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16. Abstract

Very little is known about the effect of motorcycle rider training on visual scanning and sight distance techniques in naturalistic riding situations. This study collected naturalistic data from a mix of novice and experienced motorcycle riders on a closed course and an open course. A custom data acquisition system was developed that monitored the motorcycle rider's head motions, visual behavior, motorcycle speed, GPS location, and motorcycle pitch, yaw, and roll. A portable eye tracker system actively tracked visual behavior and gaze movement of the motorcycle rider as he or she rode over a closed course and an open road course at two 6-month intervals. There were three groups of riders. One group of beginner riders had recently received their motorcycle endorsement and completed the Team Oregon Basic Rider Training course (beginner-trained). A second group of beginner riders had recently received their motorcycle endorsement but had not enrolled in any type of motorcycle rider training program (beginner-untrained). The third group consisted of experienced riders with a minimum of 5 years and 15,000 miles of riding experience (experienced).

During test sessions 2 and 3 on the curved section of the open road course, the sight distance to stopping distance ratio for beginner-untrained riders fell below 1.0 more than twice as often as the other two groups. Sight distance to stopping distance ratio indicates that the distance necessary to stop was greater than the distance the rider was looking ahead. Beginner-untrained riders also scanned a larger area during the open road course than experienced riders. The preliminary findings suggest that there may be a relationship between training, experience, and visual behavior among motorcycle riders. It is feasible to collect naturalistic eye tracking data from motorcycle riders of varying experience levels using their own vehicles. Technical challenges of collecting data with this new technology are also discussed.

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At the time this study was being conducted, Dr. Jessica Cicchino was a research psychologist at the National Highway Traffic Safety Administration's Office of Behavioral Safety Research.

EXECUTIVE SUMMARY

Motorcycle riding represents an enjoyable mode of transportation or recreation for millions of Americans. Because motorcycle riders are considered vulnerable road users, active involvement of the rider in terms of vehicle control and hazard perception is critical to safe and effective motorcycle riding. Little is known about how training on visual scanning techniques, such as training on sight distance provided in the Team Oregon Basic Rider Training course, affects the visual behavior of motorcycle riders.

This study collected over-the-road naturalistic motorcycle data, including head and eye movement, with novice and experienced motorcycle riders that monitored the motorcycle's motion and the behavior of the motorcycle rider. A custom data acquisition system was developed that recorded the motorcycle rider's head motions and visual behavior as well as motorcycle speed, GPS location and motorcycle pitch, yaw and roll. Visual behavior was monitored using a portable eye tracker system (Arrington Research, Inc.) that actively tracked the gaze movement of the motorcycle rider as he or she rode over a closed course and an open road course. The purpose of the project was to determine if visual behavior differs between beginner riders who have received training on sight distance, beginner riders who have not received training, and experienced riders. An additional objective was to develop the data acquisition system necessary to collect these data, and to demonstrate the feasibility of collecting eye-tracking data on the open road from riders with a variety of experience levels.

Methods

Data were collected from three groups of riders. Beginner-trained riders were novice riders recruited from the Team Oregon Motorcycle Program, beginner-untrained riders were novice riders who had not received motorcycle rider training, and experienced riders had at least 5 years and 15,000 miles of riding experience. Seven beginner-trained riders, 12 beginner-untrained riders, and 12 experienced riders completed three data collection sessions over one year. Beginner-trained and experienced riders were given feedback on their sight distance behavior after each testing session, and beginner-untrained riders were not given feedback.

Rider and motorcycle data was collected on a closed skills course and a 9.4-mile public road route in Portland, Oregon. Riders were monitored by Team Oregon instructors during the closed course testing and were accompanied over the road by a Team Oregon instructor who followed the riders and provided directional instruction.

Over 30 hours of video gaze data and rider/motorcycle motion data were collected during this project. Initial data analyses evaluated selected portions of the closed and open road courses to determine whether or not any quantitative differences in gaze and sight distance behavior could be observed between the different rider groups. Two visual behavior measures were evaluated. The number of times the sight distance to stopping distance ratio fell below 1.0, which indicated that the distance necessary for the rider to stop was greater than the distance the rider was looking ahead, was analyzed for a curved section of the closed course, a curved section of the open road course, and a straight section of the open road course. The size of the gaze 95% confidence ellipse, or the area the rider scanned, was analyzed over the entire closed course and entire open road course.

Results

The results showed several differences in visual behavior between the rider groups. During test sessions 2 and 3 (the open road sessions in which all rider groups were tested), the sight distance to stopping distance ratio went below 1.0 more often for beginner-untrained riders than for beginner-trained and experienced riders over the curved section of the open road course. Additionally, the number of times the sight distance to stopping distance ratio went below 1.0 decreased significantly between test session 2 and test session 3 across rider groups on the open road course sections. Over the open road course, beginner-untrained riders had a significantly larger gaze 95% confidence ellipse area than experienced riders.

Groups also differed in their speed and motorcycle handling skills. Beginner-trained riders rode more quickly over the curved section of the closed course than the other two rider groups, and the experienced riders rode more quickly over the curved section of the open road course than the other two rider groups. Riders were additionally rated on their handling skills while riding over the closed course. Across groups, riders performed significantly better on the closed course circuit ride during test sessions 2 and 3 than during test session 1. Experienced riders performed significantly better on the circuit ride than beginner-trained and beginner-untrained riders.

Conclusions

This study demonstrates that it is feasible to collect naturalistic eye tracking data from motorcycle riders of varying experience levels. On some measures, differences were observed between the visual behavior of beginner-untrained riders and the visual behavior of riders in the beginner-trained and experienced groups. The preliminary findings suggest that there may be a relationship between training, feedback on sight distance, and riders’ visual behavior on the road.

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INTRODUCTION AND BACKGROUND

Magnitude of the Problem

Motorcycle use in the United States for commuting and recreational purposes has been increasing since the mid-1990s, with motorcycle registrations having more than doubled between 1997 and 2010 (FHWA, 2012). In 2010, motorcycles represented approximately 3% of the Nation's registered vehicles, but 13.7% of all traffic fatalities (FHWA, 2012; NHTSA, 2012).

As the number of motorcyclists on U. S. roadways increases, so does the number of motorcycle riders killed and injured. Despite the motorcycling community's efforts to improve its safety record through initiatives such as rider training and licensing campaigns, the number of motorcycle injuries and fatalities continued to increase through 2008 (see Table 1). Motorcycle fatalities decreased in 2009 for the first time since 1997, but were still substantially higher than they had been a decade earlier.

Table 1. Trends in Motorcycle Fatalities and Injuries
(Source: NHTSA, Fatality Analysis Reporting System and General Estimates System)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total Killed on U.S. Roadways	42,196	43,005	42,884	42,836	43,510	42,708	41,259	37,423	33,883	32,885
Motorcyclists Killed	3,197	3,270	3,714	4,028	4,576	4,837	5,174	5,312	4,469	4,502
% Change Of Motorcyclists Killed From Previous Year	+10.4%	+2.3%	+13.6%	+8.5%	+13.6%	+5.7%	+7.0%	+2.7%	-15.9%	+0.7%
Motorcyclists Injured	60,000	65,000	67,000	76,000	87,000	88,000	103,000	96,000	90,000	82,000
Motorcyclist Fatalities as % of all Fatalities	7.6%	7.6%	8.7%	9.4%	10.5%	11.3%	12.5%	14.2%	13.2%	13.7%

In an effort to improve awareness of motorcycle safety issues, in 1998 the National Highway Traffic Safety Administration and the Motorcycle Safety Foundation (MSF) formed a technical working group of representatives of safety organizations, motorcycling groups, law enforcement agencies, the insurance industry and the motorcycling press. The mission of this group was to develop a national agenda that would indicate "the most promising avenues for future motorcycling safety efforts in the United States" (NHTSA & MSF, 2000, pg. 1). In 2000, the National Agenda for Motorcycle Safety document was published, addressing the various factors that affect motorcycle safety, including rider education and licensing, motorist awareness, motorcycle design, roadway characteristics, personal protective equipment, and motorcyclists' attitudes toward safety. This document represented a key resource for guidance on improving motorcycle safety and awareness.

Among its more than 80 recommendations was the expressed need for additional research to determine which rider crash avoidance skills are most important and to examine technological approaches to enhance crash prevention. The recent development of new technologies such as portable eye tracking systems will provide new insights into the naturalistic riding behavior of the motorcycle rider. This report summarizes efforts to use this novel technology to evaluate rider behavior in a closed course and over the open road.

Visual Gaze and Motorcycle Research

The scanning skills of a vehicle operator represent a key parameter for hazard perception and effective vehicle operation (Green, 2002; Underwood, 2007). There have been a few studies that describe the scan patterns of motorcycle riders. Nagayama, Morita, Miura, Watanabe, and Murakami (1980) found a significant difference in the visual scanning pattern of motorcyclists when compared to automobile drivers. They reported that motorcycle riders adopted a near and far visual scanning pattern (i.e., scanning the region close to the motorcycle and then scanning far ahead of the motorcycle) to obtain information from both the closer road surface as well as the distant horizon. In contrast, automobile drivers spent the majority of their visual scanning time looking at the distant horizon. Mortimer and Jorgeson (1975) found that motorcycle riders had longer mean dwell times of eye fixations when compared to the same participant driving an automobile. Based on these findings, they proposed that the motorcycle rider was more concerned with the character of the roadway, focused more upon the pavement to determine potential threats such as holes or ruts and therefore adopted a different strategy than the automobile driver. These studies suggested that the visual scanning strategy for motorcycle riding is different than the visual scanning strategy for automobile driving.

The early motorcycle scanning research that was performed in the late 1970s was difficult due to the technological limitations at the time (e.g., large video cameras and data acquisition systems). However, with the development of small and portable visual eye tracking systems, there have been a large number of publications related to typical scanning and gaze behaviors of vehicle operators as part of the task of vehicle control. For example, Robertshaw and Wilkie (2008) studied the visual gaze patterns of drivers as they proceeded to negotiate a bend in a virtual driving environment. The goal of their research was to test Land’s (1998) theory of curve negotiation by determining whether or not drivers tended to focus on the tangent point of a curve in order to control steering. Robertshaw and Wilkie (2008) found that drivers did not focus on the tangent of the curve but rather spent the majority of their time looking where they wanted to go. Monitoring of the vehicle path further indicated that in nearly all cases, the vehicle travelled along the visual path followed by the driver.

If a motorcycle also tends to travel along the rider’s visual path, it is possible that riders who fixate on the tangent or somewhere other than the forward roadway when negotiating a curve might follow a trajectory that takes them off the main roadway. These riders may be overriding their sight distance—that is, not looking far enough down the roadway to allow time to detect and respond to changes in the environment. This could explain a cause of single vehicle crashes in which no other contributing factors such as excessive speed or alcohol are present.

Eye tracking research with automobile drivers and pilots has demonstrated that novice vehicle operators exhibit different visual gaze strategies than experienced drivers and pilots. For instance, Kasarskis, Stehwien, Hickox, Aretz, and Wickens (2001) discovered that expert pilots have better defined eye scanning patterns when compared to beginner pilots and spend less time fixating on objects in their environment. Experienced automobile drivers have been found to scan a wider area of the visual scene than inexperienced drivers (Crundall & Underwood, 1998; Mourant & Rockwell, 1972). Little research exists, however, on if visual gaze strategies differ in the same way between inexperienced and experienced motorcycle riders. Furthermore, it is also unknown whether or not basic motorcycle rider training and feedback on visual skills provide sufficient information to improve the visual gaze strategies of beginner motorcycle riders. While there has been some recent work comparing the hazard perception skills of inexperienced and experienced motorcycle riders in a simulator (Hosking et al., 2010), at present there is no published research available that has reported differences between the gaze patterns of beginner motorcycle riders relative to experienced motorcycle riders in a naturalistic riding environment.

Research Goals

A primary objective of this research was to develop the instrumentation necessary to collect head and motorcycle motion as well as visual gaze behavior during normal over-the-road motorcycle operation. The design aim was to develop instrumentation that could be easily adapted to the subject's own motorcycle in order to eliminate any effect of vehicle unfamiliarity.

Once the data acquisition system was developed and implemented, the goal of this research was to capture visual scanning information from motorcycle riders participating in both closed course and open road riding scenarios. Three different rider groups participated in this study: beginner-trained riders who had received entry-level rider training, beginner-untrained riders who had not received entry-level rider training, and experienced riders. Since this research included beginner riders, a longitudinal component was added to the research to better understand changes that may take place in visual scanning behavior as riding experience increases. Data collection sessions were conducted at the initial onset of the study and then again at 6 months and 12 months after the initial data collection session. Beginner-trained and experienced riders received feedback on their visual behavior after each test sessions, and beginner-untrained riders did not receive feedback.

Research Questions

In addition to collecting as much naturalistic motorcycle riding data as possible, the present study sought to answer questions related to motorcycle rider visual scanning and examine the differences that may exist between beginner-trained, beginner-untrained and experienced riders. In order to accomplish this goal it was necessary to gain access to motorcycle riders with various levels of motorcycle riding experience and training. Oregon was chosen as a suitable location for this study because all motorcycle riders who choose to receive motorcycle training receive it from Team Oregon, which is responsible for implementing motorcycle rider training programs throughout the State. The Team Oregon Basic Rider Training (BRT) course includes continuous practice and continuous emphasis to beginner riders on getting their heads up and looking as far ahead of them as possible. This message is emphasized both in the classroom and on the range.

Sight distance and magnitude of the rider's visual gaze area were chosen as the primary variables to monitor and compare across different riding groups and over time. Sight distance is a measure of how far down the roadway the rider was looking, and was calculated as the instantaneous distance between the rider and his or eye gaze point on the roadway. The magnitude of the visual gaze area was defined as the size of the area the rider scanned, as measured by the x,y coordinate data provided by the eye tracker system.

The effects of the instruction on sight distance provided in the Team Oregon BRT course, feedback on sight distance, and riding experience were analyzed by comparing the sight distance and scanning characteristics of beginner-trained and beginner-untrained riders as well as those of beginner and experienced riders. It was hypothesized that experienced riders would have a larger visual gaze area than novice riders, which would suggest that experienced riders scanned more of the riding environment in front of them. Additionally, it was hypothesized that untrained riders, who did not receive training or feedback on sight distance, would exhibit a short sight distance (i.e. looking down at the roadway in front of the motorcycle rather than further down the road) more often than trained riders.

The present study also included both closed course and open road segments. This format provided a safe environment for the beginner riders and also provided baseline data that could be used to compare the open road visual behavior. It was assumed that the visual skills required to safely complete the closed course segment was similar to the visual skills necessary on the open road.

METHODOLOGY

Rider Participants

Fifty-eight beginner-trained, beginner-untrained and experienced riders were recruited for this study. Beginner-trained riders were defined as any rider who registered for a Team Oregon BRT course and agreed to participate. Beginner-untrained riders were recruited through a cooperative agreement between Oregon State University and the Oregon Motor Vehicles Division. The Oregon rider registration database was used to identify riders who had recently received a motorcycle endorsement but who had not registered for a Team Oregon Basic Rider Training course. The research team attempted to keep time between receiving the motorcycle endorsement and study participation to a minimum in order to allow comparison of the visual scanning characteristics of beginner-untrained riders to beginner-trained riders (i.e., both groups should have approximately the same amount of riding experience, with the exception that one group received rider training). However, as seen in Table 2, the beginner-trained riders had almost no riding experience prior to participation, while the beginner-untrained riders had an average of one year of riding experience at the start of the study.

Experienced riders were recruited from the Team Oregon database of riders that included all riders who had previously completed one or more of the Team Oregon motorcycle courses and from local newspapers. The criteria for experienced riders were that they had a minimum of 5 years and 15,000 miles of riding experience. Experienced riders were not required to have completed a rider training course.

Potential participants were initially screened via telephone for the above criteria and for their availability to participate. Each rider was asked to use his or her own motorcycle for the entire duration of the data collection. Beginner-trained riders were permitted to use a Team Oregon motorcycle for their initial baseline closed course testing; however, they were required to obtain a motorcycle for all future testing. Beginner-trained riders who did not obtain a motorcycle were dropped from the study.

Table 2. Rider Participant Characteristics

	Beginner-Trained riders	Beginner-Untrained riders	Experienced riders
Number of participants	7	12	12
Mean age (SD)	40.7 (11.1)	36.8 (9.0)	39.3 (8.9)
Males (%)	3 (43)	11 (92)	11 (92)
Females (%)	4 (57)	1 (8)	1 (9)
Average mileage per day (miles) (SD)	n/a*	28.5 (17.6)	56.0 (54.3)
Average mileage per year (miles) (SD)	n/a*	1641.7 (1140.4)	9458.3 (5824.9)
Number of years owning a motorcycle (SD)	1.1 (0.4)	1.5 (0.7)	3.1 (3.0)
Number of years riding motorcycles (SD)	0.1 (0.1)	1.0 (1.1)	18.1 (11.6)
Percent use of motorcycle for commuting	n/a*	38.8 (32.0)	52.5 (22.3)
Percent use of motorcycle for recreation	n/a*	61.2 (32.0)	47.5 (22.3)
Frequency distribution of manufacturers of motorcycles owned			
Honda	1	5	2
Harley Davidson	1	0	1
Kawasaki	1	3	2
Yamaha	1	3	2
BMW	0	0	2
Suzuki	1	1	1
Other	2	0	2

*Beginner-trained riders were not asked questions marked with “n/a.”

All participants were informed of the nature of the study as well as the risks of the study and all agreed to participate. All questionnaires and procedures related to participant contact were reviewed and approved by the Oregon State University Institutional Review Board. From the original pool of 58 riders who were originally recruited, 46 completed the first data collection in early 2009 and 31 participants completed all three phases of the study (5 female and 26 male riders). Seven beginner-trained riders, 3 beginner-untrained riders and 5 experienced riders were not able to complete all three phases of testing. The reasons for participant attrition were either personal (e.g. “I have stopped riding” and/or “I don’t have a motorcycle”) or related to difficulties associated with schedule coordination between the research staff, the testing site at Portland Community College and the participant’s own personal schedule. The distribution of riders who completed all three phases of the study is presented in Table 2.

Each rider trial was reviewed by a member of the Team Oregon staff as well as a member of the DRI staff in order to determine if the trial was acceptable or if the trial needed to be repeated. Special attention was paid to the accuracy of the calibration of the eye tracker over the course of the data collection section and the reported speed from the GPS-based Speedbox system. For those cases in which the trial was repeated, the main reason was that the eye tracker glasses had shifted while the rider was on the open road course. This shift would create a false gaze location and consequently the data collection had to be repeated. Fortunately, repeat data collection was necessary in less than 5% of collected trials.

Instrumentation

Figure 1. Helmet with eye tracking system

In order to monitor visual scanning behavior of a number of different motorcycle riders on their own motorcycles, a completely mobile and portable data acquisition system had to be developed. The system included a Giga Bit-E eye-tracker system (Arrington Research, Inc.) that could be used with a portable laptop system and small battery pack (see Figure 1). The eye-tracker software was integrated and synchronized with a Speedbox transducer that monitored the motorcycle speed as well as the instantaneous GPS location (Race Technologies, Inc.). The orientation of the motorcycle and the motorcycle rider's helmeted head were measured using two inertial measurement units (MotionNode Systems) that provided real-time orientation information in all three axes.

One inertial unit was mounted on the participant's helmet (supplied by the research staff) while the other was to be mounted into the case that contained the Speedbox unit. A complete list of all variables collected is presented in Table 3.

Table 3. List of Variables Collected

Variable	**Data Source**
x eye location in gaze space	Arrington GigaBit-E Eye Tracker
y eye location in gaze space	Arrington GigaBit-E Eye Tracker
Eye gaze in region of interest	Arrington GigaBit-E Eye Tracker
Fixation duration	Arrington GigaBit-E Eye Tracker
Motorcycle GPS position	Race Technologies Speedbox
Motorcycle speed	Race Technologies Speedbox
3 dimensional motorcycle orientation	MotionNode System 1 on motorcycle
3 dimensional head orientation	MotionNode System 2 on helmet

Once the eye tracker system and inertial sensors were properly zeroed and calibrated, custom data acquisition software was initiated and data was streamed to the computer hard disk. Data collection was continuous throughout the closed course and the open road course runs and was not terminated until the rider returned back to the staging area upon completion of the open road course. When the rider returned to the staging area, the computer program was stopped and all hardware was removed from the rider and the motorcycle.

Experimental Design and Protocols

Both closed course testing and open road testing were performed during this study. The testing schedule for each participant group is presented in Table 4. For safety reasons, those participants in the beginner-trained group were not tested on the open road during the baseline testing session, since these riders had almost no riding experience prior to participation in the study. All other participants were evaluated on both the closed course test and the open road test.

Table 4. Test Protocols over the Duration of the Project

Participant category	Baseline	6 months	12 months
Beginner-Trained (almost no experience)	Closed course test	Closed course test Open road test	Closed course test Open road test
Beginner-Untrained (on average, one year of experience)	Closed course test Open road test	Closed course test Open road test	Closed course test Open road test
Experienced (minimum of 5 years of experience)	Closed course test Open road test	Closed course test Open road test	Closed course test Open road test

All testing originated at the Sylvania Campus of Portland Community College in Portland, Oregon. Closed course testing took place at the on campus range facility used by the Team Oregon Motorcycle Safety Program. The range facility consisted of a flat paved area that was closed to vehicular traffic. Cones were placed appropriately to allow the riders to safely enter the closed course test area and to check in with the research team. Participants were then asked to complete a health questionnaire and produce evidence of a valid driver license and motorcycle endorsement. After the sign-in procedures were completed, participants were then given the opportunity to practice on the closed course circuit ride. The closed course circuit ride is currently used in the Team Oregon Riders Skill Practice curriculum (see Figure 2). All participants were allowed to take one practice ride through the course in order to familiarize themselves with the different maneuvers that were required to complete the closed course. Team Oregon staff members were available to direct the participant around the course if necessary.

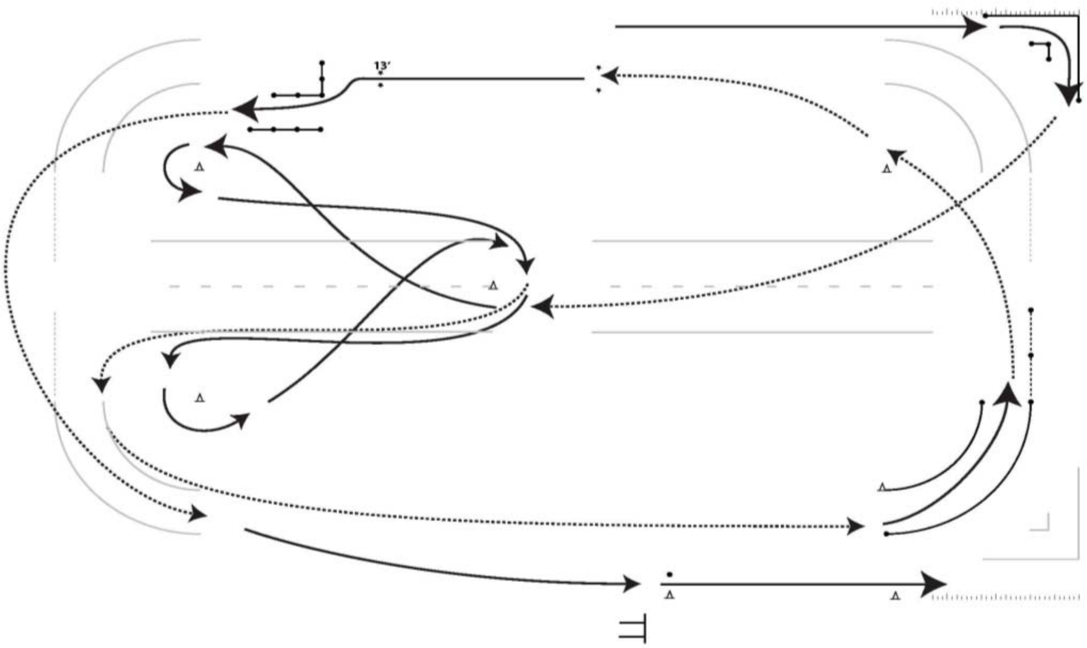


Figure 2. Rider Skills Practice (RSP) Circuit Ride
(Rider route direction indicated by arrows)

Upon completion of their practice ride, participants were asked to ride their motorcycles to the staging area tent that was located immediately adjacent to the closed course section. Each rider was asked to don the eye tracker system and the supplied DOT-compliant motorcycle helmet. The data collection computer was inserted into a backpack worn by the rider and the Speedbox and inertial units were attached to the rear of each participant's motorcycle. Once the eye tracker was properly in place, the eye tracker unit was calibrated to ensure accurate reporting of the visual gaze location of the rider within the visual field.

The rider proceeded directly to the start of the closed course following the calibration and instrumentation attachment procedures. The Closed Course RSP Circuit Ride was developed to evaluate the motorcycle rider's ability to handle a motorcycle and maneuver through a set course that includes a sharp turn, a 3-cone barrel ride, a 90-degree bend, an obstacle swerve and a quick stop. Points are added to the rider's score whenever an inappropriate maneuver is performed (e.g. rider goes off course, rider skips cone) or when an appropriate maneuver is not performed (e.g.

through turn, etc.). Since riders receive penalty points for poor skill performance, a low score indicates that the rider committed very few errors and completed the course without difficulty.

Two instructors were positioned on the course and scored each closed course trial for all rider participant categories. The subjective ratings were performed by Team Oregon instructors and used the standard Team Oregon RSP Circuit Ride Score Sheet (see Figure 3).

After completing the closed course circuit the rider was instructed to proceed out onto the open road course with the Team Oregon staff member. A 9.4-mile route was selected after a series of initial pre-study ride sessions by the Team Oregon staff. The open road course included both urban and rural areas, curves of various radii as well as ride sections through intersections and areas where lane change maneuvers were necessary.

During all open road testing, a two-way helmet mounted communications system was employed for rider to instructor communication. A Team Oregon staff member followed the participant rider at a safe distance on another motorcycle to provide riding directions, to monitor rider speed and behavior and to maximize the safety of the testing. This strategy was employed to ensure that the rider was not distracted from his or her normal riding behavior by the need to consult a map or GPS system.

The beginner-trained and experienced riders were invited to a briefing room to review the video with the instructor and to receive feedback. The instructor and participant reviewed the video imprinted with the instantaneous gaze location over specific segments of the open course roadway and discussed the rider's sight distance performance relative to the Team Oregon training concepts of aggressive visual searching and maintaining a sufficient sight distance magnitude (i.e., looking far enough ahead) so that the rider has adequate time to respond to any emergency situation. The instructor identified instances in the video footage when he believed the rider's head position and eye glance location may have affected the rider's vehicle placement (e.g., if the rider was not looking far enough ahead into a curve, and crossed the center line in the road). He discussed these examples, and his interpretation of the rider's overall performance in relation to sight distance skills, with the rider. Riders were encouraged to develop an aggressive and purposeful scan, to visually identify the presence of intersections and environmental hazards, and to increase sight distance by "getting their eyes up" to look further down the road. Beginner-untrained riders did not receive this feedback.

RSP Circuit Ride Score Sheet	*EXAMPLE*	FIRST RUN		SECOND RUN
Name:				
Date:				
Instructors:				
-				
1- Sharp Turn				
Does not turn head & look through turn	5	5		5
Puts foot down	~~3~~	3		3
One tire touches boundary/cone	~~5~~	5		5
Both tires cross boundary line	10	10		10
Sharp Turn Total	8			
2- Barrel Run				
Hits or skips cone	3 ~~5~~	3 5		3 5
Puts foot down	3 5	3 5		3 5
Does not turn head & look through turn	5 ~~10~~	5 10		5 10
Incomplete or off-course (20' > from cone)	~~5~~ 10	5 10		5 10
Barrel Run Total	20			
3- Cornering Proficiency				
Does not use both brakes to slow	5	5		5
Does not turn head to face exit	~~10~~	10		10
Decelerates in curve	~~3~~	3		3
One tire touches boundary/cone	5	5		5
Both tires cross boundary line	10	10		10
Cornering Proficiency Total	13			
4- Swerve				
Touches any line/cone	5	5		5
Brakes during swerve maneuver	~~10~~	10		10
Both tires cross obstacle line or boundary line	10	10		10
Quick Lane Change Total	10			
5- Quick Stop				
Time:	1.57			
Standard:	23			
Distance:	30			
Stops beyond standard (1 point per foot)	7			
Does not use both brakes	5	5		5
Does not downshift to first gear	~~3~~	3		3
Begins braking in timing zone	10	10		10
Quick Stop Total	10			
Overall Circuit Time	77			
Total Points Assessed	61			
TOTAL SCORE	138			
Drops motorcycle during circuit	21	21		21

Figure 3. Team Oregon RSP score card

At the conclusion of each session, participants were paid $150 for taking part. Because beginner-trained riders did not participate in the open road testing during their first session, they were paid $50 for that session. The entire testing session typically took about 45 minutes from initial participant sign-in to completion of the debrief session.

Data Reduction

Once the eye tracker system was calibrated and the data acquisition software was initiated, all collected variables were written to the computer hard drive for later download, reduction and analysis using a custom software program designed to integrate data from the eye tracker and the other data sources (e.g. Speedbox, helmet and motorcycle inertial motion units). A unique video file (*.avi format) and an ASCII flat file (*.wks format) were generated for each test participant. The video file included the forward view of the motorcycle rider as well as a visual overlay of the x and y eye location within the field of view of the rider (i.e., the eye gaze point). The duration of the eye opening was shown as a visual ring emanating from the eye gaze point. As the duration increased, the radius of the fixation ring increased. Each time that the eye blinked, the fixation duration value reset to zero.

The ASCII flat file included the x,y location of the eye gaze point within the visual field as well as the visual fixation information. This file also included data that was sampled from the Speedbox mounted on the motorcycle and the inertial motion units mounted on the motorcycle and the motorcycle rider. A complete list of all variables generated by the eye tracker system and imported into the ASCII flat file by the DRI custom software is presented in Appendix I.

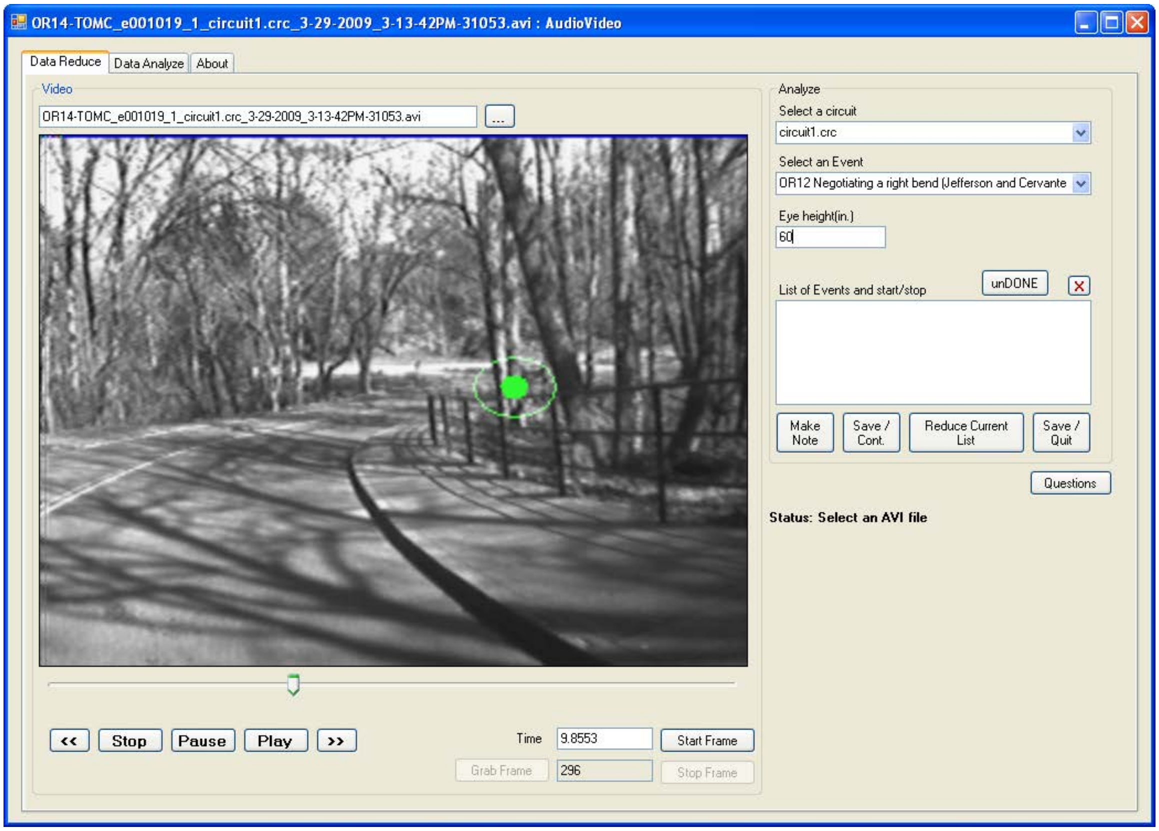


Figure 4. Data reduction software tool

A custom software tool was developed to parse the continuous data files into individual sections that could be later analyzed and reduced. Each trial was loaded into the software tool and a custom interface allowed the user to identify the start frame and stop frame for any section of roadway (see Figure 4). Physical geographic markers within the visual field (e.g., roadway signs) were used as indicators of the start and stop point of specific roadway sections. In this way, the identical roadway section could be parsed for each individual participant trial. Once all desired sections were identified, the program parsed the trial data into smaller video files and smaller ASCII flat files.

Five specific tasks were identified on the closed course, and 57 unique riding tasks were identified on the open road course. A complete list of all tasks is presented in Appendix II. From this complete list of tasks, 18 specific course sections were selected for parsing by the custom software tool and further data reduction (4 closed course sections, 14 open road sections). All data (e.g., video, eye tracker, Speedbox) were parsed concurrently to create more manageable data subsets for each rider. A list of all sections is also presented in Appendix II.

Three specific sections of course and roadway were selected for preliminary analysis. These sections were selected because they best represent the different roadway conditions and different tasks under which the sight distance behavior may vary. They included the following:

Section CC3: Left hand curve in closed course. This section evaluated a rider's sight distance behavior on a closed course, including the ability to look into a curve.

Section OR7: Left hand bend in the open road course. This section evaluated a rider's sight distance behavior on the open road, including the ability to look into a curve.

Section OR9: Straight section on the open road course. This section evaluated a rider's sight distance behavior on a straight section of open roadway. This section was expected to best represent a maximizing of sight distance among the different rider groups because the roadway was flat for a significant distance and had no view obstructions or changes in roadway geometry.

During the initial development of the project, it was planned that the inertial motion units attached to the rider's helmet would provide sufficient data regarding the orientation of the head and eyes relative to the visual horizon as the rider proceeded through the closed course and open road sections. The location of the visual horizon was a critical measure because the magnitude of the sight distance vector was computed based on the rider eye height and the angle formed by a vector joining the eye point and the visual gaze location and the ground plane. The assumption was made that the line formed by the rider eye height and the horizon was parallel to the ground plane. This provided for a simple trigonometric solution regarding the distance of the gaze point relative to the motorcycle rider.

Unfortunately, the inertial sensor was found to be too sensitive to rider movements as well as small perturbations in the roadway and consequently the inertial sensor could not provide consistent and reliable visual horizon information. In order to address this problem, an alternative methodology was developed that involved manually digitizing the location of the horizon in the visual field and then computing the sight distance based upon the location of the horizon and the visual gaze position. Manual digitizing was performed using a commercial digitizing software package (MaxTRAQ Lite, Innovisions Systems, Inc.).

Digitized roadway sections were converted into an ASCII file that could be read into the custom software tool. The software tool then loaded the corresponding video and data files and computed the magnitude of the sight distance vector for each digitized data frame. The program also computed the stopping distance necessary to bring the motorcycle to a stop given the speed of the motorcycle (as recorded by the Speedbox) and assuming a constant braking deceleration of 0.7g, which is equivalent to hard braking. These two distance values were then compared and expressed as a ratio and overlaid onto the video image along with the sight distance magnitude and the motorcycle speed information. The video overlay was set up so that whenever the sight distance to stopping distance ratio fell below 1.0, the number would turn red, indicating that the rider was now looking at a distance less than the distance required for him or her to come to a complete stop (see Figure 5). The average speed over the duration of the segment as well as a 95% confidence ellipse of the x,y glance location of each digitized segment was also computed at this time and saved to the computer hard disk.

Figure 5. Reduced gaze video with sight distance information
(Data from left to right: sight distance, sight distance to stopping distance ratio, stopping distance, motorcycle speed)

In addition to the reduced gaze video data presented in Figure 5, two data files were generated by the data reduction software. One file saved the gaze ellipse information for the digitized ride segment while the other file saved the frame by frame information of sight distance, motorcycle speed, computed stopping distance and sight distance to stopping distance ratio. A complete summary of the data variables in both of these files is presented in Appendix I and a summary of the dataflow is presented in Figure 6. Once the sight distance output files were generated, Microsoft Excel macros were used to compute average values for the given segment being analyzed.

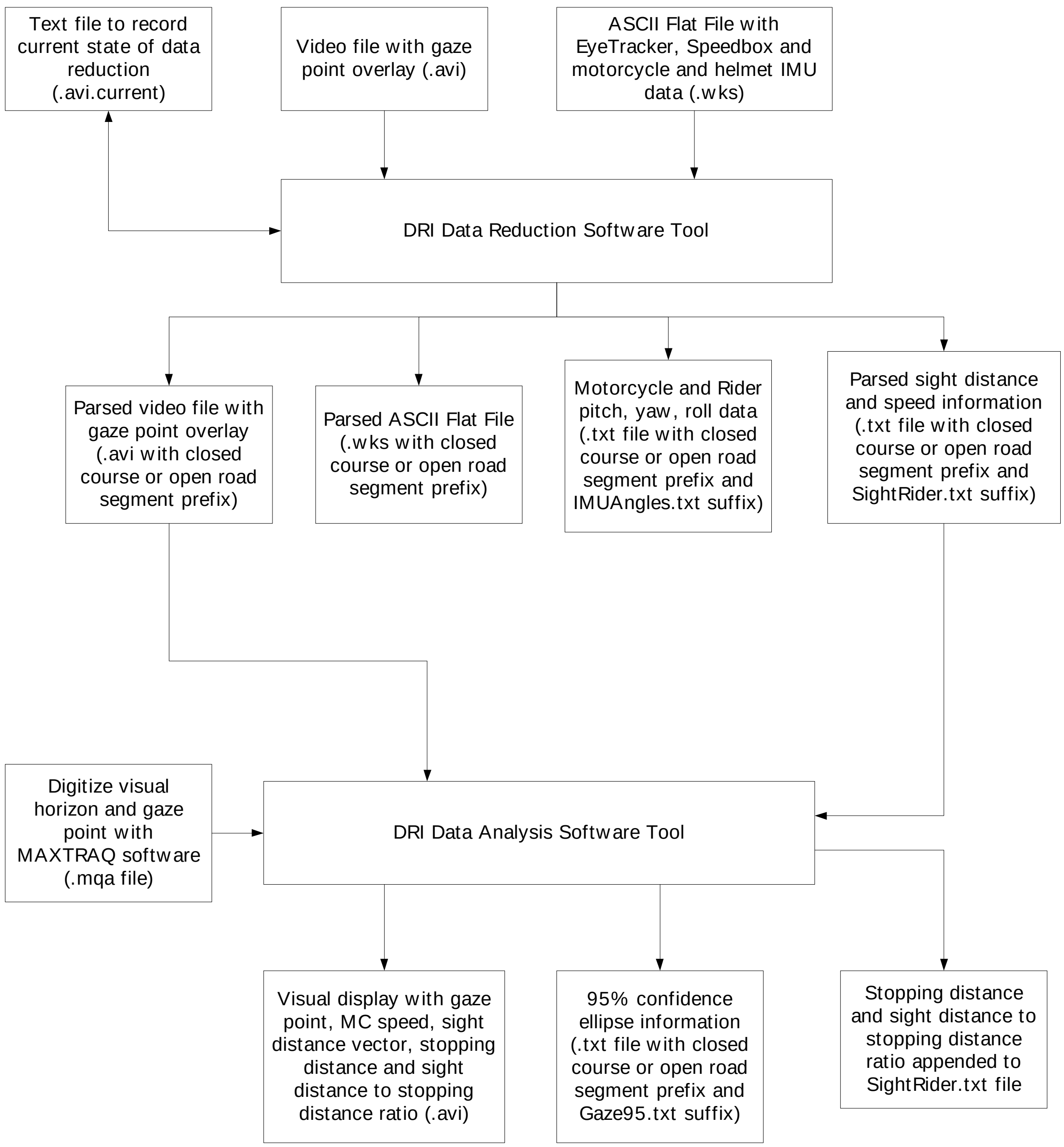


Figure 6. Eye tracker data flowchart

Data Analysis

Preliminary analyses were performed on two variables related to visual behavior: 1) the number of times that the sight distance to stopping distance ratio went below 1.0, and 2) the area of the gaze 95% confidence ellipse. The stopping distance was computed based upon the distance necessary to bring the motorcycle to a complete stop under hard braking (mu = 0.7) based upon the motorcycle speed for that frame. This value was divided into the computed sight distance value. A sight distance to stopping distance ratio of less than 1.0 indicated that the rider was not looking far enough ahead. In other words, the distance necessary to stop was greater than the rider's sight distance; therefore, if something entered the roadway at the current sight distance, the rider would not be able to effectively stop in time.

The gaze 95% confidence ellipse area was a measure of the magnitude of the visual gaze area and was defined as the area of the ellipse that encompassed approximately 95% of the rider's gaze points within the visual scene. Thus, a larger gaze 95% confidence ellipse area indicated that the rider's visual search spread over a greater area of the region in front of him or her. Speed and scores on the RSP Circuit Ride were also analyzed. Each of these variables was evaluated within the participant (i.e., over the duration of the project) and between different rider groups (i.e., beginner-trained, beginner-untrained, and experienced).

RESULTS

More than 30 total hours of naturalistic riding data with visual tracking, speed monitoring and head and motorcycle inertial orientation were collected as part of this research project. We describe the results of preliminary analyses of riders' visual behavior in this report. To examine if there were differences in performance between rider groups and over time, the data were analyzed using between-subjects or mixed analyses of variance (ANOVAs), with rider group as the between-subjects factor (beginner-trained, beginner-untrained, and experienced) and test session as the repeated measure (test sessions 1, 2, and 3).

As described earlier, each participant's closed course and open road data collection was parsed and reviewed for quality of the eye tracker and speed information. Sections in which the eye tracker information was not useful (e.g. gaze location was fixed in a remote part of the visual field) or the speed data was not useful (e.g. Speedbox reporting an unrealistic speed value) were dropped from the analysis. Imbalances in data due to missing values were dealt with using Satterthwaite's approximation for error terms and degrees of freedom. Post-hoc Tukey HSD tests were performed in response to significant main effects involving all three rider groups or all three test sessions to determine if differences exist between individual rider groups or test sessions.

For analyses of gaze behavior and speed over the open road, data from test session 1 were analyzed separately from data from test sessions 2 and 3 because beginner-trained riders were not tested on the open road course during their first test session. Because sight distance could only be computed for digitized course sections and the Speedbox did not collect reliable speed data over some sections of the open road course, sight distance to stopping distance ratio and speed were analyzed for closed course sections CC3 (left hand bend in closed course), OR7 (left hand bend in open road course), and OR9 (straight section in open road course). The gaze 95% confidence ellipse area was collected and analyzed over the entire closed course and entire open road course.

Below is a summary of the analyses that were performed on the data to assess visual behavior, speed, and motorcycle handling skills. The results of these analyses are presented in the section that follows.

- Number of times sight distance to stopping distance ratio fell below 1.0
    - Section CC3, all test sessions
    - Section OR7, test session 1
    - Section OR7, test sessions 2 and 3
    - Section OR9, test session 1
    - Section OR9, test sessions 2 and 3
- Size of gaze 95% confidence ellipse
    - Closed course, all test sessions
    - Open road course, test session 1
    - Open road course, test sessions 2 and 3

- Speed
  - Section CC3, all test sessions
  - Section OR7, test session 1
  - Section OR7, test sessions 2 and 3
  - Section OR9, test session 1
  - Section OR9, test sessions 2 and 3

- RSP Circuit Ride scores, all test sessions

Sight Distance to Stopping Distance Ratio

The number of times that the sight distance to stopping distance ratio went below 1.0 was computed for section CC3 of the closed course and sections OR7 and OR9 of the open road course. As mentioned earlier, a ratio of less than 1.0 indicated that the distance necessary to stop with hard braking was greater than the rider's sight distance. A mixed ANOVA (rider group by test session) was performed on this measure for closed course section CC3 to determine if it differed by rider group or changed over time. This analysis resulted in no significant effects, p's > 0.4.

For open road section OR7, there were no differences in the number of times the sight distance to stopping distance ratio went below 1.0 between the beginner-untrained and experienced rider groups during test session 1, $p > 0.8$. A mixed ANOVA (rider group by test session) was performed on number of times the sight distance to stopping distance ratio went below 1.0 during test sessions 2 and 3. This analysis resulted in a significant main effect of rider group, $F(2, 21.7) = 4.91$, $p = .017$. Tukey post hoc tests indicated that the sight distance to stopping distance ratio fell below 1.0 significantly more often for beginner-untrained riders ($M = 72.35$, $SD = 68.38$) than for beginner-trained riders ($M = 31.08$, $SD = 31.41$) or experienced riders ($M = 34.50$, $SD = 46.95$). The main effect of test session was also significant, $F(1, 24) = 5.03$, $p = .035$, with the sight distance to stopping distance ratio dropping below 1.0 more often during test session 2 ($M = 68.90$, $SD = 66.65$) than test session 3 ($M = 31.33$, $SD = 38.88$). There was no significant interaction between rider group and test session, $p > 0.3$. The number of times the sight distance to stopping distance ratio went below 1.0 for each rider group in each test session over open road course section OR7 is shown in Figure 7.

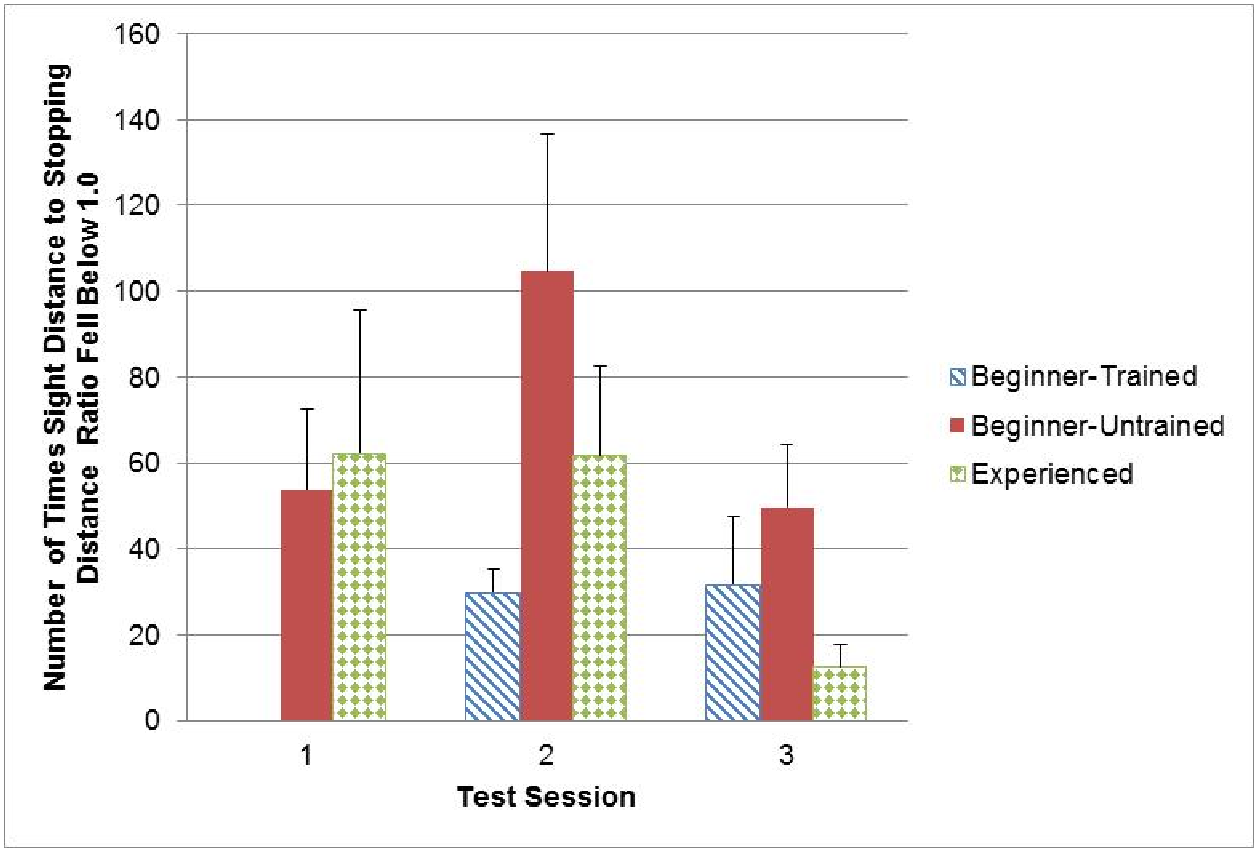


Figure 7. Mean number of times the sight distance to stopping distance ratio fell below 1.0 on section OR7 (error bars indicate standard error).

Identical analyses were performed for open road section OR9. The mixed ANOVA for test sessions 2 and 3 produced a significant main effect of test session, $F(1, 15.1) = 6.16$, $p = .025$, with the sight distance to stopping distance ratio falling below 1.0 again more often during test session 2 ($M = 124.6$, $SD = 99.96$) than during test session 3 ($M = 56.38$, $SD = 78.24$). No other analyses for section OR9 approached significance, *p*'s > 0.4. The number of times the sight distance to stopping distance ratio went below 1.0 for each rider group in each test session over open road course section OR9 is illustrated in Figure 8.

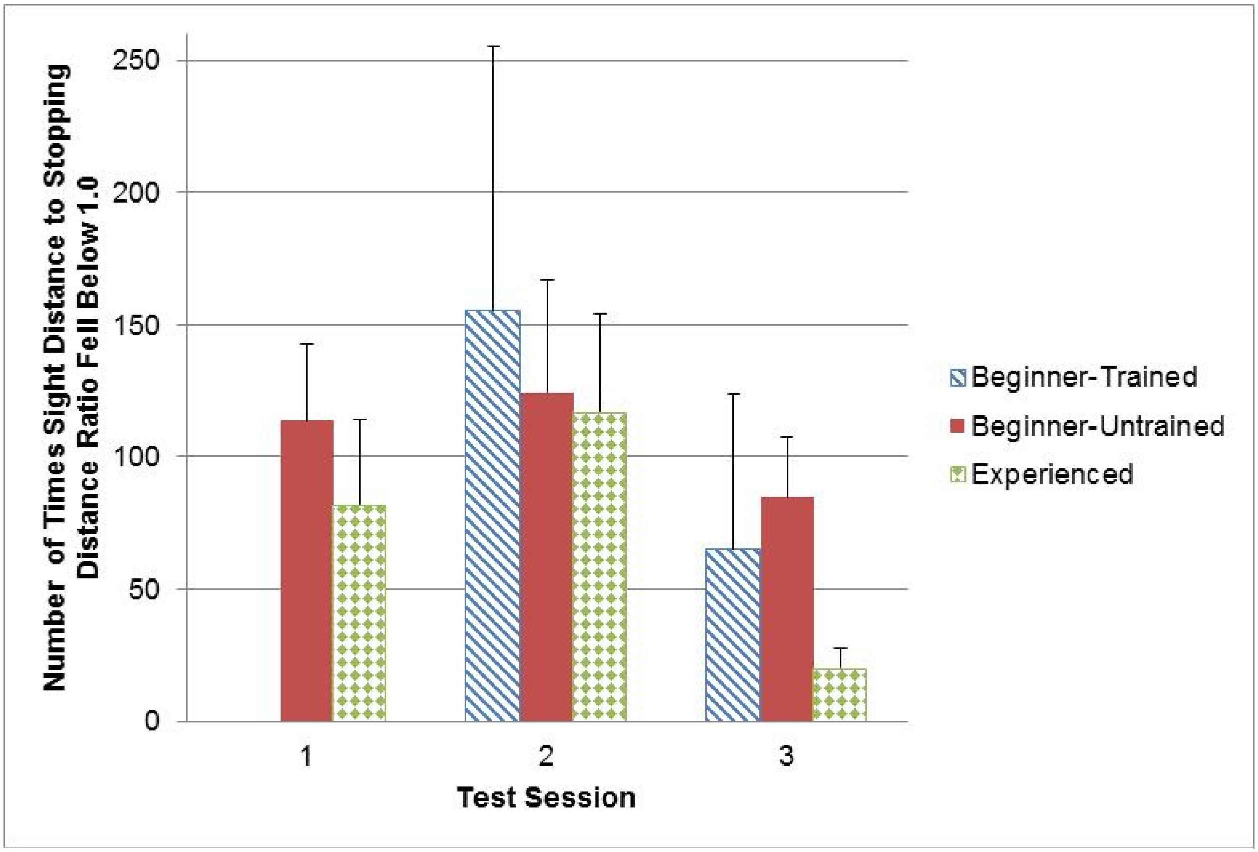


Figure 8. Mean number of times the sight distance to stopping distance ratio fell below 1.0 on section OR9 (error bars indicate standard error).

Visual Gaze Area

In addition to the sight distance to stopping distance ratio, rider gaze behavior was examined by evaluating the area of the gaze 95% confidence ellipse. This measure indicated the size of the ellipse that encompassed approximately 95% of the rider's gaze points,, and it was analyzed over the entire closed course and the entire open road course. Gaze point locations were normalized as x,y coordinates between 0 and 1. A mixed ANOVA (rider group by test session) was performed on the mean gaze 95% confidence ellipse area over the closed course to determine if this differed by rider group or changed over time. This analysis resulted in no significant effects, but the main effect of test session approached statistical significance, $F(2, 55) = 3.01$, $p = .058$. The mean gaze 95% confidence ellipse area was largest during test session 1 ($M = 0.564$, $SD = 0.207$), followed by test session 2 ($M = 0.529$, $SD = 0.164$) and test session 3 ($M = 0.489$, $SD = 0.146$). Mean gaze 95% confidence ellipse area over the closed course for each rider group during each test session is shown in Figure 9.

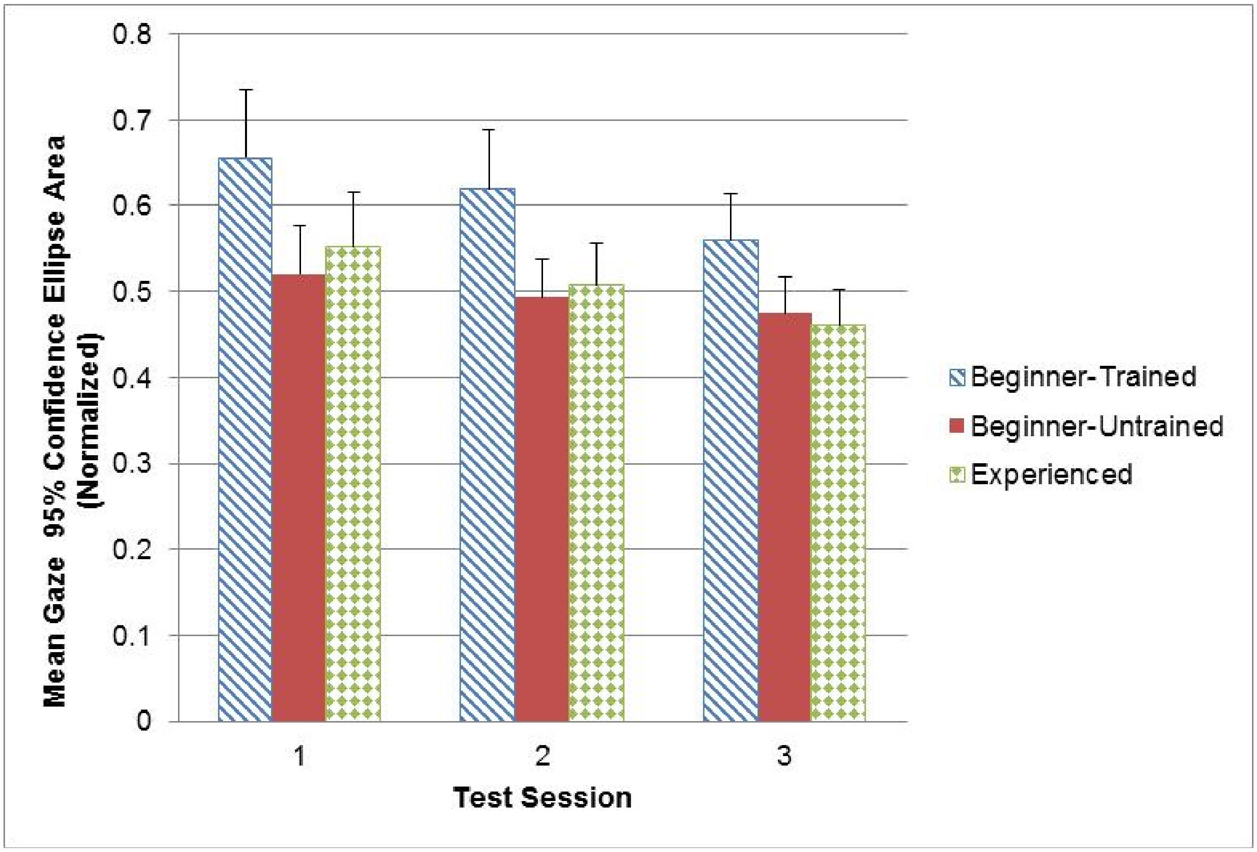


Figure 9. Mean gaze 95% confidence ellipse area on closed course (error bars indicate standard error).

Over the open road course, the mean gaze 95% confidence ellipse area did not differ between the beginner-untrained and experienced riders during test session 1, $p > 0.2$. A mixed ANOVA (rider group by test session) was performed on the area of the gaze 95% confidence ellipse area for test sessions 2 and 3, and this analysis resulted in a significant main effect of rider group, $F(2,26.8) = 6.13$, $p = .006$. A Tukey post hoc test indicated that the mean gaze 95% confidence ellipse area for the beginner-untrained riders ($M = 0.496$, $SD = 0.153$) was significantly larger than that for the experienced riders ($M = 0.337$, $SD = 0.087$). There were no significant differences between the mean 95% confidence ellipse area of the beginner-trained riders ($M = 0.398$, $SD = 0.121$) and either other rider group. The mean gaze 95% confidence ellipse area did not change between test sessions 2 and 3, nor was there a significant interaction between test session and rider group, *p*'s > 0.2. Mean gaze 95% confidence ellipse area over the open road course for each rider group during each test session is shown in Figure 10.

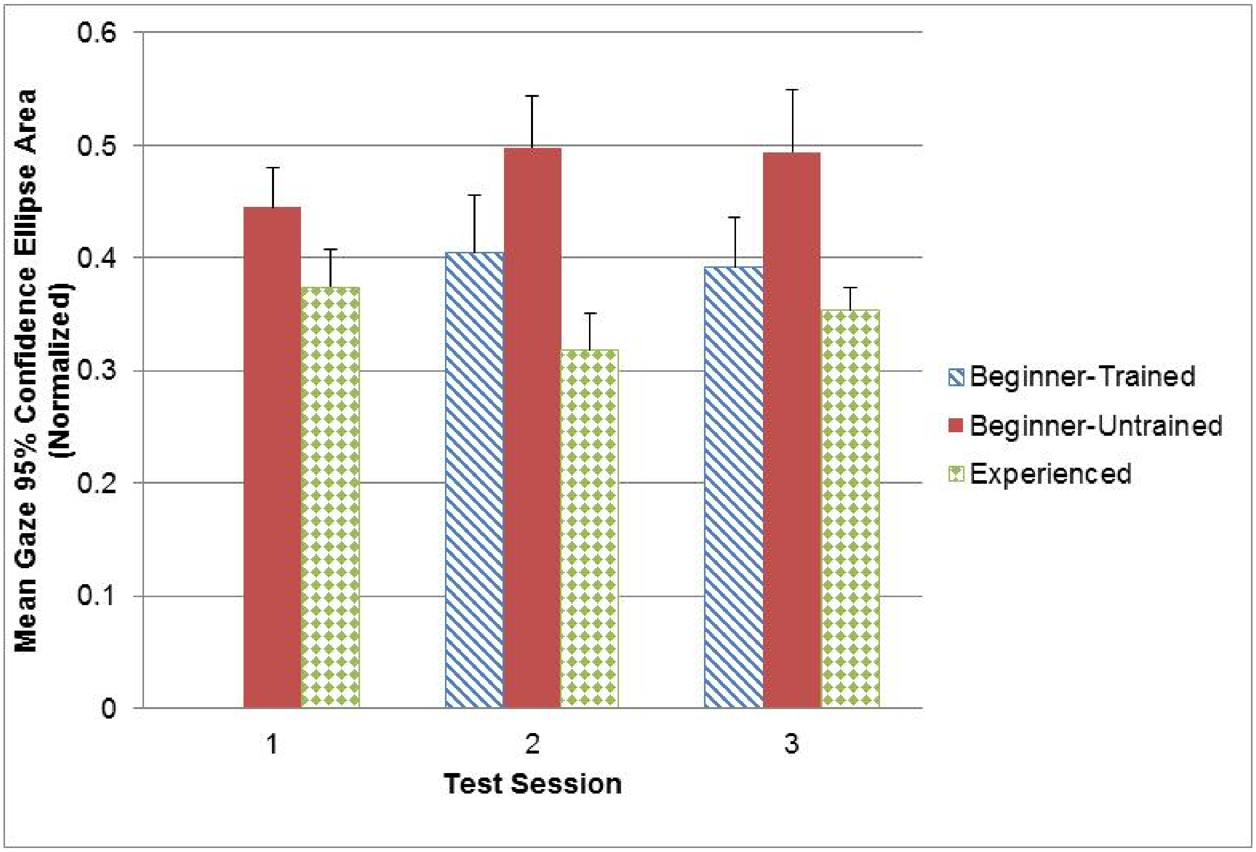
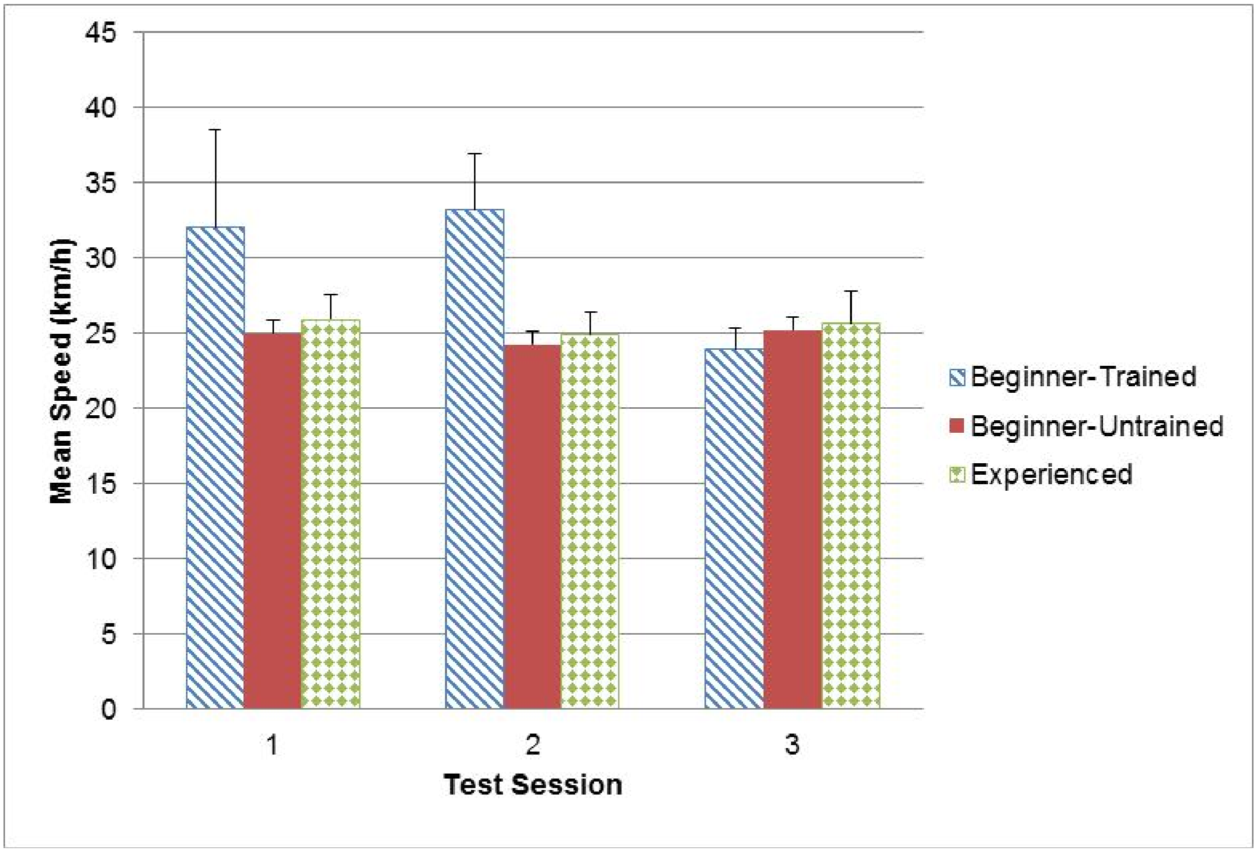


Figure 10. Mean gaze 95% confidence ellipse area on open road course (error bars indicate standard error).

Speed

Speed during the testing sessions was also collected and analyzed as a measure of performance. A mixed ANOVA (rider group by test session) on speed during section CC3 resulted in a significant main effect of rider group, $F(2, 13.2) = 5.40$, $p = .019$. A Tukey post hoc test indicated that the beginner-trained riders ($M = 28.59$, $SD = 8.61$) had a higher average speed than the beginner-untrained riders ($M = 24.94$, $SD = 2.64$). The average speed for the experienced riders ($M = 25.53$, $SD = 5.70$) did not differ significant from the other two rider groups. No other effects for section CC3 approached significance, *p*'s > .1. Mean speed for each rider group during each test session for section CC3 is shown in Figure 11.



Average speed did not differ between beginner-untrained and experienced riders during test session 1 for open road section OR7, $p > .3$. A mixed ANOVA (rider group by test session) on average speed on section OR7 during test sessions 2 and 3 resulted in a significant main effect of rider group, $F(2, 25) = 15.68$, $p < .001$. Tukey post hoc tests indicated that experienced riders ($M = 38.93$, $SD = 6.20$) rode over section OR7 at a faster speed than beginner-trained ($M = 32.16$, $SD = 3.18$) or beginner-untrained riders ($M = 32.83$, $SD = 2.83$). There was also a significant interaction between rider group and test session, $F(2, 23.4) = 7.17$, $p = .004$. Experienced riders rode section OR7 at a higher speed during test session 2 than during test session 3, but the beginner-trained and beginner-untrained rode at similar speeds during test sessions 2 and 3. Average speed for each rider group during each test session over section OR7 is illustrated in Figure 12. The main effect of test session was not significant for the analysis of test sessions 2 and 3, $p > .1$. Identical analyses were performed on average speed during open road section OR9, but no significant effects were found, *p*'s > .1.

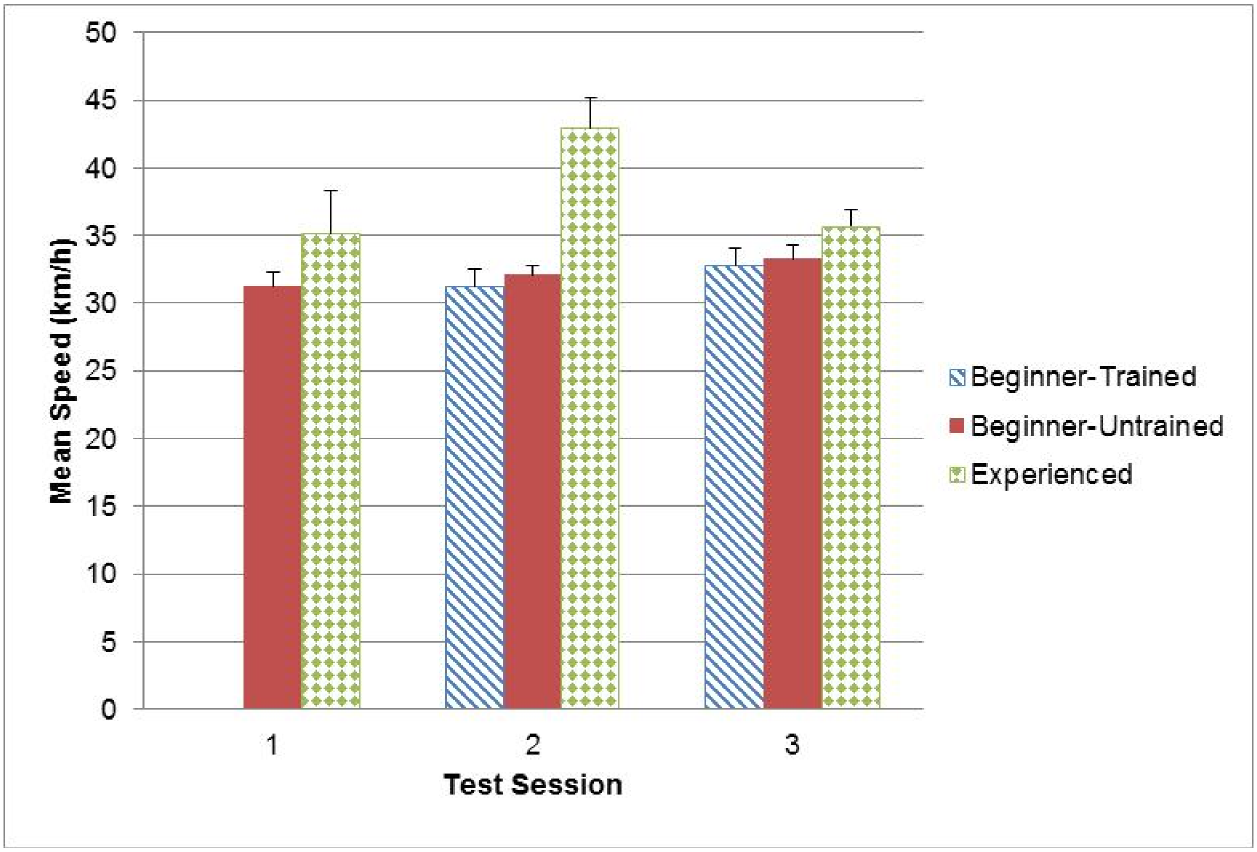


Figure 12. Mean speed on section OR7 (error bars indicate standard error).

RSP Circuit Ride Scores

Concurrently with the eye tracker collected for each participant for each test session, each rider was scored according to his or her performance on the RSP Circuit Ride. Rider scoring was based on the overall time taken to complete the course as well as scoring from two Team Oregon instructors who evaluated the rider's performance through each of the specific riding maneuvers (see Figure 3, RSP Scoring Sheet). A lower score on the RSP Circuit Ride indicated better performance on the course. Figure 13 presents the distribution of the RSP Circuit Ride scores during each test session for each rider group. A mixed design ANOVA with rider group as the between-subjects factor and test session as the within-subjects factor found a significant main effect of test session, $F(2,55) = 3.50$, $p = .037$. A Tukey post hoc test indicated that mean RSP scores were significantly higher in test session 1 ($M = 152.1$, $SD = 19.43$) than in test session 2 ($M = 145.8$, $SD = 17.26$) and test session 3 ($M = 146.2$, $SD = 20.07$). This analysis also produced a significant main effect of rider group, $F(2,27.9) = 5.72$, $p = .008$. A Tukey post hoc test reported that the experienced riders had a significantly lower score on the RSP ($M = 136.8$, $SD = 16.47$) than the beginner-trained ($M = 154.1$, $SD = 24.31$) or beginner-untrained ($M = 155.2$, $SD = 11.51$) riders across test sessions. There was no significant interaction between rider group and test session, $p > .2$.

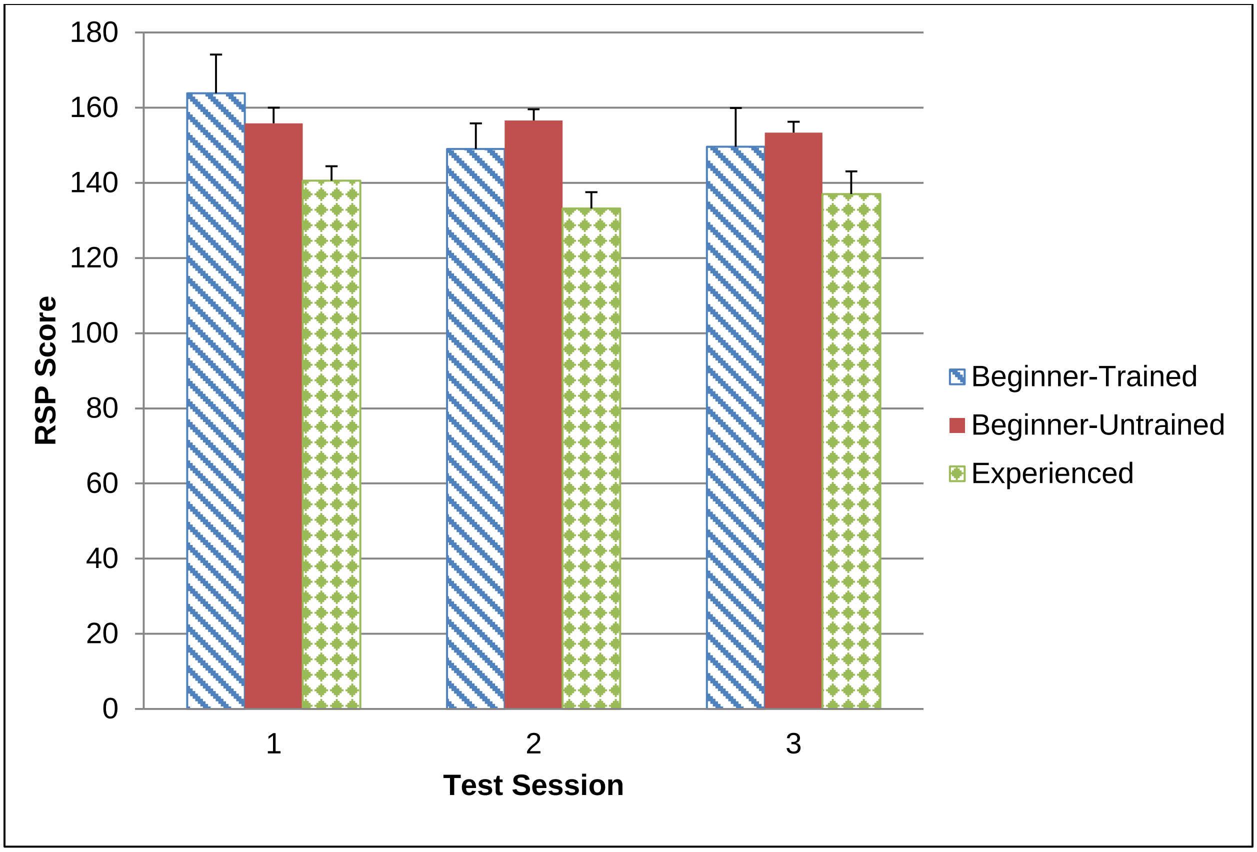


Figure 13. Mean RSP Circuit Ride scores (error bars indicate standard error).

DISCUSSION

Over the course of a one year period, 31 motorcycle riders participated in this study. The final participant group included 7 beginner-trained riders, 12 beginner-untrained riders and 12 experienced riders. A total of 93 open road and closed course test sessions were reviewed for eye tracker and speed data quality. Each of these test sessions were then parsed into 63 separate segments of which three segments for each rider for each session were analyzed in greater detail. Over 30 hours of riding with visual tracking, speed monitoring and head and motorcycle inertial orientation were collected as part of this research project.

The first goal of this project was to perform a preliminary examination into the relationship between training and feedback on sight distance, riding experience, and on-road visual behavior with three rider groups. Beginner-trained riders had almost no riding experience at the start of the study, participated in entry-level motorcycle training that included instruction on sight distance skills, and received feedback on their sight distance behavior after each test session; experienced riders had considerable riding experience at the start of the study and received feedback on their sight distance behavior after each test session; and beginner-untrained riders had little riding experience at the start of the study, did not participate in entry-level motorcycle training, and received no feedback on their sight distance behavior after each test session.

The gaze 95% confidence ellipse area (i.e., the visual gaze area) and the number of times that the sight distance to stopping distance ratio went below 1.0 were the variables selected as indicators of visual behavior. Speed and performance on the RSP Circuit Ride were analyzed as performance measures. The hypothesis was that the frequency of the sight distance to stopping distance ratio falling below 1.0 would be greatest for the beginner-untrained riders, who did not receive any sight distance training or feedback. It was also predicted that more experienced riders would have a larger gaze 95% confidence ellipse area, suggesting that these riders saw more of the riding environment in front of them and that these riders had better scanning and sight distance strategies.

Sight Distance to Stopping Distance Ratio

These preliminary results provide some support for the hypothesis that riders who received training and feedback on sight distance would have better sight distance behavior on the road than riders who did not receive training and feedback. Beginner-untrained riders, who did not receive training or feedback on sight distance, exhibited a sight distance ratio that went below 1.0 (i.e., did not look far enough ahead to safely stop) more often on curved open road course section OR7 (with a left hand bend) during test sessions 2 and 3 than beginner-trained and experienced riders. This is the first study to demonstrate that training and coaching motorcycle riders on sight distance is related to visual performance on the road.

It is noteworthy that this effect was found in a curved section of the course. Rider error in negotiating curves has been cited as a frequent cause of single-vehicle crashes (Hurt, Ouellet, & Thom, 1981), and motorcycle operator manuals advise riders to choose a lane position that increases their line of sight to mitigate the risks of riding in a curve (MSF, 2011). Although we cannot conclude from these findings that motorcycle riders' sight distance behavior affects how they operate their motorcycles on-road, gaze location has been found to be related to the path followed by car drivers (Robertshaw & Wilkie, 2008). If this were also the case for motorcycle riders, training on sight distance could potentially increase their ability to successfully negotiate curves in the road.

There were no differences between the sight distance behavior of the rider groups in section OR9, which was a straight section of the open road course, or in section CC3, which was a curve on the closed course. It is possible that section OR7 was the most sensitive to differences in sight distance because it was the most complex of the three sections analyzed. Section OR7 required riders to both negotiate a curve and monitor the open road environment for the appearance of potential hazards. In contrast, section OR9 did not have a curve, and section CC3 did not have the potential appearance of hazards because it was part of the closed course.

The number of times the sight distance to stopping distance ratio went below 1.0 decreased significantly between test sessions 2 and 3 across groups for both open road sections analyzed, OR7 and OR9. This suggests that riders' increased familiarity with the open road course over time improved their sight distance on the course. There was no interaction between rider group and test session, which indicates that the feedback on sight distance that beginner-trained and experienced riders received after each test session did not improve their sight distance behavior over time more than that of beginner-untrained riders, who did not receive feedback on sight distance between sessions.

Visual Gaze Area

The size of riders' gaze area was also analyzed as a measure of their visual scanning behavior. Experienced riders were found to have the smaller mean gaze 95% confidence ellipse than beginner-untrained riders over the open road course. This finding is contrary to the original hypothesis that experienced riders would have the largest ellipse area due to regular scanning, and also contrasts with findings from drivers demonstrating that experienced drivers tend to scan widely on the horizontal axis, while novice drivers scan narrowly in the area in front of the car (Mourant & Rockwell, 1972). However, past research has also found that experienced drivers tend to adjust their scanning patterns in different environments, while novice drivers tend to use similar scanning patterns on different types of roadways (Crundall & Underwood, 1998; Falkmer & Gergersen, 2005); thus, in some situations experienced drivers have been found to scan along a narrower horizontal and vertical path than novice drivers (Chapman & Underwood, 1998; Crundall, Chapman, Phelps, & Underwood, 2003; Crundall & Underwood, 1998). The result that beginner-untrained riders had a larger gaze area than experienced riders is also consistent with recent research using a motorcycle simulator by Hosking et al. (2010), who found that individuals who were experienced drivers and riders reduced the area of their visual search more during hazardous situations than individuals who were inexperienced drivers and riders.

Novice drivers have been found to take their eyes off of the forward roadway more often and make fewer driving-relevant glances than experienced drivers (Lee, Olsen, & Simons-Morton, 2006; Wikman, Nieminen, & Summala, 1998). It is possible that the looking patterns found in this study reflected beginner-untrained riders making more glances that were not riding-relevant around the environment, while experienced riders tended to look straight ahead. To determine if this was the case, future analyses of this dataset can examine how frequently and for how long riders looked at different aspects of the visual scene, such as ahead on the forward roadway, in the area in front of the motorcycle, and to the side of the road.

Because beginner-untrained riders had a larger gaze area than experienced riders, but the gaze area of beginner-trained riders was not significantly different from either group, it is not clear what the effect of training is on gaze area size. It could be the case that training improved beginner-trained riders' scanning behavior somewhat, but not to the degree of expert riders. That is similar to what has been seen with drivers, where novice drivers receiving training in scanning improved somewhat from novice drivers who did not receive training, but did not improve scanning to the degree of experts (Chapman, Underwood, & Roberts, 2002).

Differences were found between the visual behavior of the beginner-untrained riders and experienced riders during test sessions 2 and 3, but not during test session 1, in the analyses of sight distance to stopping distance ratio during open road section OR7 and the mean gaze 95% confidence ellipse area on the open road course. It is not clear why this is the case. One possibility is that the feedback the experienced riders received on sight distance after each session affected their visual behavior in test sessions 2 and 3, since they did not receive this feedback prior to test session 1. It is difficult to isolate the effect that feedback had on beginner-trained and experienced riders' performance, given that time varied along with feedback.

Speed and Motorcycle Handling Skills

Riders' speed and performance on the RSP Circuit Ride were additionally analyzed as part of this study. Sight distance skills are closely linked with motorcycle speed because the faster that a motorcycle rider travels, the less time that he or she may have to avoid a collision and the greater the need for effective sight distance visual behaviors. RSP score was an indicator of motorcycle handling skills on a closed course. As expected, the average speed for the experienced riders was higher during curved open road section OR7 than for beginner-trained and beginner-untrained riders. This is likely related to the experienced riders' familiarity with operating their motorcycles and understanding of their technical capabilities in terms of handling the motorcycle. Beginner-trained riders had a higher average speed during closed course section CC3 than experienced or beginner-untrained riders. This finding was surprising, but may be related to beginner-trained riders' recent experience riding on a similar closed course during their BRT course.

The mean score for the experienced riders on the RSP Circuit Ride was better than those for the beginner-trained and beginner-untrained riders across the three test sessions, and all three groups improved their scores on the RSP across test sessions. These findings were expected, and indicated that experienced riders had better motorcycle handling skills than both groups of beginning riders.

Technical Challenges

In order to capture eye tracking data over-the-road, several technical challenges had to be addressed and overcome. Firstly, an instrumentation package had to be developed that was small enough that it could fit on each rider's motorcycle and be easily changed from one rider to another. This required the development of a small integrated data capturing system that was weather resistant and did not have any significant influence on the motorcycle or the rider behavior. Such a system was developed but numerous technical difficulties were encountered over the duration of the project.

Most eye tracker systems are designed to operate either as standalone systems or as an attachment to a large desktop computer in a test laboratory. Neither of these conditions was suitable for this study because the eye tracker system had to be integrated with other instrumentation such as the GPS Speedbox and the inertial motion units mounted on the helmet and the motorcycle. All data had to be collected on a small laptop that could be worn by the rider without interfering with normal rider behavior. The integration of all this equipment required numerous cables between systems and each of these cables had to be ruggedized and weatherproofed so that they could operate repeatedly in a harsh environment (e.g., cold and precipitation) over the course of 100+ testing sessions. Power needs for the eye tracker, the GPS Speedbox, the inertial measurement units and the laptop itself had to be optimized to keep instrumentation weight to a minimum and to maximize the time over which the instrumentation would continue to perform properly. All of these challenges were adequately met by the DRI technical staff and the Team Oregon research staff; however, there were instances in which one or more of the fundamental systems failed to operate properly and the data had to be abandoned. Technical problems for this study included battery failure, USB cable failure, infrared light failure, and grounding short circuit failures, each of which had to be addressed rapidly and promptly in order to maintain study progress.

Aside from the power supply and equipment durability issues, perhaps the greatest technical challenges were related to use of the eye tracker system in a mobile motorcycle mounted configuration. From the onset of this project it was known that the eye tracker system must be properly calibrated in order to provide accurate information regarding where the rider is looking at a particular instant. This required a very specific eye tracker donning procedure as well as a multi-point calibration procedure to confirm that the eye tracker was accurately recording the gaze point for each rider.

The first step of the donning procedure was to secure the eye tracker frames to the rider using an eyeglass cord lanyard that was secured behind the rider's head. The helmet was then placed over top of the eyeframe system and the chin bar section was carefully lowered over the eye tracker video camera and eye camera. The research staff would then adjust the location of the forward camera and the eye camera to maximize the visual field (i.e., full right and full left visual field) as well as the capturing capability of the infrared eye camera. The research staff would then support the motorcycle in an upright position (i.e., off of the side stand or center stand) and ask the rider to grasp the handgrips and assume a normal riding position. The research staff would then ask the rider to specifically look at a series of calibration points located in front of the rider and the software package would be corrected so that the visual field and gaze point matched with the calibration point. This procedure took at least 15 to 20 minutes for each rider was done repeatedly for each participant for 13 specific calibration points for each testing session.

Once the face shield was lowered over the eye tracker system, the research staff would then do a secondary check to confirm that the eye tracker was still properly capturing the correct data (i.e., the eye tracker was still recording where the rider was looking). If the eye tracker system did not record the proper gaze location the entire procedure was repeated. If the eye tracker system inadvertently moved during the closed course or the open road ride, then the entire test session had to be repeated.

The most frequently occurring problem related to the eye tracker was related to rider head movement in which he or she would move their helmeted head to a maximum flexed or lateral bend position. This motion would cause the cables at the rear of the eye tracker system to be placed in tension that would in turn cause the eyeframe video camera to lift up relative to the eye and consequently give a false indication of the location of the gaze point (i.e., the gaze point would be higher than it is in reality). The qualitative video analysis following each run would specifically look for this problem by confirming that the rider properly gazed at several known landmarks (e.g., road signs, grate covers in the roadway) along the course of the open road testing segment. As mentioned above, if it was determined that the eye tracker system moved during either the closed course or the open road ride, the entire test session was repeated.

Following the first test session it was determined that there were several participants who reported problems related to the eyeframes become “stuck” against the side of the full face motorcycle helmet. This occurred most often with those participants that had smaller head sizes and wore smaller helmets. An investigation into the problem revealed that the eye tracker frames were too wide for the smaller helmet sizes and consequently they would get caught by the sides of the motorcycle helmet. This in turn would cause the visual field and the eyeframe field to report false information. In order to address this problem, a new set of eyeframes were purchase that had a much lower profile and better match to the rider’s face (i.e., the frames had a much smaller width). The eye tracker hardware was removed from the original eye tracker frames and placed upon these new frames without difficulty. Evaluation of the new eyeframes with the smaller helmet sizes resulted in a greatly improved matching between the small head sizes and the small helmet sizes and no instances of eyeframes getting caught by the sides of the helmet. Since the identical hardware was used with the new eyeframe system and the eye tracker system had to be calibrated for each rider, it was felt that this modification would have no effect upon the results of this study.

Limitations

In addition to the technical challenges that arose as a result of using new technology, the desire to compare trained and untrained novice riders introduced some further limitations. With respect to rider recruitment, one of the most challenging tasks was to identify and recruit riders who had recently obtained a motorcycle endorsement but had not taken any type of formal motorcycle rider training (i.e., the beginner-untrained). The Oregon DMV was extremely helpful in identifying these potential participants. Given the difficulty in finding these participants, Team Oregon and DRI decided to accept as many beginner-untrained participants as possible, even though some of them may have had more riding experience than desired. Informal discussions between the research staff and the riders revealed that many of these riders either had some on-street riding experience or some type of off-road motocross experience. A larger percentage of the riders recruited for the beginner-trained group were female than in the beginner-untrained group, which also made the two rider groups less comparable than desired.

Riders were not randomly assigned into groups in this study. Because the design was quasi-experimental, it is not possible to conclude that training caused differences seen between beginner-trained and beginner-untrained riders. Beginner-trained riders were also not tested on the open road during the first testing session for safety reasons. This design element introduced a methodological challenge. Because all three rider groups were not tested on the open road in all sessions, change over time could only be measured between open road sessions 2 and 3. This also meant that beginner-untrained riders had experience riding on the open road course prior to test session 2, but that beginner-trained riders did not have this experience prior to that test session. However, this same factor makes the difference seen between beginner-trained and beginner-untrained riders in sight distance to stopping distance ratio during section OR7 more impressive, given that beginner-untrained riders had more practice with the open road course than beginner-trained riders.

Finally, it is important to note limitations in how these findings can be generalized. Differences in sight distance behavior and the size of the visual gaze area between groups were not found reliably in all sections of road analyzed and in all test sessions. Although it is encouraging that differences in visual behavior were found on the road sections of most interest (the curved section of the open road for sight distance to stopping distance ratio, and the open road course for size of the visual gaze area), it is unclear how robustly the looking behavior we observed would replicate over a larger variety of road types. Similarly, we did not analyze data on the relationship between where riders gazed and how they operated their motorcycles; thus, we cannot assume from these results that the visual behavior of experienced riders indicated safe motorcycle operation.

SUMMARY AND RECOMMENDATIONS

A group of 31 beginner and experienced motorcycle riders participated in a unique motorcycle naturalistic riding study that monitored head and motorcycle motions as well as rider eye tracking and sight distance behavior using an on-board data acquisition system. Over 30 hours of motorcycle rider gaze behavior video was captured over the course of this study. Participants included riders who had received the Team Oregon BRT course (beginner-trained), riders who had recently received their motorcycle endorsement but who had not received any training (beginner-untrained) and experienced riders who had extensive riding experience.

In addition to overcoming the obstacles associated with development of an on-board data acquisition system that could be used on the rider's own motorcycle, one goal of the study was to determine the effect that sight distance training and feedback had upon motorcycle rider skills and how these skills differed amongst riders with different levels of riding experience and training. Data were collected on both closed course and open road riding circuits over three test sessions over a one year period. Specific video segments based on either a specific closed course skill or a specific roadway segment were parsed from the aggregate video and used to compute gaze 95% confidence ellipses of the visual gaze area. The video from these segments were also digitized manually to compute an instantaneous sight distance and to compare this instantaneous sight distance value to the distance required for the rider to come to a complete stop for his or her given speed. When the value of the sight distance to stopping distance ratio went below 1.0, it indicated that the distance necessary for the rider to stop was greater than the distance the rider was looking ahead. Speed and handling skills on the RSP Circuit Ride were additionally measured and analyzed.

Significant differences were found in the number of times the sight distance to stopping distance ratio went below 1.0 between the beginner-untrained rider group and the beginner-trained and experienced rider groups for curved open road course section OR7. Beginner-untrained riders also had a larger mean gaze 95% confidence ellipse area over the open road course than experienced riders. These findings preliminarily suggest that there may be a relationship between training and feedback on sight distance and sight distance behavior on the road. Further analyses of the dataset generated in this project could investigate where novice and experienced riders look on the road, and how scanning patterns may account for the differences in gaze ellipse area seen between beginner-untrained and experienced riders. This future research may provide better insight as to how these visual skills develop in new riders. Such analyses may also provide additional information regarding the best practices that may be observed in more experienced riders and consequently integrated into basic rider training courses.

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APPENDIX I

Detailed List of Variables Imported Into ASCII Flat File And DRI Custom Software

Table I-1. Data Generated by the Eye Tracker System

Data ID Tag	Column Heading	Data Type	Description
3	n/a	String	File header information in the form of an ASCII character string
5	n/a	String	An ASCII character string generated to produce column heading information
6	n/a	String	A 3 character string generated to produce truncated column heading information (see Data ID Tag 5)
7	n/a	String	Information regarding the frame rate of the eye camera
10	TotalTime	Floating	TotalTime = elapsed time of data collection in seconds
10	DeltaTime	Floating	Dt = delta time in milliseconds since the previous data entry
10	X_Gaze	Floating	X = direction of gaze normalized with respect to the x-axis
10	Y_Gaze	Floating	Y = direction of gaze normalized with respect to the y-axis
10	Region	List	Which region(s) of interest the gaze point is in
10	PupilWidth	Floating	Pupil width normalized with respect to the EyeCamera window width
10	PupilAspect	Floating	Dimensionless aspect ratio of the pupil, i.e., 1.0 is a perfect circle
10	Quality	Integer	Quality of eye movement data
10	Fixation	Floating	Fixation duration in seconds. A zero value indicates a saccade.
10	Count	Integer	Eye movement data record count
10	Marker	Character	A printable ASCII character (not used)
	Time Stamp	Floating	Time at which image is to be inserted
16	n/a	String	Startup image identification (default)
777	Time Stamp	Floating	Time at which movieframe was inserted
777	MovieFrame	Integer	MovieFrame number

Table I-2. Data Generated by the Speedbox and Inertial Motion Units

Data ID Tag	Column Heading	Data Type	Description
899	Time Stamp	Floating	Time at which the data insertion was initiated
899	Version	Alphanumeric	Version of software used to insert data
810	Time Stamp	Floating	Time at which the data was inserted
810	Motorcycle IMU local quaternion ω	Floating	Motorcycle angular position in quaternion form
810	Motorcycle IMU local quaternion x	Floating	X coordinate of the motorcycle rotation vector in quaternion form
810	Motorcycle IMU local quaternion y	Floating	Y coordinate of the motorcycle rotation vector in quaternion form
810	Motorcycle IMU local quaternion z	Floating	Z coordinate of the motorcycle rotation vector in quaternion form
810	Rider IMU local quaternion ω	Floating	Rider's helmet angular position in quaternion form
810	Rider IMU local quaternion x	Floating	X coordinate of the Rider's helmet rotation vector in quaternion form
810	Rider IMU local quaternion y	Floating	Y coordinate of the Rider's helmet rotation vector in quaternion form
810	Rider IMU local quaternion z	Floating	Z coordinate of the Rider's helmet rotation vector in quaternion form
810	MC speed (kph)	Floating	Motorcycle speed from Speedbox (kph)
810	Frame counter	Integer	Frame counter
807	Time Stamp	Floating	Time at which the data was inserted
807	Latitude	Floating	Latitude location of motorcycle (degrees)
807	Longitude	Floating	Longitude location of motorcycle (degrees)
807	GPSaccuracy	Floating	Positional accuracy estimate (cm)
807	GPSTime	Floating	Time in seconds from midnight Sunday
807	MC Speed (kph)	Floating	Motorcycle speed from Speedbox (kph)

Table I-3. Data Output Files Generated after Data Merging

Variable Identification	Description
Gaze Ellipse File (denoted by a Gaze95.txt suffix)	
GazeXMean	Mean x location of the gaze point for the ride segment
GazeYMean	Mean y location of the gaze point for the ride segment
GazeXEllipseHalfWidth	Half width x dimension of the 95% gaze ellipse computed for the ride segment
GazeYEllipseHalfWidth	Half width y dimension of the 95% gaze ellipse computed for the ride segment
Reference Degrees	Angle of the gaze ellipse in degrees relative to the horizon computed for the ride segment
Sight Distance File (denoted by a SightRider.txt suffix)	
Time	Time stamp (seconds)
epX1Norm	X location of left side horizon
epY1Norm	Y location of left side horizon
epX2Norm	X location of right side horizon
epY2Norm	Y location of right side horizon
SightDistVector	Computed sight distance vector (m)
Speed	Motorcycle speed (kph)
gazeX	Gaze x location
gazeY	Gaze y location
Frame	Frame number
StopDist	Computed stopping distance (m)
SightStopRatio	Sight distance to dtopping ratio

APPENDIX II

Detailed Task Descriptions for Closed Course and Open Road Course
And Description of Parsed Video Sections

Table II-1. Detailed Task Descriptions for Closed Course and Open Road Course

	Event	Location
CLOSED COURSE		
1*	Sharp right turn	Portland Community College Range
2*	Barrel ride	Portland Community College Range
3**	Cornering Proficiency, left hand curve	Portland Community College Range
4*	Swerve	Portland Community College Range
5*	Quick Stop	Portland Community College Range
OPEN ROAD COURSE		
	Event	**Location**
1	Turning left	From G st to SW Lesser rd
2*	Moving in a straight line in region with good sight distance	SW Lesser rd
3	Negotiating a left bend	SW Lesser rd
4	Approaching intersection with traffic control	SW Lesser rd
5*	Turning right	From SW Lesser rd to SW Haines rd
6	Approaching intersection with traffic control	SW Atlanta rd
7	Moving in a straight line in region with good sight distance	SW Atlanta rd
8	Approaching intersection with traffic control	SW Atlanta rd
9	Turning right	From SW Atlanta to SW 68th pkwy
10**	Negotiating multiple left right bends with good sight distance	SW 68th pkwy
11	Approaching intersection with traffic control	SW 68th pkwy
12*	Turning right	From SW 68th pkwy to 99W
13*	Lane change to the left	99W
14	Approaching intersection with traffic control	99W
15*	Crossing controlled intersection	99W and SW 64th ave
16	Lane change to the right	99W
17	Approaching intersection with traffic control	99W
18	Turning right unprotected	From 99W to SW 60th ave
19	Crossing controlled intersection	SW 60th
20**	Negotiating a left bend with intersections	From SW 60th to SW Capitol Hwy
21*	Turning right	From SW 60th to SW Lesser rd
22	Negotiating a right bend with intersections	SW Lesser rd
23	Moving in a straight line in region with good sight distance	SW Lesser rd
24	Negotiating a left bend	SW Lesser rd
25	Approaching intersection with traffic control	SW Lesser rd and SW Haines rd
26	Crossing controlled intersection	SW Lesser rd and SW Haines rd
27**	Moving in a straight line in region with good sight distance	SW Lesser rd
28	Approaching intersection without traffic control	SW Lesser rd and Kruse Ridge dr
29*	Crossing uncontrolled intersection	SW Lesser rd
30	Negotiating a left bend with intersections	SW Lesser rd
31	Approaching intersection with traffic control	SW Lesser rd and Fosberg rd
32	Crossing controlled intersection	SW Lesser rd and Fosberg rd
33	Negotiating a left bend with intersections	Jefferson pkwy
34*	Moving in a straight line in region with good sight distance	Jefferson pkwy
35*	Negotiating a right bend with intersections	Jefferson pkwy and Cervantes

36	Negotiating a right bend with intersections	Jefferson pkwy and Cervantes circle
37	Moving in a straight line in region with good sight distance	Jefferson pkwy
38	Negotiating a left bend	Jefferson pkwy
39	Approaching intersection with traffic control	Jefferson pkwy and Kerr pkwy
40	Turning right	From Jefferson pkwy to SW Kerr pkwy
41	Moving in a straight line in region with good sight distance	Kerr pkwy
42	Approaching intersection with traffic control	Kerr pkwy and Touchstone
43	Crossing controlled intersection	Kerr pkwy and Touchstone
44*	Negotiating multiple left right bends with limited sight distance	Kerr pkwy
45**	Turning left	From Kerr pkwy to McNary Pkwy
46	Moving in a straight line in region with good sight distance	McNary pkwy
47	Approaching intersection with traffic control	McNary pkwy and Monroe pkwy
48	Crossing controlled intersection	McNary pkwy and Monroe pkwy
49	Negotiating multiple left right bends with good sight distance	McNary pkwy
50	Approaching intersection with traffic control	McNary pkwy and Jefferson pkwy
51	Crossing controlled intersection	McNary pkwy and Jefferson pkwy
52	Negotiating a left bend with intersections	McNary pkwy
53	Approaching intersection with traffic control	McNary pkwy and Kerr pkwy
54	Turning right	From McNary pkwy to Kerr pkwy
55	Moving in a straight line in region with good sight distance	Kerr pkwy
56	Approaching intersection with traffic control	Kerr pkwy and SW Hidalgo
57	Turning left	From Kerr pkwy to SW Hidalgo

* - indicates that this section is parsed during data reduction
** - indicates that this section is parsed and digitized during data reduction

Table II-2. Description of Parsed Video Sections.

Section Identification	Description
Closed Course	
CC1	Closed course sharp right turn
CC2	Closed course barrel ride
CC3	Closed course left hand curve
CC4	Closed course swerve
CC5	Closed course quick stop
CC50	Complete closed course
Open Road	
OR1	Straight on SW Lesser Rd with left bend
OR2	Right turn from stops (SW Lesser Rd to SW Haines Rd)
OR3	Multiple left and right bends (SW 86th Pkwy)
OR4	Merge into traffic (68th Pkwy to 99W)
OR5	Lane change in traffic (99W)
OR6	Crossing controlled intersection (99W and S 64th Ave)
OR7	Negotiating a left bend (SW 60th to SW Capitol Hwy)
OR8	Negotiating a left bend AND turning right (SW 60th)
OR9	Straight on SW Lesser Rd
OR10	Crossing uncontrolled intersection (SW Lesser Rd)
OR11	Straight on Jefferson Pkwy
OR12	Negotiating a right bend (Jefferson and Cervantes)
OR13	Multiple left and right bends (Kerr Pkwy)
OR14	Unprotected left turn (Kerr Pkwy onto McNary Pkwy)
OR29	Near miss event
OR30	Collision avoidance maneuver
OR31	Other
OR50	Complete open road course

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