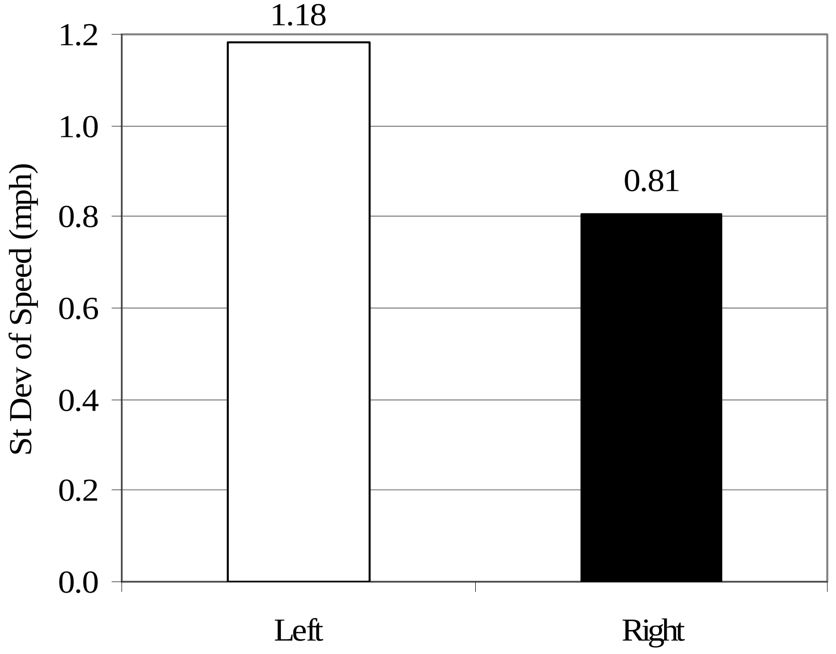


Figure 28. Speed Variation by Side of Road (significant at *p* = 0.0005).

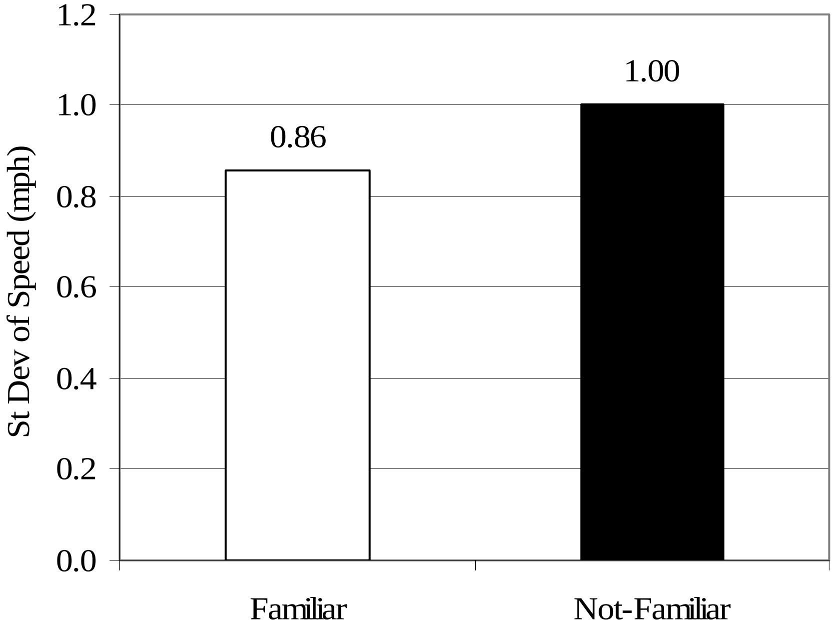


Figure 29. Speed Variation by Familiarity (significant at $p = 0.0343$).

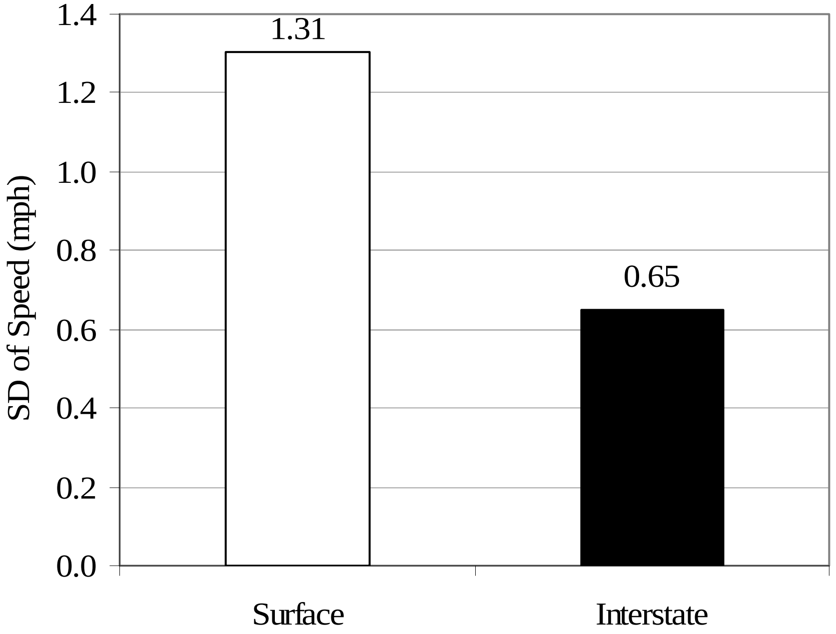


Figure 30. Speed Variation by Road type (significant at $p < 0.0001$).

Lane Keeping Behavior

This set of analyses was designed to answer the following research question:

3. Does a driver’s lane keeping behavior (standard deviation of lane position) change in the presence of billboards as compared to baseline and comparison sites?

In terms of lane position (standard deviation of lane position in inches), significant differences were only found for side of road. Locations associated with the right side of the road had significantly less lane position standard deviation as compared to sites on the left side (*p* = 0.0106). Table 17 presents the descriptive statistics for lane position and Figure 31 illustrates the single significant difference graphically.

Table 17. Standard Deviation Statistics for Lane Position.

<table>
<tr><th colspan="5">Mean Standard Deviation of Lane Position (inches)</th></tr>
<tr><th rowspan="2">Site Type</th><th>Baseline</th><th>Billboard</th><th>Comparison</th><th>Probability</th></tr>
<tr><td>6.40</td><td>8.97</td><td>7.04</td><td>n.s.</td></tr>
<tr><th rowspan="2">Side</th><th colspan="2">Left</th><th>Right</th><th>Probability</th></tr>
<tr><td colspan="2">10.27</td><td>7.50</td><td>0.0106</td></tr>
<tr><th rowspan="2">Age</th><th colspan="2">Older</th><th>Younger</th><th>Probability</th></tr>
<tr><td colspan="2">8.61</td><td>8.04</td><td>n.s.</td></tr>
<tr><th rowspan="2">Gender</th><th colspan="2">Female</th><th>Male</th><th>Probability</th></tr>
<tr><td colspan="2">8.18</td><td>8.47</td><td>n.s.</td></tr>
<tr><th rowspan="2">Familiarity</th><th colspan="2">Familiar</th><th>Not-Familiar</th><th>Probability</th></tr>
<tr><td colspan="2">8.12</td><td>8.69</td><td>n.s.</td></tr>
<tr><th rowspan="2">Road Type</th><th colspan="2">Surface</th><th>Interstate</th><th>Probability</th></tr>
<tr><td colspan="2">9.25</td><td>7.71</td><td>n.s.</td></tr>
</table>

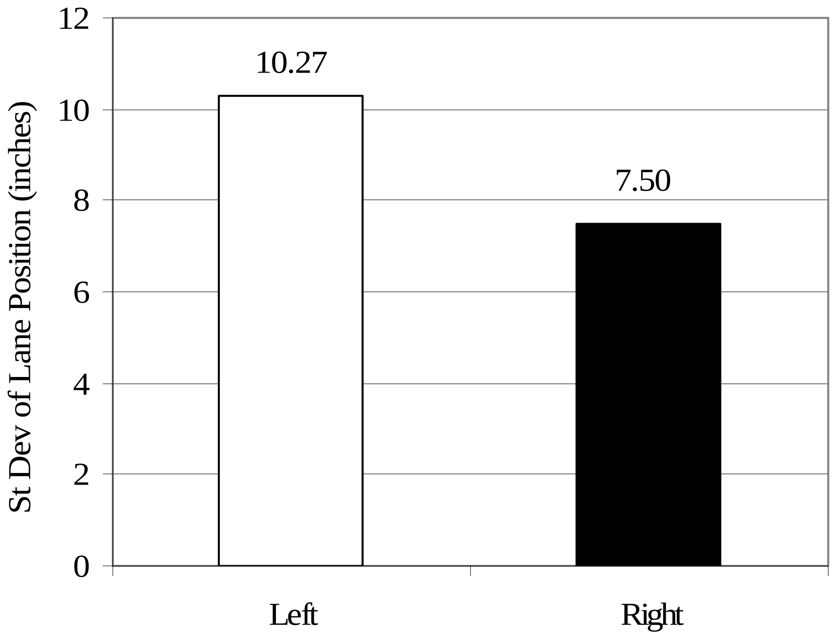


Figure 31. Lane Position Variation by Side of Road (significant at *p* = 0.0106).

Analysis of Selected Highly Attention-Getting Boards

This set of analyses was designed to answer the following research question:

4. Does a driver's forward scanning behavior, speed maintenance behavior, or lane keeping behavior change in the presence of certain highly-attention getting billboards as compared to standard billboards?

An additional analysis was conducted to first determine whether there were significant differences between individual billboards (only billboards were included in this analysis; comparison and baseline sites were excluded). This initial analysis showed significant differences for nine of the 11 dependent variables analyzed to this point--all except left-forward and right forward average glance duration. Six specific boards were then chosen out of the set of 30 boards for in-depth analysis, emphasizing the expected worse-case scenarios. Four out of the six boards were chosen because they were considered to be more attention-getting than the average billboard. Two changeable message boards, two high attention-getting boards (as judged by the researchers and mentioned by two participants), and two fairly standard comparison boards were chosen. One of each pair was on the left side of the road, and one of each pair was on the right side of the road.

The Least Squares Difference statistical procedure was used to determine how each of these boards differed from every other board in the set of 30 billboards. The results are shown in Table 18 for those dependent variables for which initial significant differences were found (thus this table has nine rows instead of 11). If a significant difference is indicated in a cell in this table, it means that that board was significantly different from at least two other boards out of the entire set of 30 billboards for this variable. Following the table, findings for each of the specific billboards are discussed in more detail.

Table 18. Results for Selected Highly Attention-Getting Billboards.

Boards: Dependent Variables	#8998: Electronic (Left side)	#8537: Electronic (Right side)	#9159: Attention-getting (Right)	#7716: Attention-getting (Left)	#9128 Standard copy (Left)	#13351 Standard copy (Right)
Number of Center Forward Glances	Sig. more CF glances (board on left)	No sig. diff. (board on right)	Sig. fewer CF glances (board on right)	Sig. more CF glances (board on left)	Sig. fewer CF glances (board on left)	Sig. more CF glances (board on right)
Number of Left Forward Glances	Sig. more LF glances	Sig. fewer LF glances	No sig. diff.	Sig. more LF glances	Sig. fewer LF glances	Sig. more LF glances
Number of Right Forward Glances	Sig. more RF glances	No sig. diff.	Sig. fewer RF glances	Sig. more RF glances	Sig. more RF glances	No sig. diff.
Average Glance Duration – Center Forward	Sig. lower avg. glance duration	No sig. diff.	Sig. higher avg. glance duration	No sig. diff.	Sig. higher avg. glance duration	Sig. lower avg. glance duration
Total Glance Duration - Center Forward	No sig. diff.	Sig. higher total glance duration	Sig. higher total glance duration	Sig. higher total glance duration	Sig. higher total glance duration	No sig. diff.
Total Glance Duration - Left Forward	Sig. higher total glance duration	Sig. lower total glance duration	Sig. lower total glance duration	No sig. diff.	Sig. lower total glance duration	No sig. diff.
Total Glance Duration - Right Forward	Sig. higher total glance duration	Sig. lower total glance duration	No sig. diff.	No sig. diff.	Sig. lower total glance duration	No sig. diff.
Standard Deviation of Speed	Sig. less speed variation	Sig. less speed variation	Sig. less speed variation	Sig. more speed variation	Sig. lower than some, higher than some	Sig. lower than some, higher than some
Standard Deviation of Lane Position	Sig. less lane position variation	Sig. less lane position variation	Sig. less lane position variation	Sig. more lane position variation	Sig. less lane position variation	Sig. less lane position variation

An examination of Table 18 reveals several interesting patterns. Electronic billboard #8998 on the left side showed a very active eyeglance pattern that did not necessarily correspond to the location of the sign on the left side of the road (e.g., total glance duration to the right was significantly greater for this board than for some other boards, even though the sign was on the left). Speed variation and lane deviation were significantly lower for this board. The other electronic billboard (on the right) showed a pattern of greater glance duration to the center forward location with significantly less speed variation and lane deviation than for other boards. Taken together, these results show no evidence of greater visual distraction in the direction of a changeable message billboard.

For attention-getting billboard #9159 on the right side of the road, there was no evidence of a greater number of glances to the right (significantly fewer right forward glances than for other boards) or for longer glance durations to the right (no significant difference) during the seven seconds preceding the subject vehicle passing the billboard. Speed variation and lane deviation were significantly lower for this board than for many of the other boards. The other attention-getting billboard (on the left side of road) showed an active eyeglance pattern, which had significantly more glances in all directions, not just to the left. Lane deviation and speed variation were both significantly higher for this board as compared to others, which could mean that the traffic in this area was usually heavy or that this was a visually cluttered area, causing an active glance pattern and greater driving performance variations.

The first standard (not electronic, not especially attention-getting) board was #9128 on the left side. There were significantly more glances to the right side for this board, with few other differences noted. None of the differences were in the direction of more glance activity to the left. Speed variation had mixed results (i.e., lower than some boards, higher than others), while lane deviation was lower for this board. The other standard billboard (#13351on the right side) showed very few significant differences, and none of the differences was to the right. As for the first standard board, speed variation had mixed results (i.e., lower than some boards, higher than others), while lane deviation was lower for this board than for others.

This analysis provides insight into the overall results. In the two cases where significant site type differences were found (number of left forward glances and left forward total glance duration), the question arises as to whether these left forward glances correspond to glances to specific billboards. It becomes apparent that this was not the case when the four billboards that might be expected to draw the most glances were compared to two standard boards. Some billboard sites seemed to have a more active glance pattern than others, but the glance directions did not correspond to the side of the road where the billboards were situated.

Eyes-Off-Road Percentage

This set of analyses was designed to answer the following research question:

5. Does a driver's eyes off road percentage (the sum of all glance times except center forward, left forward, and right forward divided by the sum of all glance times) change in the presence of billboards as compared to baseline and comparison sites?

Glances to all locations (not just center forward, left forward, and right forward) were captured during the video analysis; this analysis made use of the full set of eyeglance data. The eyes-off-road (EOR) percentage is often used by transportation safety researchers as a measure of driver attention to the driving task. For this analysis, the total time of eye glances to off road locations (any positions other than center forward, left forward, and right forward) was divided by 7 seconds (total event duration) to produce a measure of EOR percentage.

Results showed a significant difference in EOR percentage (*p* = 0.0226) for the site type independent variable. The Least Squares Difference statistical procedure was used to determine which site types differed from one another. Results showed that billboard and comparison sites exhibited significantly less EOR time than baseline sites. Conversely, this means that drivers exhibited significantly more *eyes-on-road* time in the presence of billboards and comparison sites than for baseline sites. Table 19 provides the descriptive statistics for this analysis and Figure 32 illustrates the magnitude of this effect.

Table 19. Eyes-off-Road Percentages for Site Type.

	Mean Eyes-off-Road Percentage			
Site Type	**Baseline**	**Billboard**	**Comparison**	**Probability**
	18.1%	13.4%	14.6%	0.0226

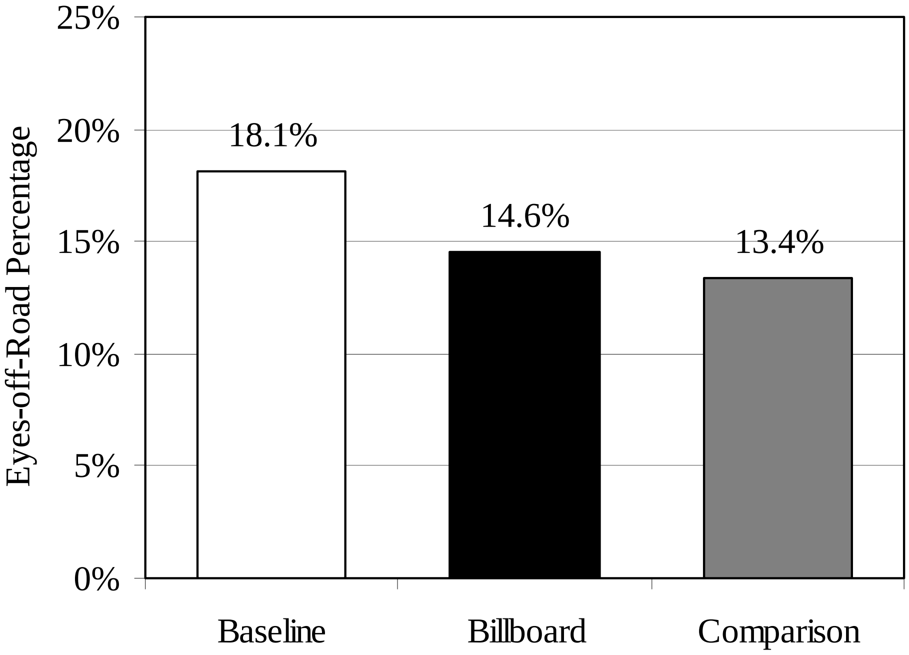


Figure 32. Eyes-off-Road Percentage by Site Type (significant at *p* = 0.0245). Billboard sites did not differ significantly from comparison sites, but both billboard and comparison sites differed significantly from baselines sites.

Non-Forward Glance Location Percentages

This set of analyses was designed to answer the following research question:

6. If a driver's eyes off road percentage changes in the presence of billboards as compared to baseline and comparison sites, are there then corresponding differences in off road glance allocations (i.e., other exterior locations, rear view mirror, and other interior locations)?

Given that significant differences were noted in the EOR percentage for baseline vs. billboard sites, were there also difference in the percentage of time that drivers spent looking at certain off-road locations such as other exterior locations, the rear view mirror, and other interior locations? Glances to exterior locations other than through the front windshield (e.g., to the left and right mirrors, left and right blind spots, etc.) may be an indicator that a driver has extra visual capacity available to monitor surrounding traffic more closely. Glances to the rear view mirror are considered part of the driving task, so finding differences in the percentage of time spent glancing at this location could indicate differences in the other visual demands of the driving task. Finally, more time spent glancing at interior locations would indicate a compelling secondary task taking the driver's visual attention away from the primary task of driving. For these analyses, the total time of any eye glances to exterior locations other than forward locations, to the rear view mirror, and to interior locations other than rear view mirror was divided by 7 seconds (total event duration) to produce three measures of non-forward glance location percentage. The results showed no significant differences in non-forward glance locations percentages for any of these three measures for the site type independent variable.

DISCUSSION AND CONCLUSIONS

Method

As discussed in the literature review section of this report, past research efforts have attempted to determine the safety impact of billboards, although the impetus behind these research efforts have often been grounded in aesthetic or even moral concerns. To date, billboards have neither been proved to be a quantifiable cause of accidents nor proved to result in driver distraction. The purpose of this project was to further investigate the driver distraction aspect; specifically, whether billboards cause eyeglance diversions away from the forward view, an increase in speed variation, or an increase in lane deviation, all of which are commonly used by transportation researchers as indicators of driver distraction. An instrumented vehicle (with no experimenter present) was driven by 36 participants who were unaware of the underlying purpose of the study. Participants represented a range of age, gender, ethnicity, income, and education levels. The route was a 35 mile loop-route in Charlotte, North Carolina, consisting of both interstate and surface streets. A total of 30 billboards, 6 comparison sites, and 6 baseline sites were analyzed in terms of nine eyeglance measures and two driving performance measures.

Post-Drive Questionnaire

The average participant age was 25 years for younger drivers and 56 years for older drivers. On average, drivers had completed 14 years of education (high school plus two years of college). For marital status, 78% of participants were single or married, while 14% were divorced and 8% widowed. Over 61% of drivers were European (Caucasian) and 39% of drivers had an African American, Native American, or Multi-racial background. Seventy-two percent of drivers reported an annual income of less than $49K. All drivers were familiar with the roadway system in Charlotte and most drivers both lived and worked there.

Analysis of the questionnaire results revealed that the most common item that caught drivers' attention during the route included traffic, other drivers, road signs, and highway signs, as well as construction, landmarks, landscaping, and buildings. Only 25% of drivers indicated that billboards caught their attention during the drive. Upon further inquiry, these drivers indicated that they either tended to look at billboards in general or at specific billboards that caught their attention. None of these nine drivers indicated that they found billboards to be distracting. Other questions asked drivers to indicate what was memorable about the drive or what they noticed about other drivers. Most comments involved traffic, construction, the weather, or aggressive driving by other drivers. Many drivers indicated that they also typically performed other activities while driving, such as listening to music, talking on a cell phone, eating, drinking, smoking cigarettes, or talking to passengers.

Overall Results for Eyeglance and Driving Performance Measures

Table 20 presents the results for each dependent and independent variable. This table is presented here as a reference tool for the discussions of the results which follow. It is worth noting that road type had by far the greatest number of significant findings across all dependent variables, indicating that surface roads exhibit greater degradations in driver visual behavior and driving performance than do interstates. This finding is much more pronounced, usually by an order of magnitude, than for the same dependent variable in regard to site type (billboards versus comparison sites versus baseline sites).

Table 20. Summary of All Results (NS = not significant).

Independent variables **Dependent variables**	**Site Type**	**Side of Road**	**Age**	**Gender**	**Familiar**	**Road Type**	**Specific Board**
Number of Center Forward Glances	NS	NS	NS	NS	NS	*0.0003*	*<0.0001*
Number of Left Forward Glances	*0.0021*	NS	NS	NS	NS	*<0.0001*	*0.0002*
Number of Right Forward Glances	NS	NS	NS	NS	NS	*<0.0001*	*0.0025*
Average Glance Duration – Center Forward	NS	NS	NS	NS	NS	*0.0012*	*0.0010*
Average Glance Duration – Left Forward	NS	NS	NS	NS	NS	NS	NS
Average Glance Duration – Right Forward	NS	NS	NS	*0.0383*	NS	*<0.0001*	NS
Total Glance Duration - Center Forward	NS	NS	NS	NS	NS	*0.0160*	*<0.0001*
Total Glance Duration - Left Forward	*0.0245*	NS	NS	NS	NS	*0.0027*	*0.0049*
Total Glance Duration - Right Forward	NS	NS	NS	*0.0451*	NS	*<0.0001*	*0.0056*
Standard Deviation of Speed	NS	*0.0005*	NS	NS	*0.0343*	*<0.0001*	*<0.0001*
Eyes-Off-Road Percentage	*0.0226*	NS	NS	*0.0494*	NS	*0.0016*	NA
Exterior Locations Percentage	NS	NS	NS	NS	NS	NS	NA
Rear View Mirror Percentage	NS	*0.0012*	NS	NS	NS	*0.0112*	NA
Interior Locations Percentage	NS	NS	NS	NS	NS	*0.0370*	NA

Forward Scanning Behavior

1. Does a driver's forward scanning behavior (glances through the windshield—center forward, left forward, and right forward) change in the presence of billboards as compared to baseline and comparison sites?

This analysis of forward scanning behavior provided insight as to whether drivers changed their forward scan patterns when passing billboards. Glances were analyzed in terms of number of glances, average duration of glances, and total duration of glances for each of three site types: billboard, baseline, and comparison sites. Billboard sites had significantly more left forward glances as compared to the baseline sites, but did not differ from the comparison sites. There was also a difference in terms of total glance duration; billboard and comparison sites had significantly longer left forward total glance durations than baseline sites, but did not differ from one another. This was not a surprising finding, since baseline sites were chosen to have fewer buildings, signs, and other items thought to catch the attention of the driver. There were no differences for the average glance durations in any direction between three site types.

As indicated in the literature review, some researchers have suggested that driving performance may improve in the presence of billboards (Rykken, 1951; Wachtel and Netherton, 1980). If this were the case, one might expect to find a more active forward scanning pattern in the presence of billboards, since the forward view is the primary visual channel for driving. The only measures with significant differences between billboard and baseline driving were left forward—there were more glances and greater total glance duration for the billboards sites. No definite conclusions can be drawn that this more active left forward scan pattern indicates improved driving performance in the presence of billboards. However, it should be noted that left forward is the direction of oncoming traffic, so it can be stated that *drivers took more glances and spent more total time looking in the direction of oncoming traffic when billboards were present as compared to baseline sites.*

No differences were found for eyeglance behaviors in terms of side of road, age, or familiarity, and only one finding was revealed for gender. Females displayed longer average and total right forward glance durations across all site types; this difference, although significant, was relatively small in terms of magnitude and does not seem to have any practical significance.

Not surprisingly, there were significant differences for road type, with surface streets showing a more active glance pattern than interstates. More glances were observed in all directions on surface segments as compared to interstate segments. The average and total center forward glance durations were longer for the interstate segments; in most cases, the right and left forward average and total glance durations were shorter on the interstate than on surface streets. It is not surprising that more glances were made to the sides for surface road sites, where speeds are lower and more side items are available to view. In most cases, surface road sites have more signs, buildings, etc. to look at and it is not surprising that drivers would look at locations other than center forward while driving in these areas. Also, some differences may be attributed to drivers looking left to monitor traffic in the adjacent or oncoming lanes or looking to the right to monitor vehicles merging onto the roadway or exiting from the roadway.

Speed Variability

2. Does a driver's speed maintenance behavior (standard deviation of speed) change in the presence of billboards as compared to baseline and comparison sites?

There was no indication of speed variability in the presence of billboards (the site type main effect was not significant for this dependent variable). In terms of speed variability, statistically significant differences were revealed for side of road, familiarity, and road type; however, from a practical perspective, differences varied by no more than 0.7 miles per hour (or 1 foot/second). For side of road, sites on the right were associated with lower deviations in speed (difference of 0.4 mph). For sites rated as familiar, drivers had lower speed variations (0.1 mph difference). The largest difference was in terms of road type: sites on the interstate had lower speed variability than did sites on the surface streets (0.7 mph difference).

Lane Deviation

3. Does a driver's lane keeping behavior (standard deviation of lane position) change in the presence of billboards as compared to baseline and comparison sites?

Lane deviation did not differ in the presence of billboards. Lane position analysis revealed differences only for side of road. For sites on the left side of the road, lane position varied by 10 inches during the 7-second segment as compared to 7.5 inches for sites on the right side. These differences, although significantly different from one another, are within the expected range of deviation of 5 to 62 inches (reported by Alm & Nilsson, 1994; Serafin et al. 1993, for simulated driving).

Specific Board Analysis

4. Does a driver's forward scanning behavior, speed maintenance behavior, or lane keeping behavior change in the presence of certain highly-attention getting billboards as compared to standard billboards?

A rigorous analysis of specific boards was performed to determine: 1) how specific billboards compared to other billboards in terms of eyeglance and driving performance measures, and 2) how the eyeglance measures corresponded to the placement of the billboards (left or right) in relation to the road. By choosing the four billboards that might be expected to draw the most glances as well as two more ordinary boards and comparing their results to all other billboards, it became obvious that this was not the case. *Some billboard sites seemed to have a more active glance pattern than others, but the glance directions did not correspond to the side of the road where the billboards were situated.*

Eyes-Off-Road Percentage

5. Does a driver's eyes off road percentage (sum of all glance times except center forward, left forward, and right forward divided by sum of all glance times) change in the presence of billboards as compared to baseline and comparison sites?

Drivers had a greater percentage of eyes-off-road (EOR) time for baseline sites than for billboard and comparison sites. Likewise, drivers spent a greater proportion of time looking forward for billboard and comparison sites than for baseline sites. In combination with the more active left forward scan pattern discussed previously, this is another indication that driving performance may actually improve in the presence of billboards as compared to baseline areas, as originally proposed by Rykken (1951) and Wachtel and Netherton (1980).

Non-Forward Glance Location Percentages

6. If a driver's eyes off road percentage changes in the presence of billboards as compared to baseline and comparison sites, are there then corresponding differences in off road glance allocations (i.e., other exterior locations, rear view mirror, and other interior locations)?

There were no significant differences in the non-forward glance allocations among the three site types. The allocation of the additional off-road glances for baseline driving were distributed in approximately the same proportions among other exterior locations, rear view mirror, and other interior locations as was true for billboard and comparison sites.

Limitations of the Research Method

This study was conducted in a specific city chosen to be representative of mid-sized U.S. cities. The route was chosen to include both urban and suburban sections (and some sections were close to rural in nature). The billboards in Charlotte, North Carolina are generally situated close to the side of the road, therefore placing the boards within the forward-view of the participants for a longer period of time than if they were further offset from the road. Both the setting (urban/suburban/rural) and the billboard offsets were typical of most billboard locations found in the U.S. For each of the above-mentioned parameters, every attempt was made to conduct a balanced, representative study for which the results could be generalized to other cities and routes.

One limitation of this study was that there were few electronic boards along the route, so no conclusions can be drawn regarding driver behavior in the presence of this type of billboard. All three of the electronic billboards available on the route were included, however, for a total of 10% of the sampled billboards. Future research into this topic should focus on routes with a greater number of available electronic billboards so that an electronic/non-electronic analysis can be conducted.

Conclusions

Based on over 1,500 events in which a driver passed a billboard, comparison site, or baseline site, the overall conclusion from this study is that the presence of billboards does not cause a measurable change in driver behavior, in terms of visual behavior, speed maintenance, or lane keeping. A rigorous examination of individual billboards that could be considered to be the most visually attention-getting demonstrated no measurable relationship between glance location and billboard location. Driving performance measures in the presence of these specific billboards generally showed less speed variation and lane deviation. Thus, neither visual behavior nor driving behavior changes measurably, even in the presence of the most visually attention-getting billboards. One major finding was that significantly more time was spent with the eyes looking forward (eyes on road) for billboard and comparison sites as compared to baseline sites, providing a clue that billboards may actually improve driver visual behavior.

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APPENDICES

Appendix A. Initial Contact Participant Screening Questionnaire

My name is Erik Olsen and I'm a researcher with the Virginia Tech Transportation Institute in Blacksburg, VA. Thank you for your time – We are collecting names of potential participants now. The project involves participation in a driving study to help researchers understand how people drive.

This study involves meeting me at the University Residence Inn Hotel in Charlotte, NC on N. Tryon St. one time for approximately 2 hours. During this session you would help us by completing some questionnaires, having a short eye exam, driving one of our vehicles along a pre-selected route for about 35 miles, and filling out a questionnaire after the drive. The vehicle will be equipped with data collection equipment to allow observation of recordings of the drive.

Name:___________________________ Male/Female

I would like to write down your phone number or phone numbers, and/or email where you can be reached and hours/days when it's best to reach you.

Phone Numbers ____________________________________ Age: ______

Best Time to Call ____

Email ______________________________

Next, I would like to ask you several questions to see if you are eligible to participate.

Questions

1. Do you have a valid driver's license?
   Yes _____ No _____

2. How often do you drive each week?
   Every day ____ At least 2 times a week___ Less than 2 times a week_____

3. How old are you? ______ (stop if not 18-35 years old or 50-75 years old.)

4. What type of vehicle do you usually drive?__________________________

5. Have you previously participated in any experiments at the Virginia Tech Transportation Institute? If so, can you briefly describe the study?
   Yes _____ ____
   No _____

6. How long have you held your drivers' license? ________________________________

7. Are you able to drive an automatic transmission without assistive devices or special equipment?
   Yes _____ No _____

8. Do you have a history of any of the following? If yes, please explain.

Stroke	No____	Yes___
Brain tumor	No____	Yes___
Head injury	No____	Yes___
Epileptic seizures	No____	Yes___
Respiratory disorders	No____	Yes___
Motion sickness	No____	Yes___
Inner ear problems	No____	Yes___
Dizziness, vertigo, or other balance problems	No____	Yes___
Diabetes	No____	Yes___
Migraine, tension headaches	No____	Yes___

9. (Females only, of course) Are you currently pregnant?
   Yes _____ No _____ (If "yes" then read the following statement to the participant: *"It is not recommended that pregnant women participate in this study. However, female participants who are pregnant and wish to participate must first consult with their personal physician for advice and guidance regarding participation in a study where risks, although minimal, include the possibility of collision and airbag deployment."*)

10. Are you currently taking any medications on a regular basis? If yes, please list them.
    Yes _____ ____
    No _____

11. Do you have normal or corrected to normal hearing and vision? If no, please explain.
    Yes _____
    No _____ ____

12. Would you be willing to drive without wearing sunglasses?

13. Have you ever had radial keratotomy, LASIK, or other eye surgeries? If yes, please specify.
    Yes _____ ____
    No _____

A total of 2 hours of time will be needed. What days and times would you be able to participate?

Saturday:	9:30	11:30	1:30	3:30
Sunday:	9:30	11:30	1:30	3:30
Monday:	9:30	11:30	1:30	
Tuesday:	9:30	11:30	1:30	

Thank you for your time. I will contact you to schedule a session if you are selected as a participant.

Appendix B. Informed Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants of Investigative Projects

Title of Project: Influence of driver characteristics on driving performance

Investigators: Dr. Suzanne E. Lee, Research Scientist, Virginia Tech Transportation Institute.

Mr. Erik C. B. Olsen, Graduate Research Assistant, Virginia Tech Transportation Institute.

I. The Purpose of this Research Project

This study will collect driver performance data to help understand the way people drive in a natural environment (with no experimenter present). The goal of this study is improve the understanding of how people drive.

II. Procedures

For this study you will be asked to drive on a loop-route on freeways and highways in Charlotte, North Carolina. We want you to drive as you normally would on any roadway, following the typical laws and regulations of the road. The session is expected to last about two hours, including this orientation. You will then be paid for your participation.

This vehicle contains sensors and data processing equipment that will capture aspects of your driving behavior. Small video cameras are also mounted in the vehicle. One of these cameras will be directed toward your face while you are driving. The equipment has been installed in such a way that you will hardly be able to notice its presence. It will not interfere with your driving, and there is nothing special that you will need to do in regard to the equipment.

This experiment will consist of five experimental stages:

1. Introductory stage

This stage consists of preliminaries. You will be asked to read the informed consent form. Once you have signed this form, we will also ask to see your driver's license, and an eye exam will be administered. Finally, we will have you complete a medical questionnaire. Once you have completed this stage we will go on to stage 2.

2. Familiarization with the test vehicle
While the instrumented vehicle is parked you will be shown how to operate the vehicle (for example, lights, mirror adjustments, windshield wipers, etc.) as this may be different from your personal vehicle. You will then be asked to set each control to the best level for your comfort and driving performance. You will then take a short drive with the experimenter riding along in the passenger's seat to become familiar with the vehicle. This stage should take approximately 15 minutes.

3. Preparation for loop route
The experimenter will then review the loop-route with you. You will be given a map and written directions that the experimenter will review with you

4. Driving the loop route
You will then drive the instrumented vehicle for approximately 1.5 hours over the pre-planned loop route of approximately 63 miles. You are expected to follow the posted speed limit and to wear your seatbelt. Also, please stay in the right-hand lane to the extent possible during the drive. The loop route is to be completed in one session if possible.

5. Debriefing and Payment
After completing the experiment, you will return here for a short debriefing session. You will then be paid for your participation. It is expected that the complete session will last approximately 2 hours, including orientation, loop-route, and debriefing.

III. Risks

Anytime you operate a motor vehicle there are certain risks involved, and this study is no different. Although minimal, risks include the possibility of collision and airbag deployment. However, every effort has been made to ensure your safety such that any risk toward you and others is minimized.

IV. Benefits of this Research Project

The information collected from this project will provide new information on how people tend to drive in a natural setting. This information will be used to improve roadway and vehicle design, so that roadside and in-vehicle devices can be better designed to fit in with what people expect. While there are no direct benefits of participating in this study (apart from payment), you may find the experiment interesting. No guarantee of benefits has been made to encourage you to participate. However, to avoid biasing other potential participants, you are requested not to discuss this study with anyone for at least 8 months after participation.

V. Extent of Anonymity and Confidentiality

The results obtained from this study will be kept completely anonymous. Your name will not appear on data derived from your session. Only a number will differentiate your data from others who take part in the study. This number, and not your name, will also be used in subsequent data analyses and reports.

As indicated, video will be recorded while you are driving. The video includes an image of your face, so that we can determine where you are normally looking. The video will be treated with confidentiality and kept secure. It will be shared only with other qualified researchers, and not published except as noted in the following paragraph.

If at a later time we wish to use the video information for other than research purposes, say, for public education, or if we wish to publish (for research or for other purposes) your likeness or other information from the study that identifies you either directly or indirectly, we will only do so after we have contacted you again and obtained your permission.

VI. Compensation

You will be paid $20 per hour for the time you actually spend in the experiment. It is estimated that the entire session, including orientation, driving, and debriefing will be 2 hours. Payment will be made immediately after you have finished your participation.

VII. Freedom to Withdraw

You are free to withdraw at any time without penalty. If you choose to withdraw from this study you will be compensated for your time up until that point.

VIII. Medical Treatment and Insurance

If you should become injured in an accident, the medical treatment available to you would be that provided to any driver or passenger by emergency medical services in the vicinity where the accident occurs. The vehicle you will be driving is insured for automobile liability and collision/comprehensive through Virginia Tech and the Commonwealth of Virginia. There is medical coverage for you under this policy. The total policy amount per occurrence is $2,000,000. This coverage would apply in case of an accident, except as noted below.

Under certain circumstances, you may be deemed to be driving in the course of your employment, and your employer's worker's compensation provisions may apply in lieu of the Virginia Tech and Commonwealth of Virginia insurance provisions, in case of an accident. The particular circumstances under which worker's compensation would apply are specified in Virginia law. If worker's compensation provisions do not apply in a particular situation, the Virginia Tech and Commonwealth of Virginia insurance provisions will provide coverage.

Briefly, worker’s compensation would apply if your driving for this research can be considered as part of the duties you perform in your regular job. If it is not considered as part of your regular job, then the insurance policy would apply.

IX. Approval of Research

This research project has been approved, as required by the Institutional Review Board for Research Involving Human Participants at Virginia Polytechnic Institute and State University, and the Virginia Tech Transportation Institution.

X. Participant's Responsibilities

I voluntarily agree to participate in this study. I have the following responsibilities:

1) I should not participate in this study if I do not have a valid driver's license or if I am not in good health.

2) I should notify the experimenter if at any time I do not want to continue my participation.

3) I should operate the instrumented vehicle in a safe and responsible manner.

4) I should answer all questions truthfully.

XI. Participant’s Permission

Check one of the following:

____ I have **not** had an eye injury/eye surgery (including, but not limited to, LASIK, Radial Keratotomy, and cataract surgery.

____ I **have** had eye injury/eye surgery and I have been informed of the possible risks to participants who have had eye surgery. I choose to accept this possible risk to participate in this study.

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I may withdraw at any time without penalty. I agree to abide by the rules of this project.

____

Signature **Date**

Should I have any questions about this research project or its conduct, I may contact:

Dr. Suzanne E. Lee, Principal Investigator	(540) 231-1511
Erik C. B. Olsen, Graduate Research Assistant	(540) 231-1536
David Moore, Chair of the Virginia Tech Institutional Review Board	(540) 231-4991

Participants must be given a complete copy (or duplicate original) of the signed Informed Consent.

Participant #_____

Appendix C. Post Driving Questionnaire

Thank you for participating in this driving study. We would appreciate if you would respond to the following items. All information will remain confidential.

1. Please circle either "Familiar" (driven at least once a week) or "Not Familiar" (driven less than one time a week) for the following roadway sections:

Along I-85 to I-77	Familiar	Not Familiar
From I-77 to Tyvola Road	Familiar	Not Familiar
Tyvola Road, South Blvd, and Downtown Charlotte	Familiar	Not Familiar
Independence Blvd (74/27)	Familiar	Not Familiar
Albemarle Road (24/27)	Familiar	Not Familiar
Harris Blvd	Familiar	Not Familiar

---

2. For the following systems, please mark what you liked or disliked:

Seating	like	neutral	dislike
Air conditioning	like	neutral	dislike
Engine power	like	neutral	dislike
Visibility	like	neutral	dislike
Steering	like	neutral	dislike

---

3. Please check the top five items that most caught your attention during your drive:
   - Surrounding traffic
   - Other drivers
   - Construction areas
   - Road/street signs
   - Emergency vehicles
   - Buildings
   - Landmarks
   - Walls
   - Landscaping/scenery
   - Gas Stations
   - Restaurants
   - Motels/Hotels
   - Billboards
   - Towers
   - Highway/Exit Signs
   - Smoke Stacks
   - Apartments/housing
   - Other__________________

Did you experience any problems while following the written directions? If so, please describe.

4. What was most memorable about the drive? For example, where there any objects that stood out?

5. What other activities do you typically engage in while driving?

6. Does anything about other drivers bother you? If so, please briefly describe:

7. Please provide any other input about this study:

1. In what city do you live?

2. In what city do you work?

3. What level of education have you completed?

_____ Elementary/Secondary
_____ Junior High School
_____ High School degree
_____ 2-yr Associate degree
_____ Bachelor’s degree
_____ Master’s degree
_____ Doctoral/Professional degree

4. Please indicate your marital status:

single married widowed divorced separated

5. Which of the following groups best represent your ethnicity?

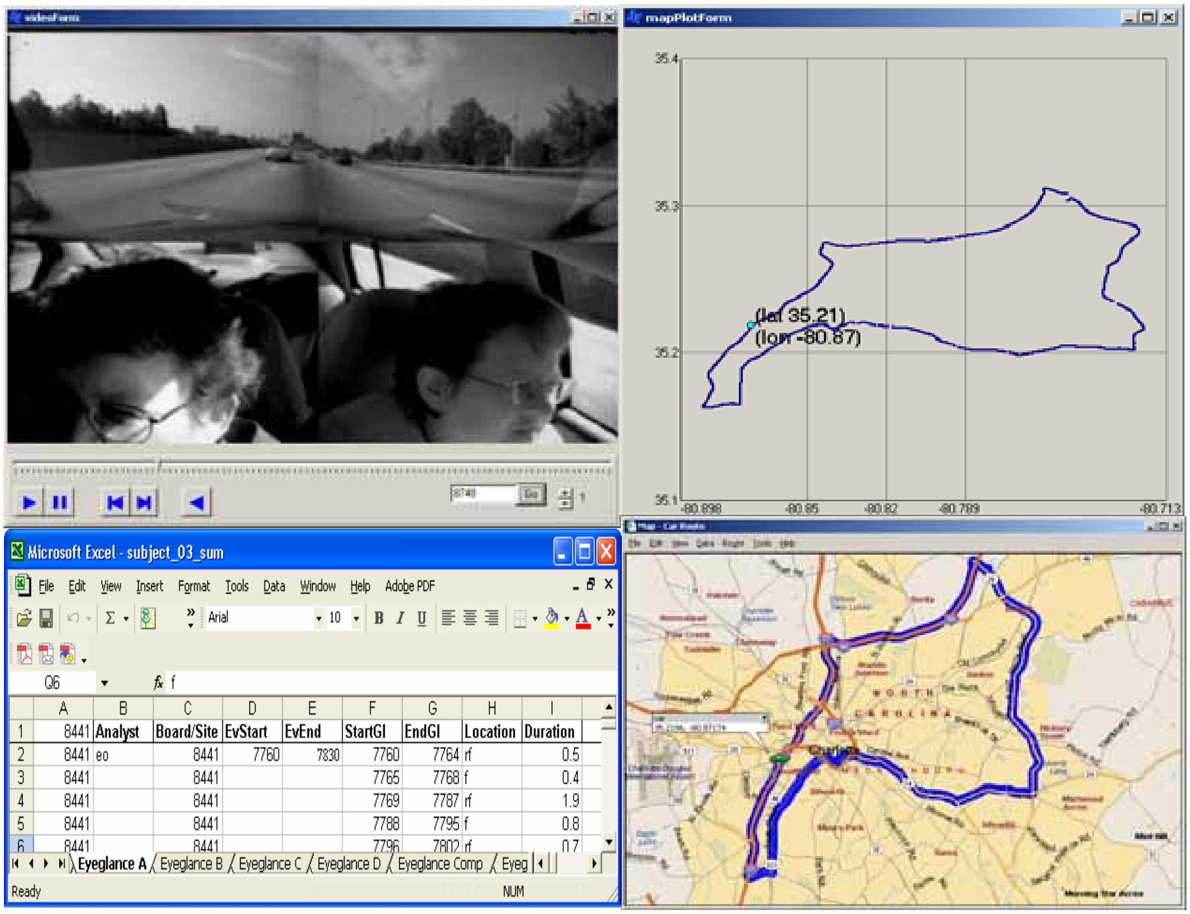
_____ African American
_____ Hispanic (Latino)
_____ Asian
_____ Native American (American Indian)
_____ European (Caucasian, White)
_____ Multi-racial

6. Which of the following best represents your annual household income?

_____ $0-$24,999
_____ $25,000-$49,999
_____ $50,000-$74,999
_____ $75,000-$99,999
_____ > $100,000

What was the purpose of this study?

Appendix D. Analyst Training Manual



	A	B	C	D	E	F	G	H	I
1	8441	Analyst	Board/Site	EvStart	EvEnd	StartGl	EndGl	Location	Duration
2	8441	eo	8441	7760	7830	7760	7764	rf	0.5
3	8441		8441			7765	7768	f	0.4
4	8441		8441			7769	7787	rf	1.9
5	8441		8441			7788	7795	f	0.8
6	8441		8441			7796	7802	rf	0.7

Billboard Analysis Instructions
5/27/03

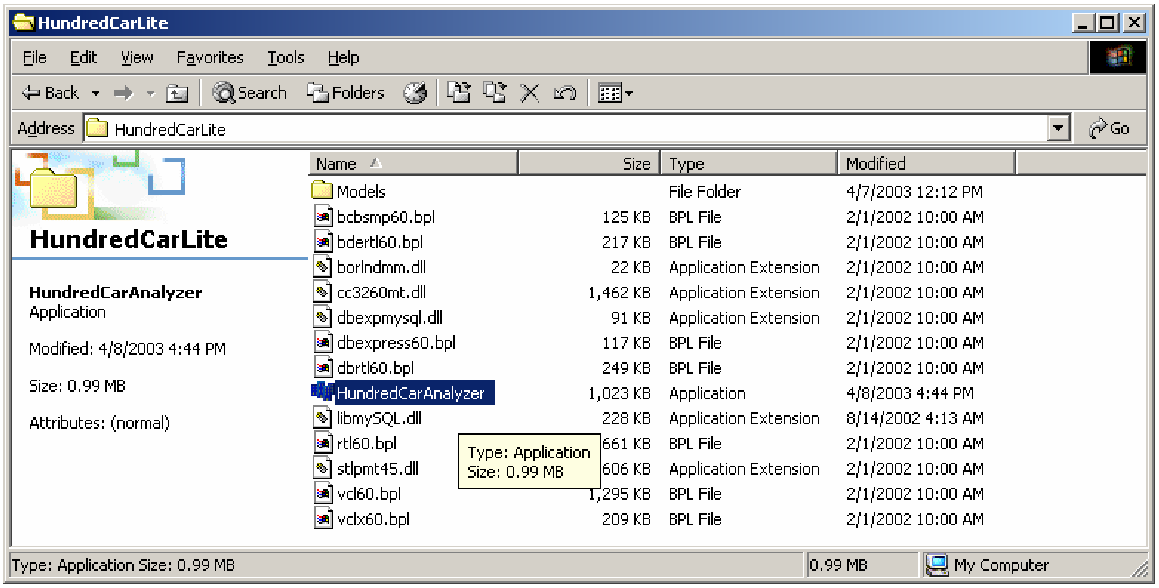
This document describes how to manually analyze data files for the billboard project. Analysis includes identifying events by start and end time (synch numbers), and then recording GPS coordinates (latitude and longitude) and if the driver performed a lane change maneuver, talked on the phone, or was stopped in traffic during the event. Preliminarily, data will be entered into an Excel spreadsheet for each participant and saved for later access. For these instructions, subject_03 (with image on experimenter) will be used for the examples. NOTE: The application works best if all other applications are closed. The files used are VERY large and all available computing power will allow the application to work most efficiently. The MapPoint application must also be installed for the analysis program to work properly.

The sections covered are the following:

- Software Preparation
- Event Identification
- Eye glance Analysis

Software Preparation

1. Open the HundredCarLite application. (A short cut can be created on the desktop for easy access later).



HundredCarLite

HundredCarAnalyzer
Application

Modified: 4/8/2003 4:44 PM

Size: 0.99 MB

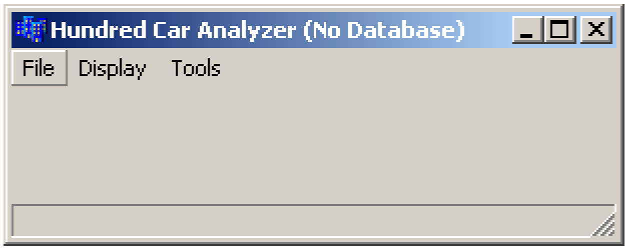
Attributes: (normal)

Name	Size	Type	Modified
Models		File Folder	4/7/2003 12:12 PM
bcbsmp60.bpl	125 KB	BPL File	2/1/2002 10:00 AM
bdertl60.bpl	217 KB	BPL File	2/1/2002 10:00 AM
borlndmm.dll	22 KB	Application Extension	2/1/2002 10:00 AM
cc3260mt.dll	1,462 KB	Application Extension	2/1/2002 10:00 AM
dbexpmysql.dll	91 KB	Application Extension	2/1/2002 10:00 AM
dbexpress60.bpl	117 KB	BPL File	2/1/2002 10:00 AM
dbrtl60.bpl	249 KB	BPL File	2/1/2002 10:00 AM
HundredCarAnalyzer	1,023 KB	Application	4/8/2003 4:44 PM
libmySQL.dll	228 KB	Application Extension	8/14/2002 4:13 AM
rtl60.bpl	661 KB	BPL File	2/1/2002 10:00 AM
stlpmt45.dll	606 KB	Application Extension	2/1/2002 10:00 AM
vcl60.bpl	1,295 KB	BPL File	2/1/2002 10:00 AM
vclx60.bpl	209 KB	BPL File	2/1/2002 10:00 AM

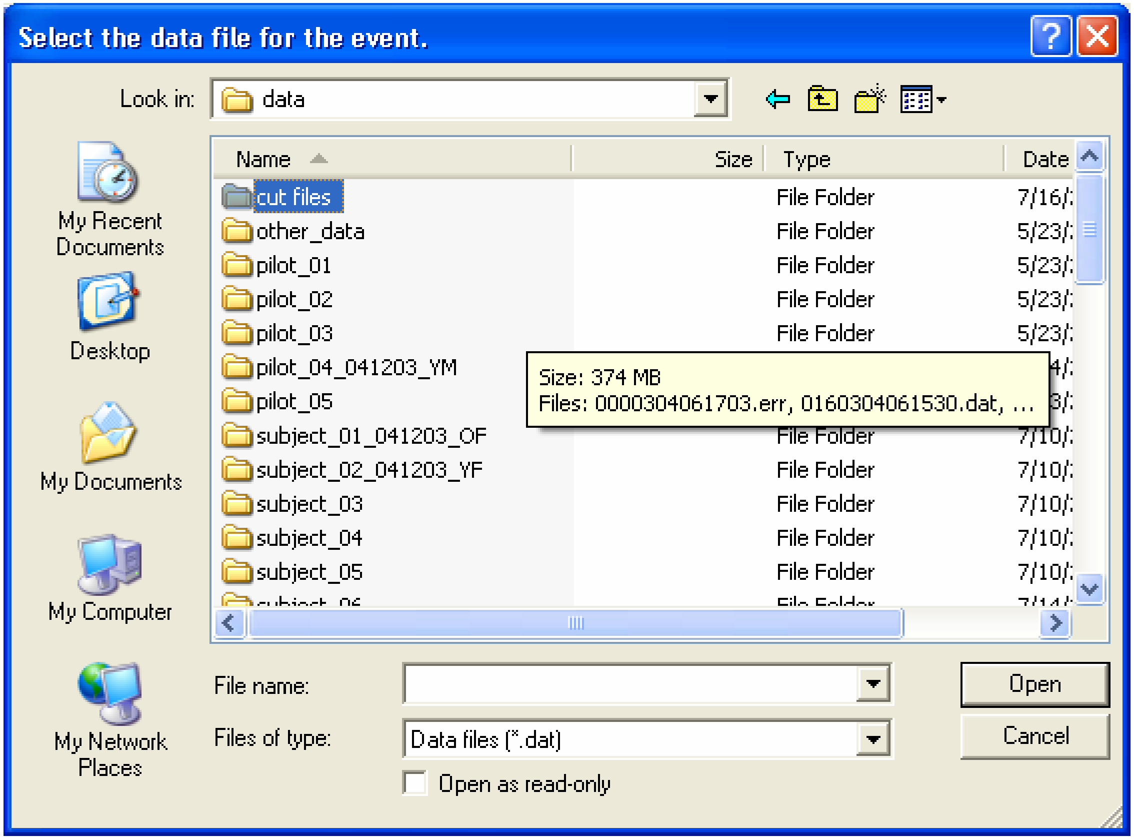
Type: Application
Size: 0.99 MB

Type: Application Size: 0.99 MB | 0.99 MB | My Computer

1. From the File menu, select Admin Tools.



2. From Admin Tools, select Open Trip. The data files are in the “data” folder.
3. Select the folder called cut_files.



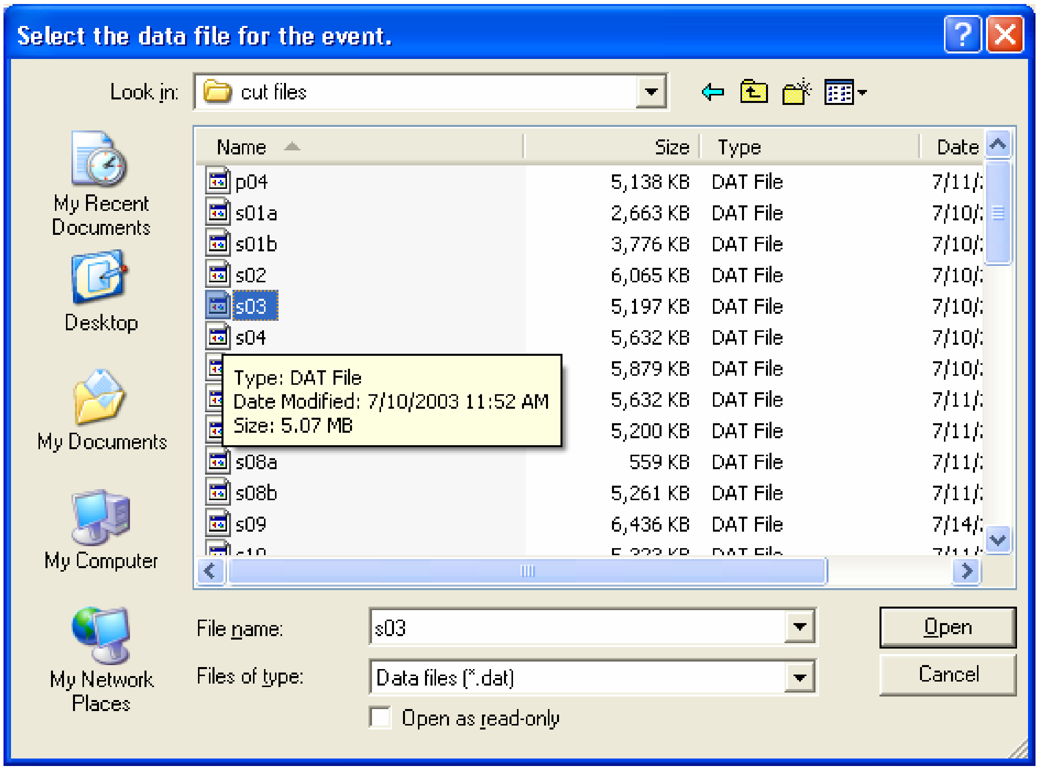
Look in: data

Name	Size	Type	Date
cut files		File Folder	7/16/
other_data		File Folder	5/23/
pilot_01		File Folder	5/23/
pilot_02		File Folder	5/23/
pilot_03		File Folder	5/23/
pilot_04_041203_YM			4/
pilot_05			3/
subject_01_041203_OF		File Folder	7/10/
subject_02_041203_YF		File Folder	7/10/
subject_03		File Folder	7/10/
subject_04		File Folder	7/10/
subject_05		File Folder	7/10/

Size: 374 MB
Files: 0000304061703.err, 0160304061530.dat, …

File name:
Files of type: Data files (*.dat)
☐ Open as read-only

4. Select subject_03. The system will take a few minutes to open all the windows.



Look in: cut files

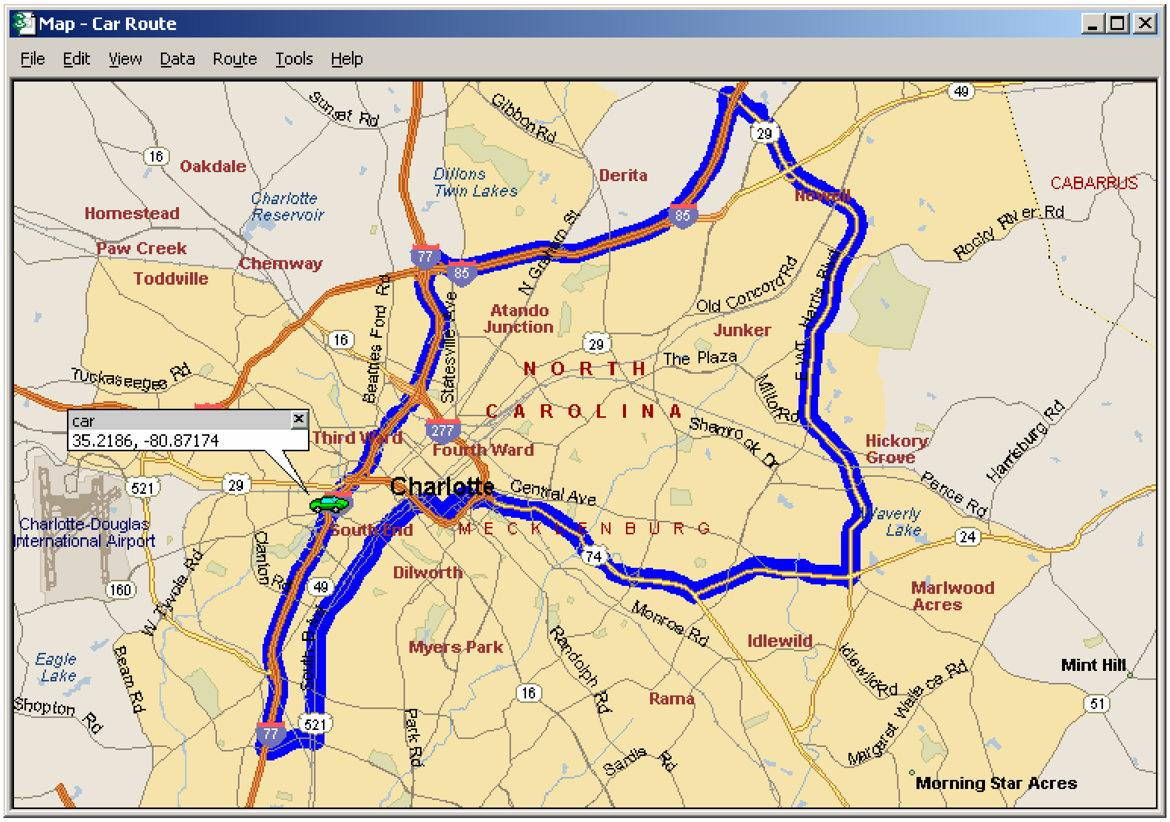
Name	Size	Type	Date
p04	5,138 KB	DAT File	7/11/
s01a	2,663 KB	DAT File	7/10/
s01b	3,776 KB	DAT File	7/10/
s02	6,065 KB	DAT File	7/10/
s03	5,197 KB	DAT File	7/10/
s04	5,632 KB	DAT File	7/10/
	5,879 KB	DAT File	7/10/
	5,632 KB	DAT File	7/11/
	5,200 KB	DAT File	7/11/
s08a	559 KB	DAT File	7/11/
s08b	5,261 KB	DAT File	7/11/
s09	6,436 KB	DAT File	7/14/

Type: DAT File
Date Modified: 7/10/2003 11:52 AM
Size: 5.07 MB

File name: s03
Files of type: Data files (*.dat)
☐ Open as read-only

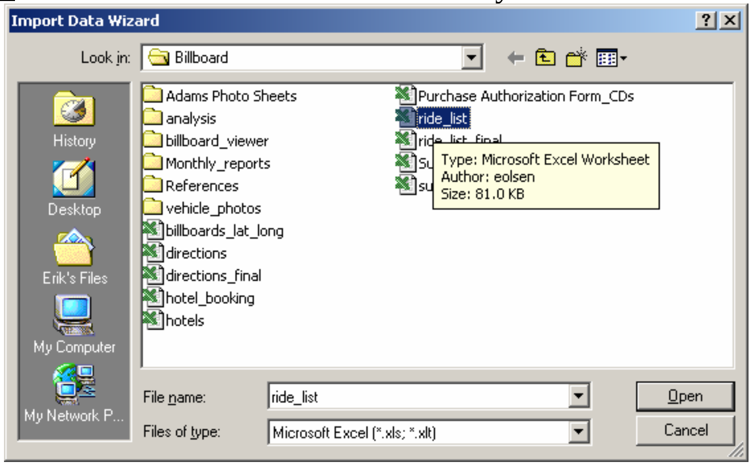
5. Close all the windows, except:

6. From the Display menu select “MapPoint.” Wait a minute for the application to launch completely.
7. Zoom in to the Charlotte, NC area (the blue area on the right side of the USA map) by using the “+” key. The map should look something like this:



Now you can see that that MapPoint map and the mapPlotForm (in the Hundred Car Analyzer application) window correspond to the same route. The MapPoint map will be used to read the GPS coordinates. The mapPlotForm is used to move the position of the vehicle along the map.

8. Within MapPoint, go to the Data menu and select “Import Data Wizard”
9. Select “ride_list.xls” from the “Billboard” directory.



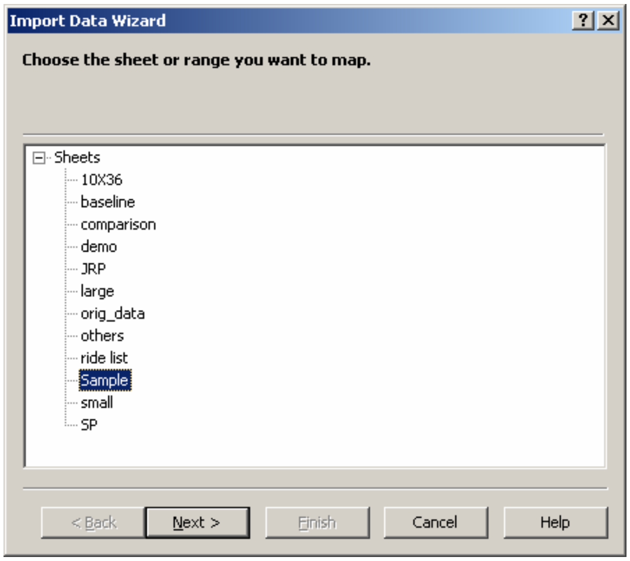
Look in: Billboard

Adams Photo Sheets
analysis
billboard_viewer
Monthly_reports
References
vehicle_photos
billboards_lat_long
directions
directions_final
hotel_booking
hotels
Purchase Authorization Form_CDs
ride_list
ride_list_final
Su
su

Type: Microsoft Excel Worksheet
Author: eolsen
Size: 81.0 KB

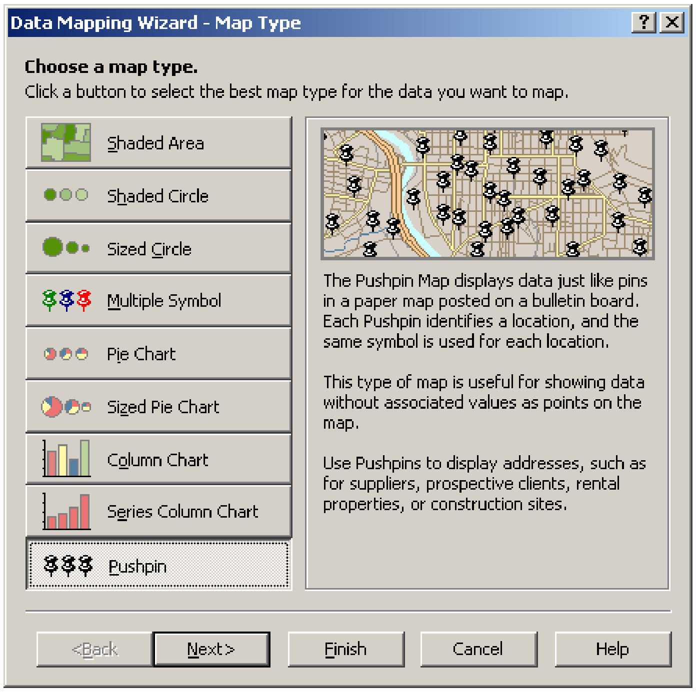
File name: ride_list
Files of type: Microsoft Excel (*.xls; *.xlt)

10. From “ride_list.xls” select “Sample”



Choose the sheet or range you want to map.

11. Select “Next >”
12. Select “Finish”
13. At the bottom of the next window, select “Pushpin”



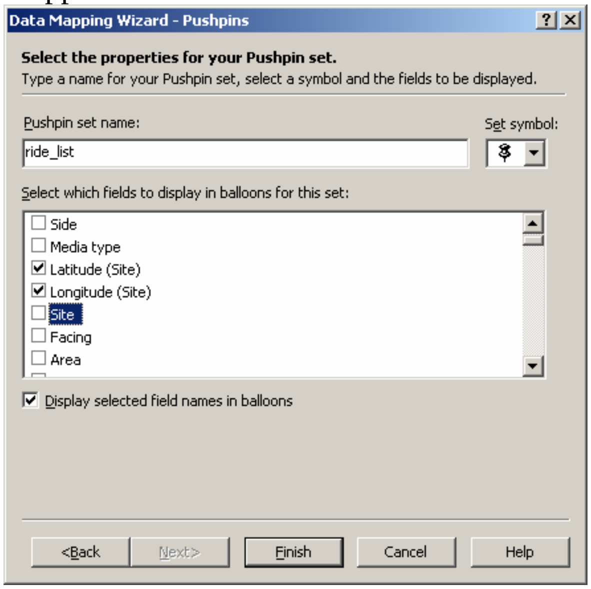
Choose a map type.
Click a button to select the best map type for the data you want to map.

The Pushpin Map displays data just like pins in a paper map posted on a bulletin board. Each Pushpin identifies a location, and the same symbol is used for each location.

This type of map is useful for showing data without associated values as points on the map.

Use Pushpins to display addresses, such as for suppliers, prospective clients, rental properties, or construction sites.

The following window will appear:



Data Mapping Wizard - Pushpins

Select the properties for your Pushpin set.
Type a name for your Pushpin set, select a symbol and the fields to be displayed.

Pushpin set name: ride_list

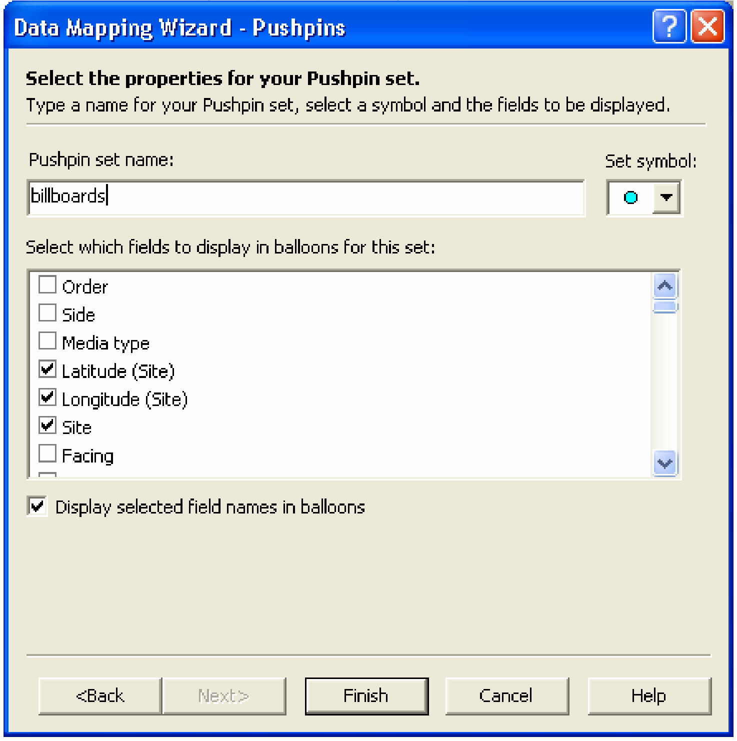
Set symbol:

Select which fields to display in balloons for this set:

- ☐ Side
- ☐ Media type
- ☑ Latitude (Site)
- ☑ Longitude (Site)
- ☐ Site
- ☐ Facing
- ☐ Area

☑ Display selected field names in balloons

14. Set the symbol to a aqua blue dot using the pull down menu labeled “Set symbol”
15. Then select “site” under “Select which fields to display in balloons for this set.” (Latitude and Longitude should already be selected by default.)



Data Mapping Wizard - Pushpins

Select the properties for your Pushpin set.
Type a name for your Pushpin set, select a symbol and the fields to be displayed.

Pushpin set name: billboards

Set symbol: ●

Select which fields to display in balloons for this set:

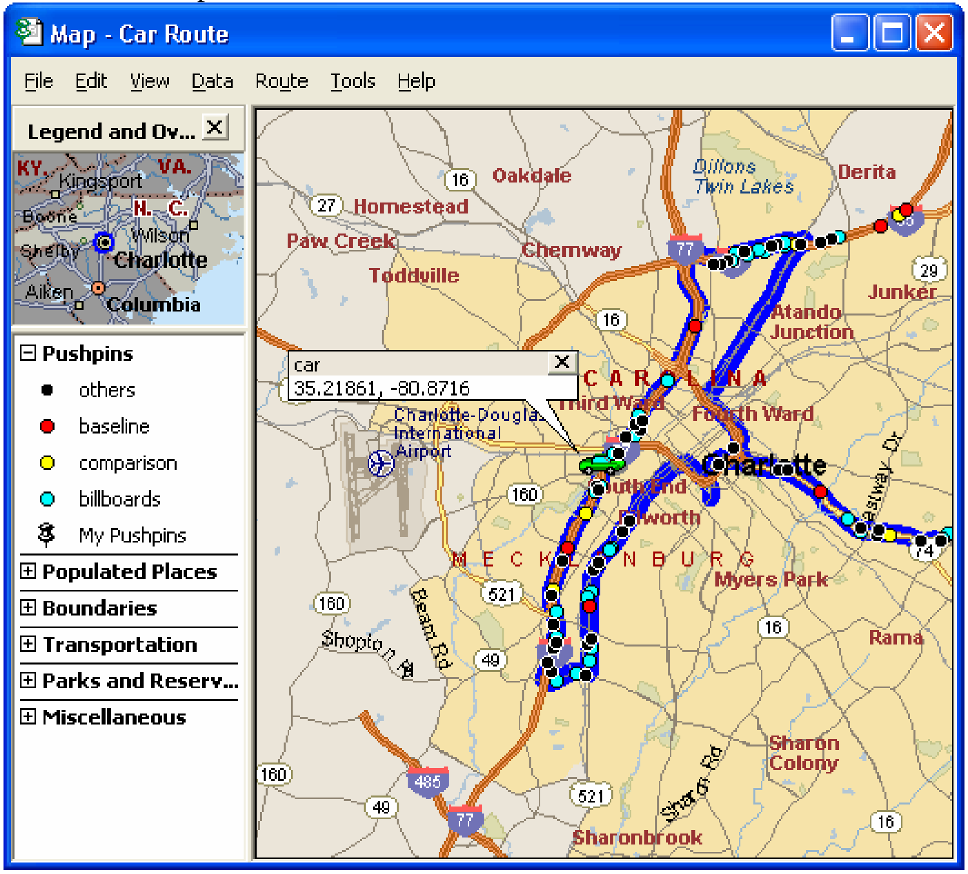
- ☐ Order
- ☐ Side
- ☐ Media type
- ☑ Latitude (Site)
- ☑ Longitude (Site)
- ☑ Site
- ☐ Facing

☑ Display selected field names in balloons

16. Hit the “Finish” button. The map will now show 30 aqua blue dots. These represent the 30 billboard locations.
17. Now repeat the process for:
    - “others” as black dots
    - “baseline” as red dots
    - “comparison” as yellow dots.

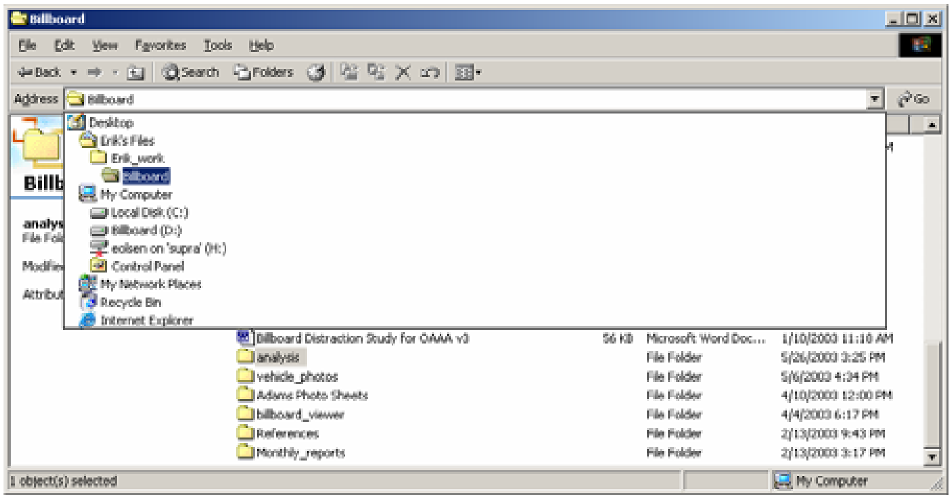
18. Rename each set of push pins listed as shown (ride_list becomes “sample,” ride_list_2 becomes “others” and so on)

The final result will be a map that looks like this:

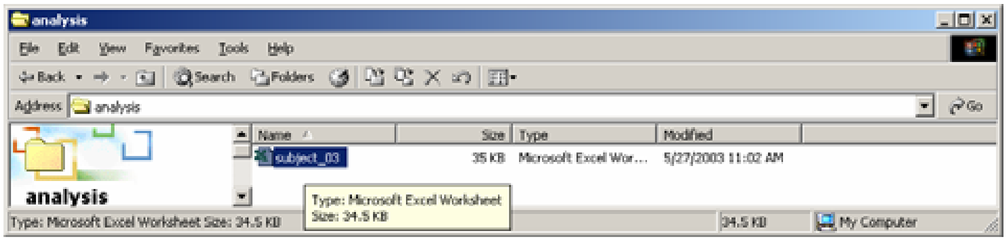


car
35.21861, -80.8716

19. Now, open the Excel file“subject_03.xls” file in the “analysis” directory (within the “Billboard” directory)



Billboard Distraction Study for OAAA v3	56 KB	Microsoft Word Doc...	1/10/2003 11:10 AM
analysis		File Folder	5/26/2003 3:25 PM
vehicle_photos		File Folder	5/6/2003 4:34 PM
Adams Photo Sheets		File Folder	4/10/2003 12:00 PM
billboard_viewer		File Folder	4/4/2003 6:17 PM
References		File Folder	2/13/2003 9:43 PM
Monthly_reports		File Folder	2/13/2003 3:17 PM



Name	Size	Type	Modified
subject_03	35 KB	Microsoft Excel Wor...	5/27/2003 11:02 AM

Type: Microsoft Excel Worksheet
Size: 34.5 KB

Type: Microsoft Excel Worksheet Size: 34.5 KB

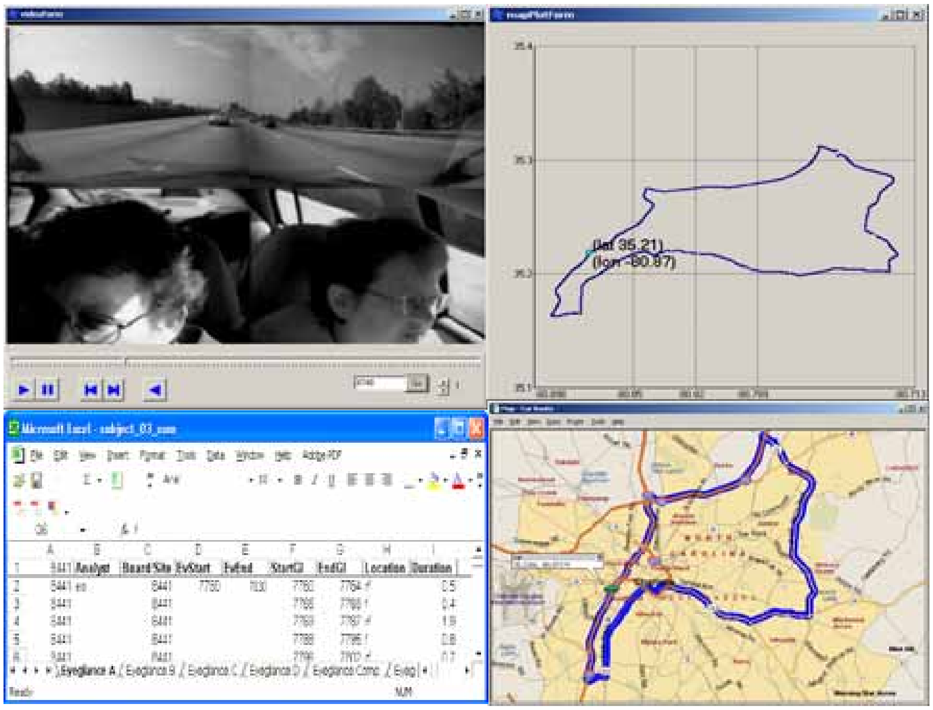
34.5 KB

This data will be entered and saved in Excel. The file will look like this:

Lat	Long	Start	End	Name	Side	Media Type
35.28432	-80.7773	7065	7165	8441	R	14 X 48
35.28174	-80.78312	7302	7402	8489	R	Jr. P.
35.27822	-80.796	7728	7828	12239	L	14 X 48
35.27715	-80.81296	8263	8363	13652	L	14 X 48

etc.

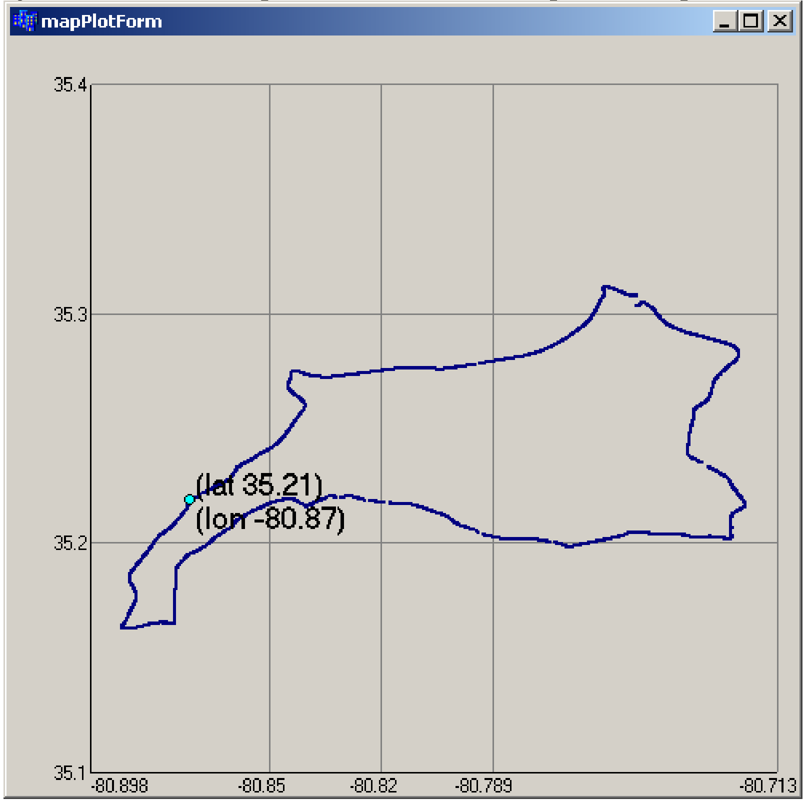
20. Arrange all the windows in the screen so it has the Excel file in the bottom left corner and the MapPoint file on the bottom right corner like this:



Event Identification

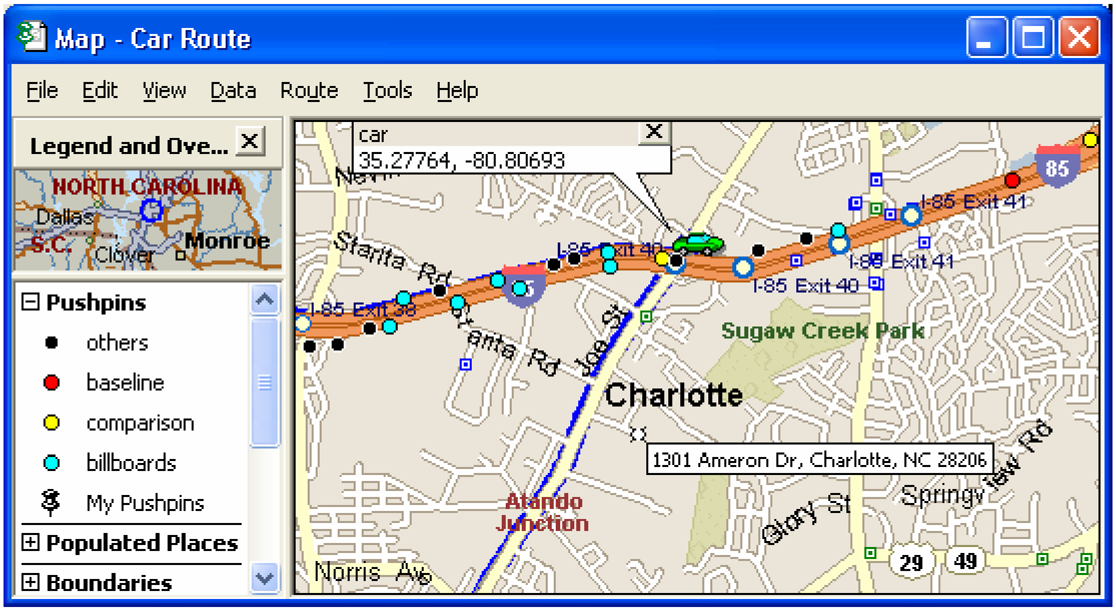
The first step in the analysis is the Event Identification process. This involves forwarding the video using the mapPlotForm.

21. Make sure you can see the mapPlotForm and the MapPoint map at the same time.

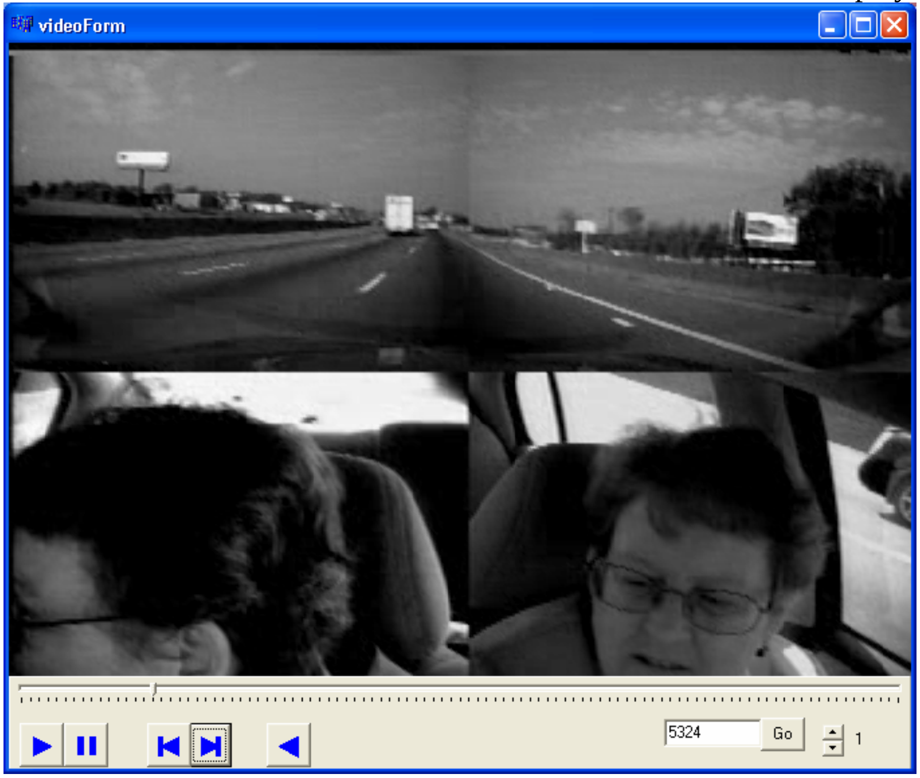


22. Locate the location, a yellow circle (right click and select “show information” to see the info on the map about this location). This is comparison site #2

23. Click on the mapPlotForm at a location just before (to the right of) the aqua blue circle. After you click on the mapPlotForm, the Map Point map should look like this:

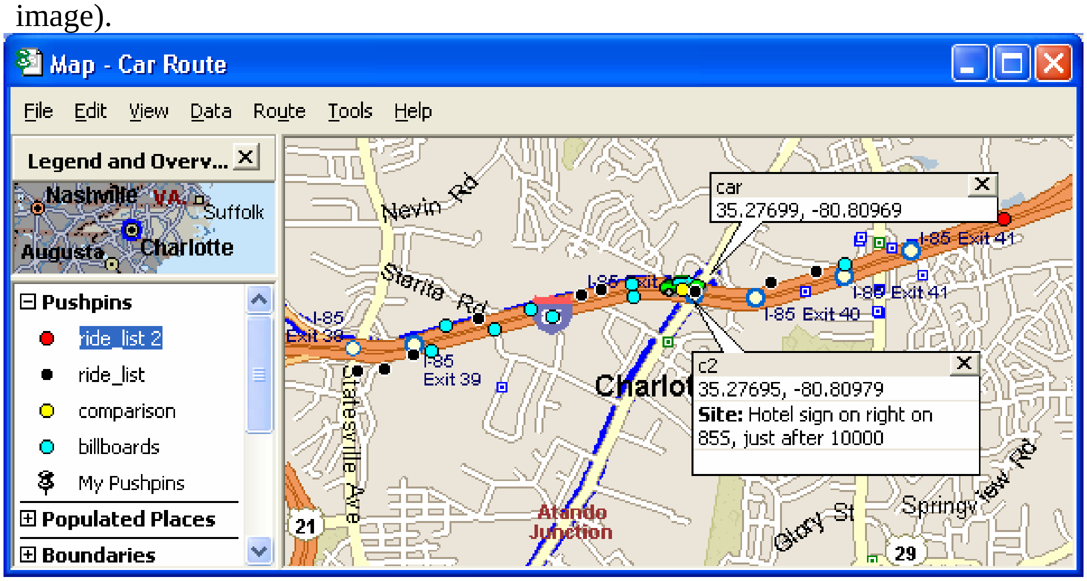

Map - Car Route
File
Edit
View
Data
Route
Tools
Help
Legend and Ove...
NORTH CAROLINA
Dallas
S.C.
Clover
Monroe
Pushpins
● others
● baseline
● comparison
● billboards
My Pushpins
Populated Places
Boundaries
car
35.27764, -80.80693
Starita Rd
I-85 Exit 38
I-85 Exit 40
I-85 Exit 41
I-85 Exit 40
I-85 Exit 41
85
Sugaw Creek Park
Joe St
Charlotte
1301 Ameron Dr, Charlotte, NC 28206
Atando Junction
Glory St
Springview Rd
Norris Av
29
49

24. Use the PLAY and STOP buttons on the Video window to let the video play.



5324

25. Stop the video just as the car lines up with the yellow circle. The lat/long values should be very close (if not exactly) the same for both the car and the location. (Notice also the 2 aqua blue dots on the map corresponding to billboards that are also visible on the video image).



car
35.27699, -80.80969

c2
35.27695, -80.80979
Site: Hotel sign on right on 85S, just after 10000

26. Record (cut and paste) the lat/long values (35.27699, -80.80969) into the Excel file in the first 2 columns.
27. Record the Sync value (7165) in the "End" column
    - The Start value will automatically be filled in (7165-70=7095)
    - Each 10 sync units = 1 second of time

Repeat this process for all 42 locations. There are:

- 30 Billboards (aqua blue dots)
- 7 comparison sites (yellow dots)
- 7 baseline sites (red dots)

NOTE: DO NOT ANALYZE BLACK DOTS. These are other billboards that will not be analyzed (there are 43 black dots). These are included only so that billboard identification is easier during the event identification process.

If you go past a location and need to "go back," stop the video before doing so.

- Then use the mapPlotForm window and click on a location further back on the map to move the video back.

28. For billboard, comparison, and baseline analysis, stop the video on the first sync at which the vehicle icon actually touches the site dot when the map is at the closest zoom level. If the vehicle does not touch the dot at any point, record the last sync before the vehicle passes the dot. Double check the video to be sure the participant is passing the appropriate billboard at the identified time.
    - For example, for the first aqua dot (board #8441), the video will look like the following. Notice the billboard in the upper right corner.

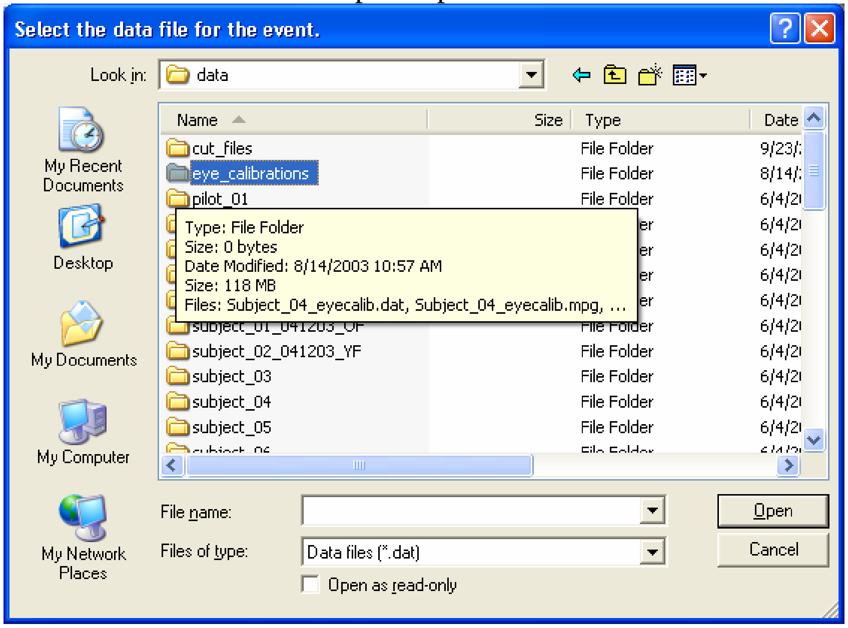
Billboard
#8441

This completes the event identification process. Repeat this process for all events.

Eye glance Analysis

The second step in analysis is recording the direction the participant is looking at each 10th of a second. Before actual analysis, familiarize yourself with that participant's individual eye glance calibrations.

29. By using Admin Tools from the File menu of HundredCarLite application, open the EyeCalibration file for the individual participant.



Select the data file for the event.

Look in: data

Name	Size	Type	Date
cut_files		File Folder	9/23/
eye_calibrations		File Folder	8/14/
pilot_01		File Folder	6/4/2
subject_02_041203_YF		File Folder	6/4/2
subject_03		File Folder	6/4/2
subject_04		File Folder	6/4/2
subject_05		File Folder	6/4/2

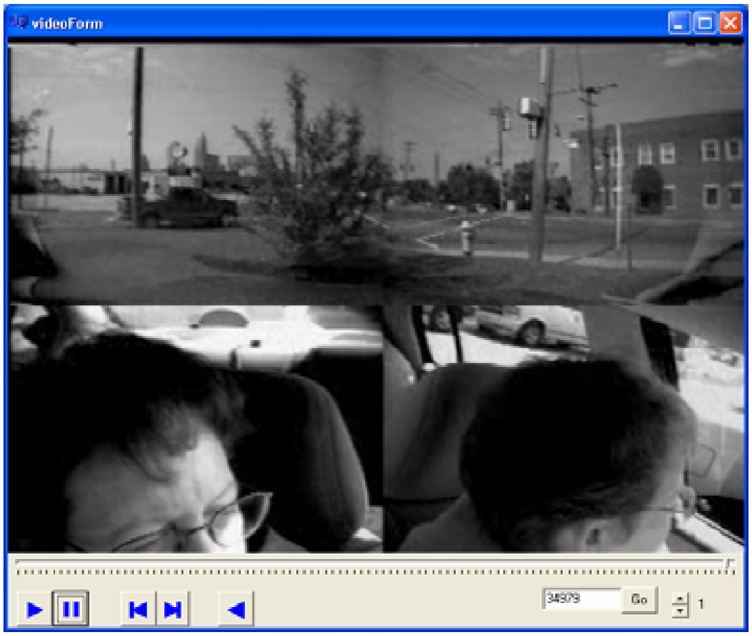
Type: File Folder
Size: 0 bytes
Date Modified: 8/14/2003 10:57 AM
Size: 118 MB
Files: Subject_04_eyecalib.dat, Subject_04_eyecalib.mpg, ...

File name:

Files of type: Data files (*.dat)

☐ Open as read-only

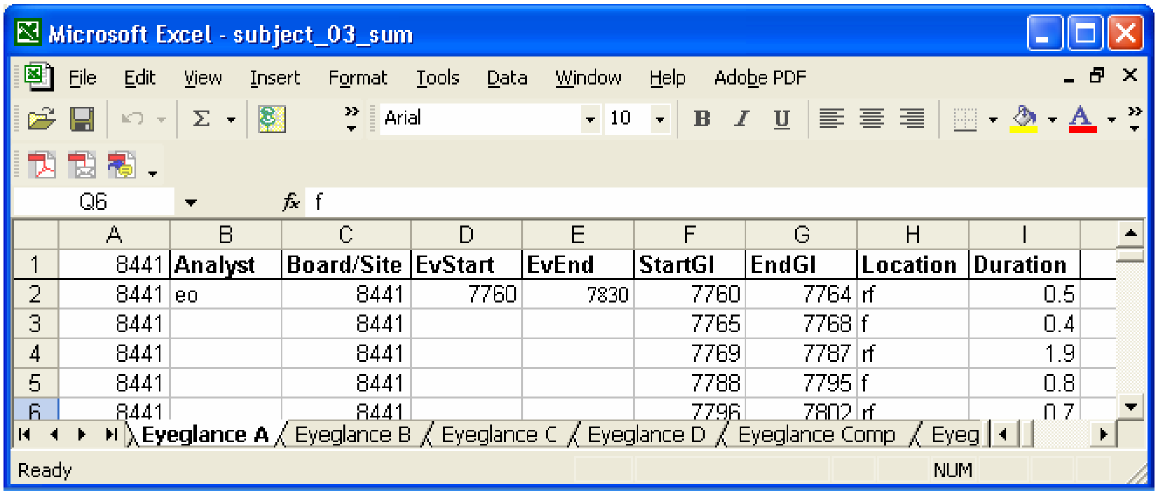
30. Review the eye calibrations several times. Follow the protocol script so you know when the subject is looking in each direction. This subject is looking at the driver's side mirror, which would be coded as OX.



31. By using Admin Tools from the File menu of HundredCarLite application, open the Cut_files file for the individual participant.

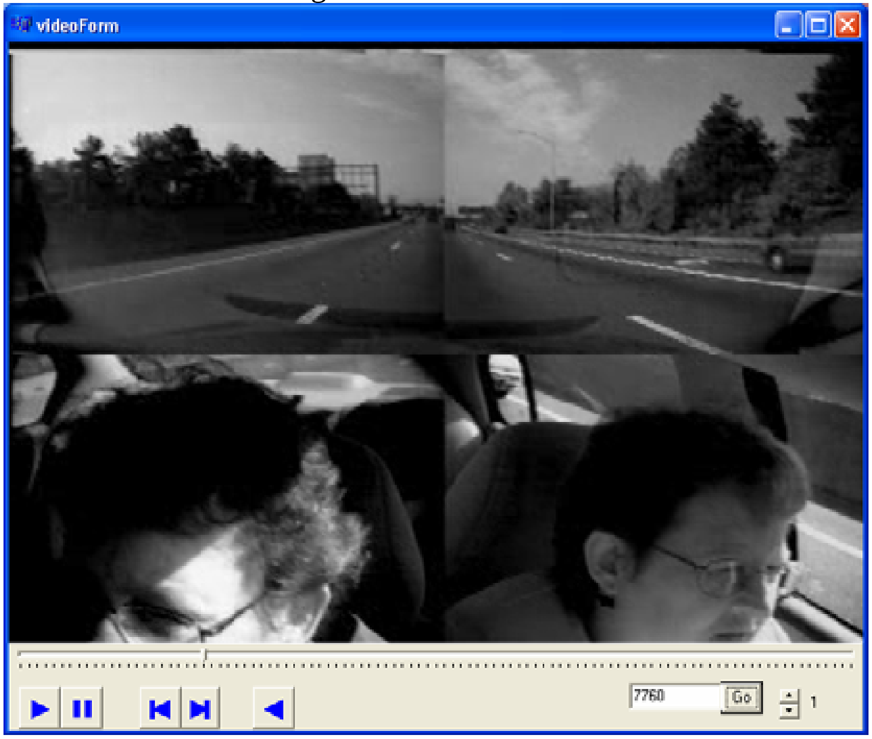
32. Be sure the correct participant's analysis spreadsheet is open.

33. In each participant's spreadsheet there are 6 event analysis tabs, named Eye glance A through D for the 30 primary billboards, Comp for comparison sites, and Base for baseline. Start with Eye glance A and go to the first board (#8441).



	A	B	C	D	E	F	G	H	I
1	8441	**Analyst**	**Board/Site**	**EvStart**	**EvEnd**	**StartGI**	**EndGI**	**Location**	**Duration**
2	8441	eo	8441	7760	7830	7760	7764	rf	0.5
3	8441		8441			7765	7768	f	0.4
4	8441		8441			7769	7787	rf	1.9
5	8441		8441			7788	7795	f	0.8
6	8441		8441			7796	7802	rf	0.7

34. Enter your initials in the "Analyst" column.
35. In the videoForm window of Hundred Car Analyzer, enter in the EvStart value from the Excel sheet and click on "Go" to go to that location.

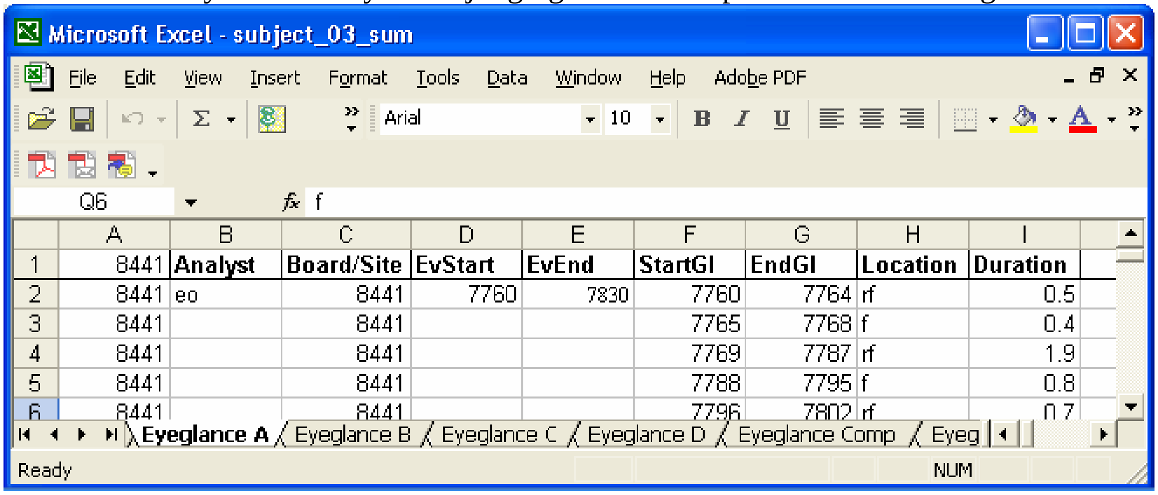


36. Play video until sync in videoForm window reaches EvEnd value in spreadsheet. Review the event several times, forward and backward, to become familiar with the basic eye glance pattern.

37. Note now if the event has a lane change, involves cell phone use, or occurs stopped in traffic. Highlight the analysis master sheet with the appropriate color if necessary. Use yellow for cell phone, green for lane change, and blue for stopped in traffic.

38. Put videoForm on EvStart Sync again. Decide which direction the participant is looking.

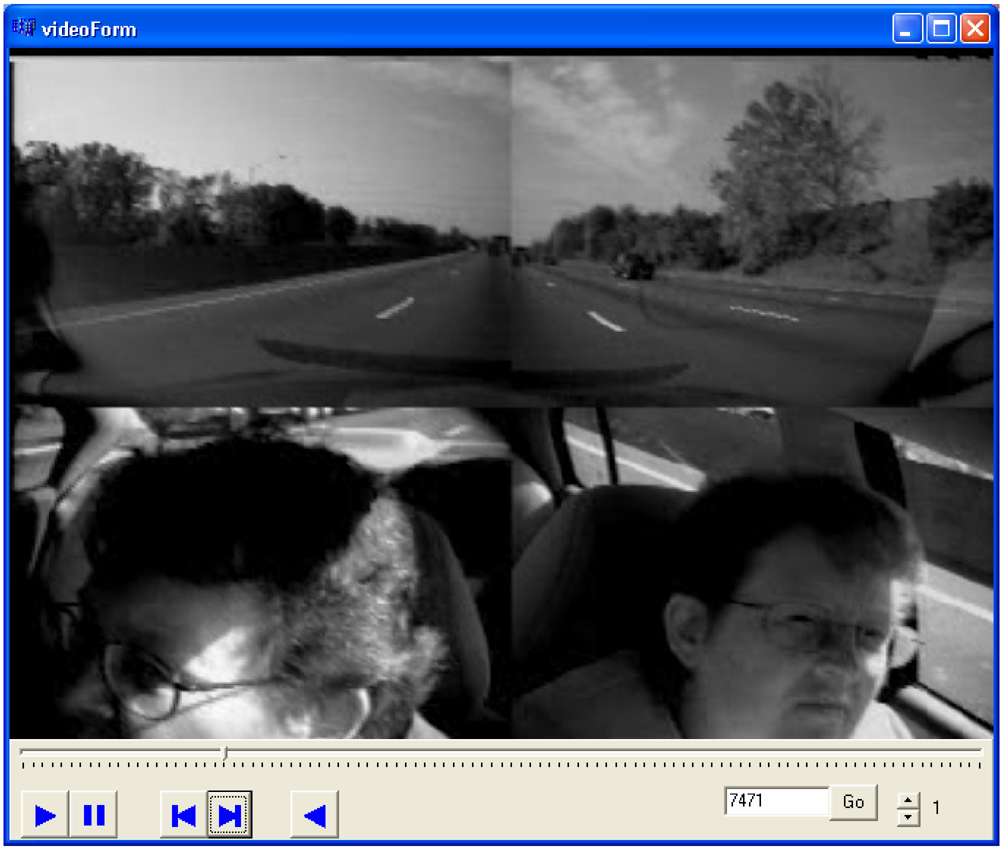
39. Enter the corresponding code into the "Location" column. Be sure to put it in the same row as the sync number you are judging. This example shows "rf" for right forward.



	A	B	C	D	E	F	G	H	I
1	8441	Analyst	Board/Site	EvStart	EvEnd	StartGl	EndGl	Location	Duration
2	8441	eo	8441	7760	7830	7760	7764	rf	0.5
3	8441		8441			7765	7768	f	0.4
4	8441		8441			7769	7787	rf	1.9
5	8441		8441			7788	7795	f	0.8
6	8441		8441			7796	7802	rf	0.7

40. The directions and corresponding codes are as follows:
   - F: forward
   - LF: left forward
   - RF: right forward
   - RVM: rear view mirror
   - OX: other exterior (side windows, left and right mirrors etc.)
   - DIR: directions
   - OINT: other interior (speedometer etc.)

41. Advance the video one sync at a time. When the participant's eyes rest on a different location, enter that sync below the previous one in the StartGl column. That is, the transition time from one location to another is included in the duration calculation for the first location.



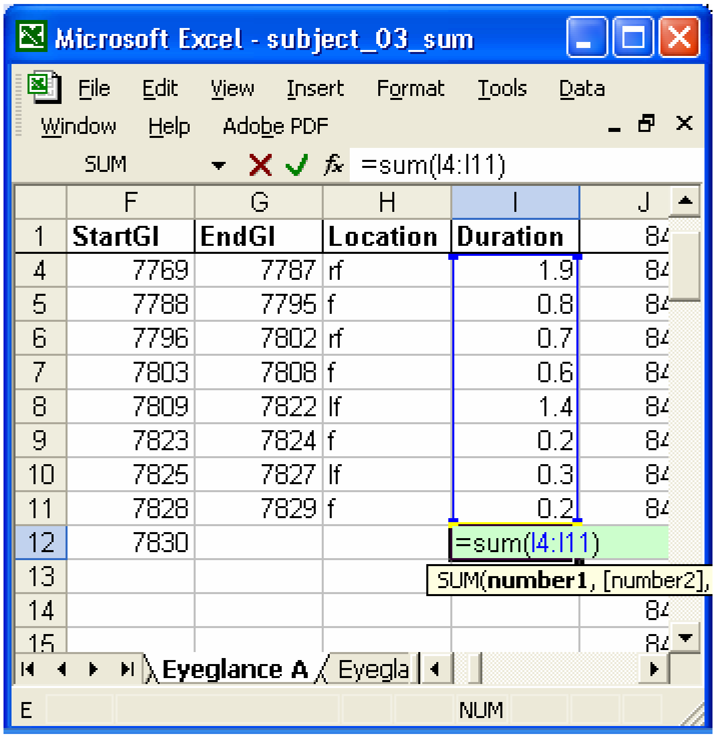
42. The EndGl and Duration values will be calculated automatically.

43. Enter the new glance direction in the Location column. Be sure to stay in the appropriate row.

44. Repeat this process until EvEnd sync has been reached. Do not record a direction for the EvEnd sync.

45. When complete, check duration column to make sure it adds up to 7.

    – Erase the 7 and color the cell green to indicate that it has been checked.



=sum(I4:I11)

	F	G	H	I	J
1	**StartGI**	**EndGI**	**Location**	**Duration**	84
4	7769	7787	rf	1.9	84
5	7788	7795	f	0.8	84
6	7796	7802	rf	0.7	84
7	7803	7808	f	0.6	84
8	7809	7822	lf	1.4	84
9	7823	7824	f	0.2	84
10	7825	7827	lf	0.3	84
11	7828	7829	f	0.2	84
12	7830			=sum(I4:I11)	
13				SUM(**number1**, [number2],	
14					84
15					84

46. Mark your initials and the date with a check mark on the master sheet in the square for that subject, that event.

47. Continue analyzing events, about 1 of every four, until your share of that subject has been completed.

48. Move on to the next subject and repeat.

This is the end of the eye glance analysis process.

Appendix E. Descriptive Statistics for Eyeglance Measures

Table E1. Baseline Site Glance Statistics

# of Glances	**b1**	**b2**	**b3**	**b4**	**b5**	**b6**		**Avg**	**SD**	**Min**	**Max**	**Range**
Forward	3.47	3.89	3.17	3.14	3.47	3.64		3.46	0.28	3.14	3.89	0.75
Left Forward	0.97	0.72	0.50	0.69	0.85	0.50		0.71	0.19	0.50	0.97	0.47
Right Forward	1.28	1.42	0.86	0.86	1.41	2.11		1.32	0.46	0.86	2.11	1.25
Avg Glance Dur.	**b1**	**b2**	**b3**	**b4**	**b5**	**b6**		**Avg**	**SD**	**Min**	**Max**	**Range**
Forward	1.84	1.67	2.00	2.37	1.78	1.65		1.88	0.27	1.65	2.37	0.73
Left Forward	0.22	0.26	0.23	0.33	0.23	0.14		0.23	0.06	0.14	0.33	0.18
Right Forward	0.36	0.34	0.29	0.31	0.51	0.47		0.38	0.09	0.29	0.51	0.22
Total Glance Dur.	**b1**	**b2**	**b3**	**b4**	**b5**	**b6**		**Avg**	**SD**	**Min**	**Max**	**Range**
Forward	4.46	4.79	4.47	4.94	4.83	4.22		4.62	0.28	4.22	4.94	0.72
Left Forward	0.46	0.43	0.29	0.45	0.40	0.23		0.38	0.09	0.23	0.46	0.23
Right Forward	0.73	0.65	0.51	0.44	0.82	1.29		0.74	0.31	0.44	1.29	0.85

Table E2. Comparison Site Glance Statistics

# of Glances	**c1**	**c2**	**c3**	**c4**	**c5**	**c6**		**Avg**	**SD**	**Min**	**Max**	**Range**
Forward	3.86	3.06	2.97	3.40	3.32	3.33		3.32	0.31	2.97	3.86	0.89
Left Forward	0.78	0.53	0.47	1.23	1.06	0.86		0.82	0.29	0.47	1.23	0.76
Right Forward	1.31	1.03	0.92	1.34	1.74	1.53		1.31	0.30	0.92	1.74	0.82
Avg Glance Dur.	**c1**	**c2**	**c3**	**c4**	**c5**	**c6**		**Avg**	**SD**	**Min**	**Max**	**Range**
Forward	1.56	2.13	2.39	1.86	2.13	2.35		2.07	0.31	1.56	2.39	0.82
Left Forward	0.28	0.13	0.20	0.79	0.34	0.47		0.37	0.24	0.13	0.79	0.65
Right Forward	0.40	0.32	0.30	0.42	0.70	0.40		0.42	0.15	0.30	0.70	0.40
Total Glance Dur.	**c1**	**c2**	**c3**	**c4**	**c5**	**c6**		**Avg**	**SD**	**Min**	**Max**	**Range**
Forward	4.40	4.77	4.72	4.16	4.49	5.29		4.64	0.39	4.16	5.29	1.13
Left Forward	0.43	0.23	0.34	1.21	0.57	0.63		0.57	0.35	0.23	1.21	0.98
Right Forward	0.81	0.64	0.59	0.83	1.46	0.84		0.86	0.31	0.59	1.46	0.88

Table E3. Billboard Glance Statistics (first 15 boards)

# of Glances	**12209**	**13052**	**13200**	**13346**	**13351**	**13353**	**1856**	**1895**	**3068**	**3130**	**3197**	**3240**	**7194**	**7245**	**7716**
Forward	3.75	3.26	3.61	3.54	4.06	3.97	3.79	3.62	4.26	4.00	3.69	4.08	3.92	3.53	3.86
Left Forward	1.11	0.68	1.06	1.20	1.21	1.18	1.18	1.44	1.32	1.06	1.06	1.39	1.39	1.32	1.14
Right Forward	1.44	1.62	1.92	1.00	1.56	1.97	1.71	1.26	1.88	1.59	1.39	1.58	1.61	1.24	1.71
Avg Glance Dur.	**12209**	**13052**	**13200**	**13346**	**13351**	**13353**	**1856**	**1895**	**3068**	**3130**	**3197**	**3240**	**7194**	**7245**	**7716**
Forward	1.89	1.56	1.64	1.93	1.40	1.72	1.66	1.79	1.29	1.50	1.69	1.17	1.36	2.01	1.91
Left Forward	0.32	0.44	0.31	0.31	0.32	0.37	0.25	0.45	0.36	0.39	0.33	0.32	0.44	0.38	0.27
Right Forward	0.32	0.53	0.59	0.26	0.44	0.39	0.53	0.42	0.52	0.41	0.57	0.60	0.50	0.52	0.45
Total Glance Dur.	**12209**	**13052**	**13200**	**13346**	**13351**	**13353**	**1856**	**1895**	**3068**	**3130**	**3197**	**3240**	**7194**	**7245**	**7716**
Forward	4.59	3.25	4.03	4.71	4.46	4.63	3.85	4.61	4.09	4.32	4.66	4.06	4.15	4.54	4.63
Left Forward	0.65	0.52	0.58	0.64	0.63	0.61	0.59	0.89	0.79	0.70	0.59	0.67	0.85	0.76	0.59
Right Forward	0.71	1.16	1.27	0.44	0.87	0.99	1.26	0.84	1.20	0.91	0.98	1.09	1.04	0.92	0.97

Table E4. Billboard Glance Statistics (last 15 boards)

# of Glances	**7723**	**8441**	**8489**	**8532**	**8537**	**8568**	**8574**	**8960**	**8998**	**9027**	**9034**	**9071**	**9106**	**9128**	**9159**
Forward	3.60	3.56	3.94	3.23	3.56	3.31	2.94	3.03	4.14	3.25	3.06	3.33	3.34	3.03	3.09
Left Forward	1.00	0.56	1.31	0.63	0.67	0.94	0.83	1.03	1.26	0.75	0.75	0.56	0.80	0.43	0.86
Right Forward	1.74	1.67	1.53	1.46	1.36	1.31	1.11	1.03	1.91	1.08	1.33	0.92	1.09	0.94	1.17
Avg Glance Dur.	**7723**	**8441**	**8489**	**8532**	**8537**	**8568**	**8574**	**8960**	**8998**	**9027**	**9034**	**9071**	**9106**	**9128**	**9159**
Forward	1.99	1.69	1.66	2.02	1.90	2.00	2.53	2.37	1.84	1.94	2.81	1.86	2.07	2.71	2.17
Left Forward	0.29	0.20	0.55	0.23	0.20	0.38	0.34	0.42	0.27	0.33	0.27	0.22	0.27	0.17	0.26
Right Forward	0.60	0.43	0.35	0.49	0.35	0.53	0.35	0.42	0.61	0.47	0.44	0.44	0.29	0.27	0.38
Total Glance Dur.	**7723**	**8441**	**8489**	**8532**	**8537**	**8568**	**8574**	**8960**	**8998**	**9027**	**9034**	**9071**	**9106**	**9128**	**9159**
Forward	4.38	4.51	4.24	4.38	4.86	4.26	4.90	4.95	4.60	4.84	4.83	4.68	5.09	5.31	4.61
Left Forward	0.41	0.34	0.88	0.36	0.29	0.56	0.51	0.67	0.67	0.50	0.39	0.34	0.41	0.20	0.50
Right Forward	1.51	1.05	0.77	0.94	0.72	0.96	0.71	0.64	1.16	0.73	0.85	0.65	0.57	0.59	0.86

Table E5. Billboard Glance Statistics (summary for all billboards)

# of Glances	**Avg**	**SD**	**Min**	**Max**	**Range**
Forward	3.58	0.37	2.94	4.26	1.32
Left Forward	1.00	0.28	0.43	1.44	1.01
Right Forward	1.44	0.31	0.92	1.97	1.05
Avg Glance Dur.	**Avg**	**SD**	**Min**	**Max**	**Range**
Forward	1.87	0.38	1.17	2.81	1.63
Left Forward	0.32	0.08	0.17	0.55	0.38
Right Forward	0.45	0.10	0.26	0.61	0.35
Total Glance Dur.	**Avg**	**SD**	**Min**	**Max**	**Range**
Forward	4.50	0.41	3.25	5.31	2.06
Left Forward	0.57	0.17	0.20	0.89	0.69
Right Forward	0.91	0.24	0.44	1.51	1.08

Table E6. Glance Statistics for Baseline, Comparison, and Billboards

	Baseline		**Comparison**		**Billboard**	
# of Glances	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**
Forward	3.46	0.28	3.32	0.31	3.58	0.37
Left Forward	0.71	0.19	0.82	0.29	1.00	0.28
Right Forward	1.32	0.46	1.31	0.30	1.44	0.31
Avg Glance Dur.	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**
Forward	1.88	0.27	2.07	0.31	1.87	0.38
Left Forward	0.23	0.06	0.37	0.24	0.32	0.08
Right Forward	0.38	0.09	0.42	0.15	0.45	0.10
Total Glance Dur.	**Avg**	**SD**	**Avg**	**SD**	**Avg**	**SD**
Forward	4.62	0.28	4.64	0.39	4.50	0.41
Left Forward	0.38	0.09	0.57	0.35	0.57	0.17
Right Forward	0.74	0.31	0.86	0.31	0.91	0.24

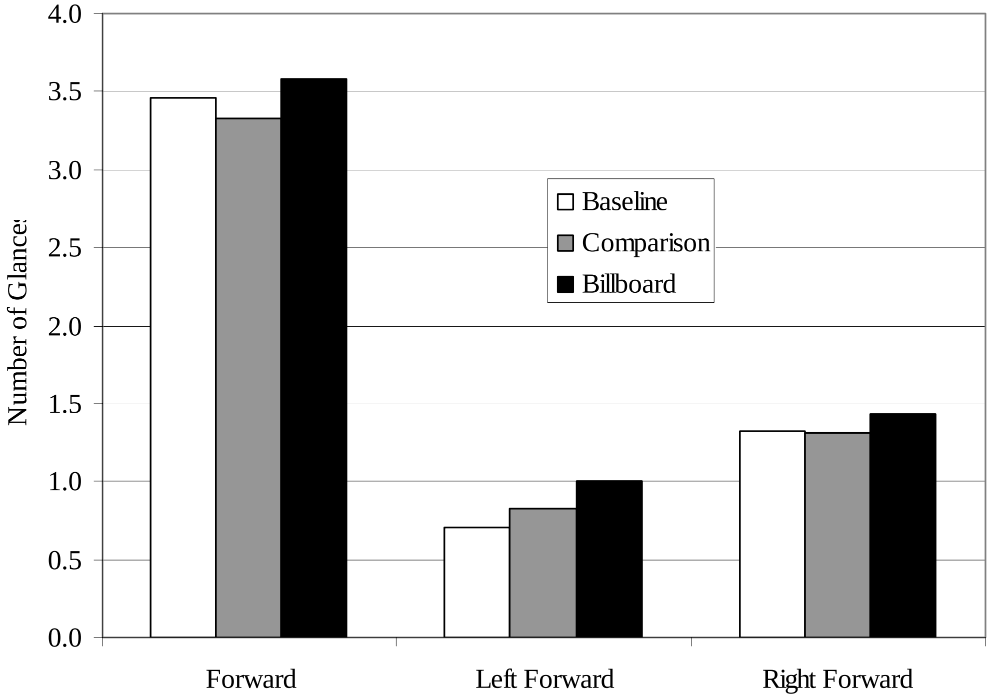


Figure E1. Number of Glances (Averaged) for Baseline, Comparison, and Billboard Sites.

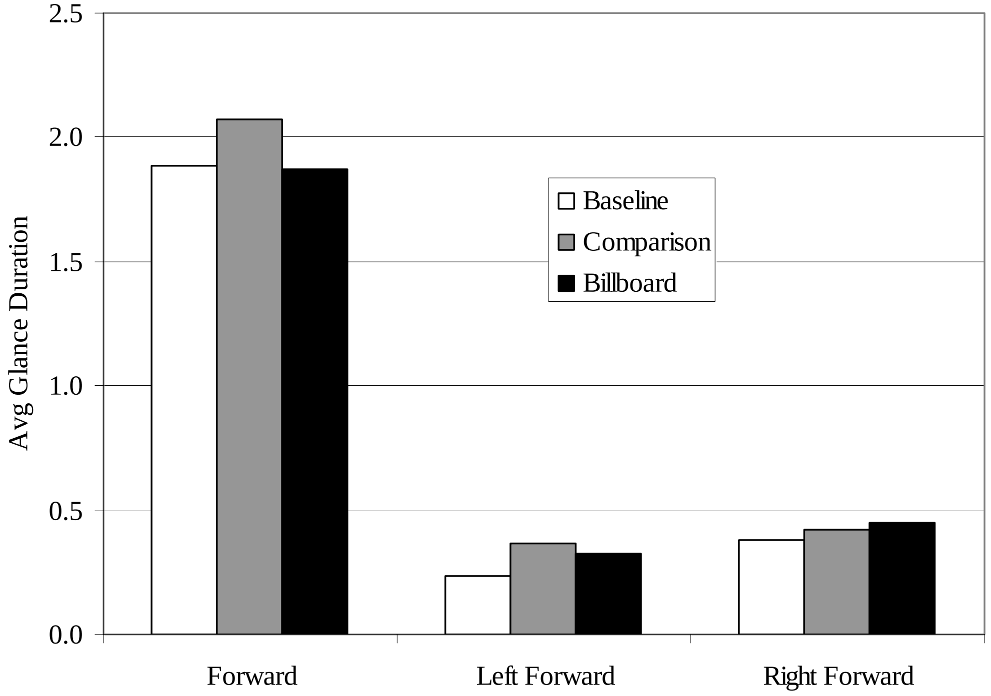


Figure E2. Mean Glance Duration (Averaged) for Baseline, Comparison, and Billboard Sites.

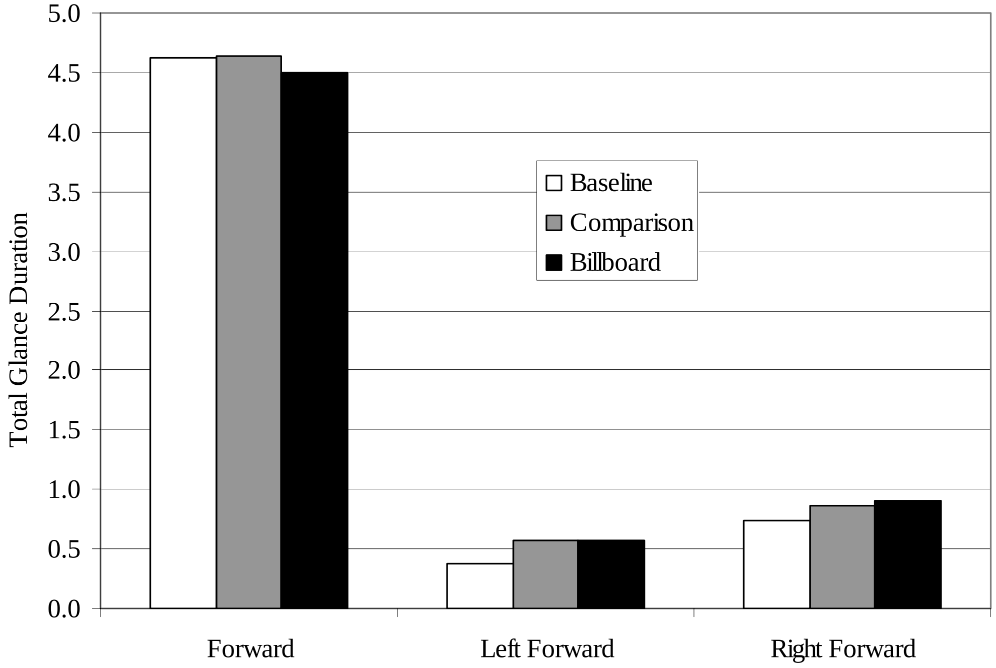


Figure E3. Total Glance Duration (Averaged) for Baseline, Comparison, and Billboard Sites.