Visual scanning of motorcycle riders: a preliminary look

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ABSTRACT

It is generally understood that motorcycle riding is an interactive activity that relies heavily upon visual scanning skills. Very little is known about the effect of motorcycle rider training on visual scanning patterns and sight distance techniques used by motorcycle riders in naturalistic riding situations. This study collected naturalistic data from a mix of beginner-trained, beginner-untrained and experienced motorcycle riders on both a closed course as well as an over-the-road course. A custom on-board data acquisition system was developed for installation on the rider's own motorcycle. The system monitored the motorcycle rider's head motions, visual scanning 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 both the closed course and the open road course.

The data showed several differences in visual scanning behavior depending upon the training and experience of the rider as well as the riding location. The preliminary findings suggest that beginner-untrained riders scan a much larger area during the open road course than experienced riders and that sight distance to stopping 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. Qualitative review of the eye scanning video data suggests that novice riders appear to have no distinct scan strategy. This may be due to the fact that novice riders have not yet fully developed the skills to apportion their attention less to the roadway and more to the hazards in their riding environment (as seen by experienced riders). The findings from this study have implications for beginning rider as well as experienced rider training programs. While technically challenging, this study has shown that it is feasible to collect naturalistic eye tracking data from motorcycle riders of varying experience levels and provides a unique insight into the human element of motorcycle riding in a naturalistic riding situation.

INTRODUCTION

Motorcycle riding represents an enjoyable mode of transportation and 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 effect motorcycle riding. Current US motorcycle rider training program curricula emphasize the importance of these skills in both the classroom environment as well as during on-motorcycle training, but very little is known about how these skills are integrated by beginner riders. Similarly, very little is known about how these skills are

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retained over time. It was one of the goals of this study to examine these questions and provide insight into how riders interact with their riding environment.

Magnitude of the Problem

Motorcycle use in the United States for commuting and recreational purposes has been increasing since the mid-1990's, with motorcycle registrations having nearly doubled between 2001 and 2010 (NHTSA, 2012). Motorcycles represent approximately 3 percent of the nation's registered vehicles, but 13 to 14 percent of all traffic deaths (NHTSA, 2013).

As the number of motorcyclists on US roadways increases, the number of motorcycle riders killed and injured also tends to increase. Despite the motorcycling community's efforts to improve its safety record through initiatives such as rider training and licensing campaigns and a significant decrease in fatalities in 2009 (see Table 1), the number of motorcycle injuries and fatalities has been increasing for the past two years.

Table 1. Trends in Motorcycle Fatalities and Injuries.
(Source: NHTSA, 2013)

	2007	2008	2009	2010	2011
Total killed on US roadways	41,259	37,423	33,883	32,999	32,367
Motorcyclists killed	5,174	5,312	4,469	4,518	4,612
% change of motorcyclists killed from previous year	+7.0	+2.7	-15.9	+1.1	+2.1
Motorcyclists injured	103,000	96,000	90,000	82,000	81,000
Motorcyclist fatalities as % of all fatalities	12.5	14.2	13.2	13.7	14.3

In an effort to improve awareness of motorcycle safety issues, in 1998 the National Highway Traffic Safety Administration (NHTSA) 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 paper summarizes some of the 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 motorcycle rider represent a key parameter for crash avoidance and effective vehicle operation. A rider must be able to effectively look ahead and identify the risks in front of him or her, and successfully avoid those risks. 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 comparing 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 1970's 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 these same results were found in a motorcycle riding population it would suggest that riders with poor visual gaze patterns may tend to fixate on the tangent of the curve or some other part of the roadway, and as a result tend to 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 the root cause of many 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, Liu, & Bayly, 2010), at present there is no published research available that has measured and monitored the gaze patterns of beginner motorcycle riders relative to experienced motorcycle riders in a naturalistic riding environment. Eye tracking research by Muttart et al., 2011 reported no significant difference in the glance performance of a group of experienced riders when participants with less than 5 years of licensure were compared with riders where

were licensed for more than 5 years. This would suggest that learning glance behaviors, particularly those behaviors that help you operate the motorcycle and avoid potential hazards, occurs very early in a motorcycle riding career.

MATERIALS AND METHODS

Rider Participants

Thirty-one beginner-trained, beginner-untrained and experienced riders were recruited for this study. Beginner-trained riders (n = 7) were defined as any rider who registered for a TEAM OREGON BRT course and agreed to participate. Beginner-untrained riders (n = 12) 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. These riders were contacted and asked to participate in the study. 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).

Experienced riders (n = 12) were recruited from Craigslist. The criteria for experienced riders were that they had a minimum of 5 years and 15,000 miles of riding experience. Rider participant characteristics are presented in Table 2.

Table 2. Rider Participant Characteristics

	Beginner-Trained riders	Beginner-Untrained riders	Experience 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[2]	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)

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[2] Beginner-trained riders were not asked questions marked with "n/a"

Instrumentation

Figure 1. Helmet with eye tracking system and inertial measurement unit

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) which 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.

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 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. All subjects participated in three testing sessions, separated by a minimum of 6 months between sessions. For safety reasons, those participants in the beginner-trained group were not tested on the open road during the baseline (initial) 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 during each testing session.

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.
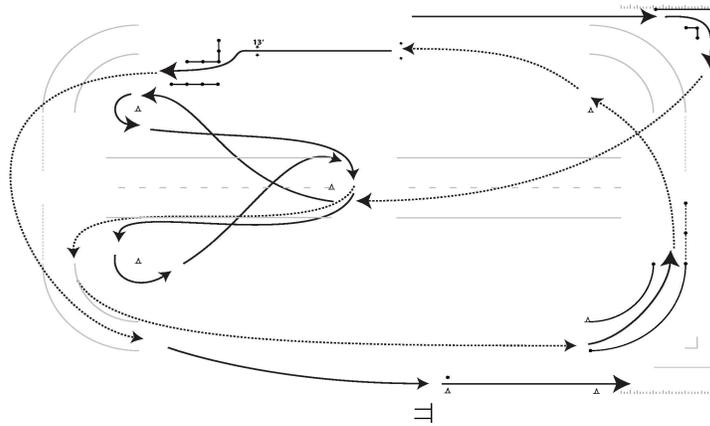
After completing the closed course circuit the rider was instructed to proceed out onto the open road course with the TEAM OREGON staff member. A 9.4 mile route was selected after a series of initial pre-study ride sessions by the TEAM OREGON staff. The open road course included both urban and rural 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. Immediately following the ride, the TEAM OREGON instructor made notes regarding their observations of the rider behavior on the open road course.

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. 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 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 3). 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.
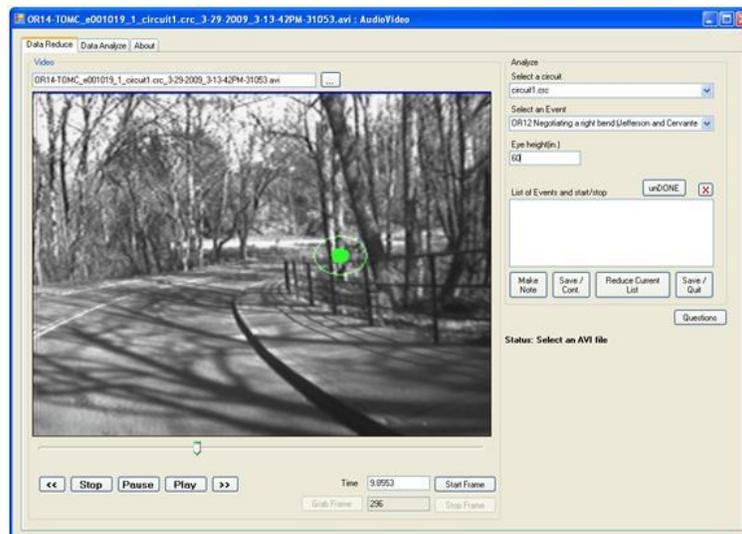

Figure 3. Data software reduction tool

Five specific tasks were identified on the closed course, and 57 unique riding tasks were identified on the open road course. 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.

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. 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. 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.

In addition to the reduced gaze video data, 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. Once the sight distance output files were generated, Microsoft Excel macros were used to compute average values for the given segment being analyzed.

Data Analysis

The main independent variables (rider group and testing session) were evaluated relative to the dependent variables used for this study. The primary dependent variables of interest were the number of times that

the sight distance to stopping distance ratio went below 1.0 and 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 defined as the area in which the rider spent 95% of his or her time gazing within the visual field. Thus, a larger gaze 95% confidence ellipse area indicated that the rider's visual search spread over a wider area of the region in front of him or her. Each of these variables was evaluated both within the participant (i.e., over the duration of the project) as well as between different participant groups (i.e., beginner-trained versus beginner-untrained riders).

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. 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. Speedboxtm 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. Sight distance to stopping distance ratio and speed were analyzed for both the closed course section CC3 (left hand bend in closed course), as well as the open road 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.

Rider Gaze Behavior

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 course section OR7 is shown in Figure 4.

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.
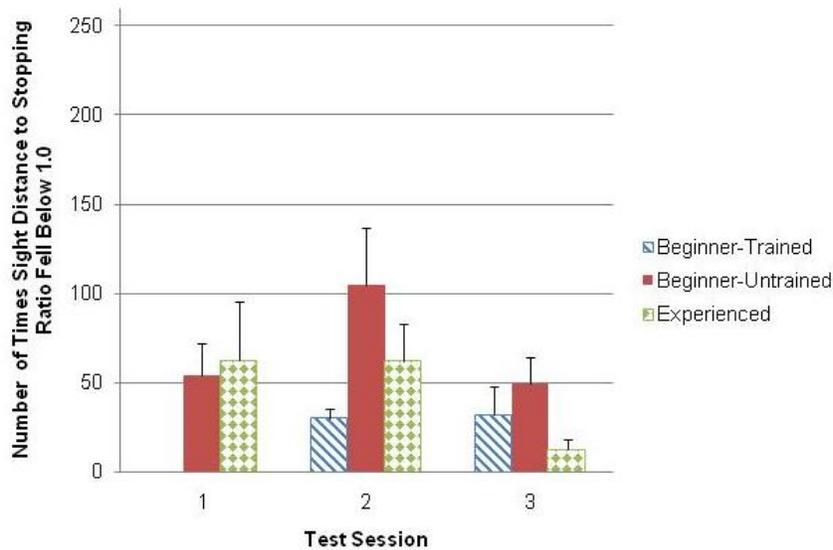

Figure 4. Mean number of times the sight distance to stopping ratio fell below 1.0
for open road section OR7 (standard error bars shown).

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 area in which the rider spent 95% of his or her time gazing within the visual field, and it was analyzed over the entire closed course and the entire open road course. A mixed ANOVA (rider group by test session) was performed on the mean 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 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 95% confidence ellipse area over the closed course for each rider group during each test session is shown in Figure 5.
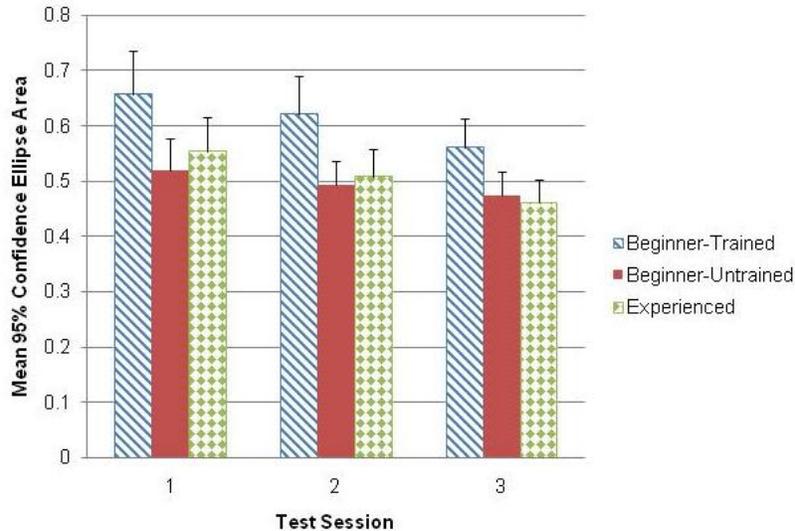
Figure 5. Mean 95% confidence ellipse area and standard error for closed course

Over the open course, the mean 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 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 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.

DISCUSSION

Over the course of a one year period, 31 motorcycle riders participated in this study. 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. These data represent some of the first naturalistic motorcycle riding study data published and it is anticipated that in the future these data will provide additional insight into naturalistic motorcycle riding behavior and the changes in that behavior as a motorcycle rider gains experience.

In addition to the development of a naturalistic motorcycle riding data acquisition system, one goal of this study was to determine the effect of motorcycle training and feedback on sight distance skills for three different 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 quantitative variables selected as indicators of sight distance skills. The research hypothesis was 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. It was also hypothesized that the frequency of the sight distance to stopping distance ratio going below 1.0 would be greatest for the beginner-untrained riders, who did not receive any sight distance training or feedback.

The Effect of Training upon Sight Distance Skills

The results of this study support 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.

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. 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). If training on sight distance increases riders' line-of-sight in curves, it could potentially also increase their ability to successfully negotiate curves in the road.

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 finding suggests that riders' increased familiarity with the open road course over time improved their visual skills 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.

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 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). While not specifically quantified, this phenomenon was clearly visible in the gaze patterns of the beginner-untrained and beginner-trained riders when compared to the experienced riders. It is possible that the gaze 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. It could be suggested that as a rider gains more experience operating in the riding environment, their ability to focus on the more hazardous aspects of their riding environment improves.

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 33 sight distance to stopping distance ratio during open road section OR7 and the mean 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.

CONCLUSIONS

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. To our knowledge, this represents the first such published data of this type that includes both eye tracking data and vehicle data. Participants included riders that 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 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. Speed, handling skills on the RSP Circuit Ride, and subjective ratings of head and eye skills 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 95% confidence ellipse area over the open road course than experienced riders. These findings are the first to demonstrate differences in the visual behavior of novice and experienced riders on the open road, and also 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. Further research could additionally investigate if there is a causal link between training and sight distance behavior. 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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