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A Holistic Approach to Reducing Adolescent Risky Behavior

Combining Driving Performance Measures with Psychosocial and Neurobiological Measures of Risky Adolescent Behavior

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EXECUTIVE SUMMARY

Adolescent drivers are one of the age groups with the highest crash risks due to factors such as inexperience and poor judgment, an increased propensity for risk-taking, and a higher likelihood to engage in secondary tasks. Previous research has indicated that there may be correlations between teen risky driving behaviors and health risk behaviors such as substance use. Therefore, it is important to understand if there is a relationship between adolescent risky behaviors and unsafe driving outcomes. To investigate this, the Virginia Tech Transportation Institute (VTTI) partnered with the Virginia Tech JK Lifespan Development Lab to conduct a pilot study. During this study, 17 novice teen drivers within 1 month of obtaining their provisional license who were also participating in the Neurobehavioral Determinants of Health-Related Behaviors (NDHRB) Study were recruited. Participants' personal vehicles were instrumented with VTTI's mini-data acquisition system, which collected driving performance and behavior data. Data was collected over a 6-month period and analyzed for kinematic risky driving events, eye-glance behavior, secondary task engagement, and seatbelt use. This data was combined with the psychosocial/neurobiological data collected from the surveys, questionnaires, and tests during the NDHRB study. Correlations were discovered between risky driving behaviors (kinematic risky driving events, eye-glance behaviors, secondary task engagement and cellphone use, and proper seatbelt use), and psychosocial/neurobiological measures (reported substance use, insula activation during a lottery task, general health self-assessment, Domain-Specific Risk-Taking Scale health safety risk, health risk behavior, and self-reported risk). The results from this pilot study were promising and point to the need for future research into teen risky behaviors, either driving or otherwise, to create countermeasures to reduce teen crash rates.

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LIST OF ABBREVIATIONS AND SYMBOLS

DOSPERT	Domain-Specific Risk-Taking Scale
KRD	kinematic risky driving
MGOR	mean off-road glance duration
MiniDAS	mini-data acquisition system
NDHRB	Neurobehavioral Determinants of Health-Related Behaviors
NORG	number of off-road glances
PCR	Parent-Child Relationship Scale
SD	secure digital high capacity
SLG	single longest off-road glance
TEORT	total eyes-off-road time
UNC	Uncertainty Task

CHAPTER 1. INTRODUCTION

Adolescent drivers, specifically teenagers ages 16-19, are one of the groups associated with the highest crash risk. The National Highway Traffic Safety Administration (NHTSA, 2022) reported that in 2020, drivers between the ages of 16 and 20 had the highest rate of involvement in crashes at 9,320 per 100,000 licensed drivers. This trend has been relatively consistent for many years. Between 2000 and 2001, the rate of crashes per million miles for drivers 16-19 was four times greater than the rate of crashes for drivers over the age of 20 (Braitman et al., 2008); in 2005, it was reported that per population, teenagers were involved in twice as many crashes as drivers between the ages of 30 and 59 (Hedlund, 2007). Additionally, drivers at age 16 were reported to have the highest crash rates compared to 17-, 18-, and 19-year-old drivers (26, 21, 15, and 14 crashes per million miles traveled, respectively; Insurance Institute for Highway Safety, 2006). Simons-Morton et al. (2015) conducted a naturalistic driving study over an 18-month period where a group of newly licensed teenagers and at least one of their parents were recruited; results showed that, on average for both the teens and adults, crashes and near-crashes declined over time, but the crash and near-crash rates were four times higher for teens than for adults during the first 18 months of licensure.

Researchers have identified several factors to explain why teen drivers are more likely to be involved in crashes. To begin, teen drivers are inexperienced and much of their attention is directed towards the physical driving task and controlling the vehicle (Hedlund, 2007). As drivers gain more experience, driving becomes an automatic skill, such that processing capacity that is allocated to the physical driving task during early years of driving can be freed up to focus on more important demands and emergent situations (Keating, 2007). Due to their inability to allocate attention resources like scanning the road, teen drivers often have difficulty recognizing hazards, which results in more judgement errors (Dingus, 2007). This may explain why teen drivers have higher crash rates at night or when there are other passengers in the vehicle (Hedlund, 2007). To add to the performance errors, teen drivers also have an increased propensity for risk-taking, such as speeding, especially in poor conditions, such as low-friction road surfaces (Braitman et al., 2008). In a study conducted on a test track, teen drivers were more likely to engage in secondary tasks compared to adult drivers (Lee et al., 2006). Similarly, in the study conducted by Simons-Morton et al. (2015), while secondary task engagement prevalence was similar between teenagers and adults, tasks such as using phones, reaching for objects, eating, and staring for long periods of time at objects outside the vehicle were associated with higher crash/near-crash risk. Survey results also found a correlation between risky driving outcomes and having friends who engaged in risky driving or other risky behaviors (Simons-Morton et al., 2015). Teens have also been reported to use seatbelts less frequently than older drivers (Williams, 2007). Across two naturalistic driving studies, 10% of the teen drivers were involved in over 50% of the safety-related events (Hedlund, 2007), which could possibly indicate that there are certain factors related to these drivers that need to be investigated further.

While there are many risky behaviors that teenagers engage in as drivers, adolescent risky behavior is also a well-studied phenomenon outside of driving research. Many adolescents not only are more likely to engage in a broad array of risky behaviors, those that do engage in risky behaviors also tend to engage in multiple risky behaviors (Terzian et al., 2011). A few studies have also investigated other factors related to adolescent development, such as neurobiological and psychosocial tendencies, that may be associated with risky driving outcomes. Kim-Spoon et al. (2016) investigated the association between health-risk behaviors and risky decision-making during a laboratory driving task. Findings revealed an association for the group of adolescents: those who took more risks during the driving task also reported earlier onsets of, and more frequent, substance use. This association was not found in the adult group. Due to this finding, along with some of the contributing factors from the naturalistic driving studies, it is relevant to explore if certain adolescent risky behaviors are correlated with unsafe driving outcomes.

RESEARCH OBJECTIVES

This pilot study will serve as a "proof of concept" for assessing objective measures of risk, outside of the driving domain, that can be used to compare and support other neurobiological and psychosocial measures of risky adolescent behavior within the driving domain. Furthermore, this study will lay the foundation for understanding the neurobiological and psychosocial basis of risky driving among adolescents.

CHAPTER 2. METHODS

PARTICIPANTS

Seventeen novice teen drivers within 1 month of obtaining their provisional license who were also participating in the Neurobehavioral Determinants of Health-Related Behaviors (NDHRB) Study were recruited as primary drivers in this research effort. The NDHRB study was conducted by Drs. Kim-Spoon and King-Casas (VT IRB # 13-516). At least one parent or legal guardian of each teen was recruited as a fully participating secondary driver in this study.

Participants in this study were required to hold a valid driver's license and be between the ages of 16.25 and 19 years old. Participant requirements also included having not yet completed the 12th grade and planning to live at home for the 4 months of data collection. Each teen participant was required to drive the instrumented vehicle unsupervised by their parent or guardian at least one time per week. The participant's parent/legal guardian drove the instrumented vehicle on a regular basis (at least once per week). Participants were enrolled in the naturalistic driving phase of this study for 4 months.

For completing the intake paperwork and vehicle instrumentation appointment, teen participants received $50; after completing 4 months of data collection and having the system removed from the vehicle, they received a final payment of $100. In addition to the standard payment of $150, teen participants were compensated $20 for attending the data collection session at a public location. All payments were administered using a pre-paid ClinCard MasterCard. Parent drivers were not compensated for their participation in this study.

EQUIPMENT

The personal vehicle of study participants was instrumented with a VTTI mini-data acquisition system (MiniDAS) that allowed the research team to continuously collect driving performance and behavior data. The MiniDAS was designed to be unobtrusive and easily installed in most vehicles in under 60 minutes via a connection to the vehicle's On-Board Diagnostics II (OBD-II) port. Table 1 provides further details about the system.

Table 1. MiniDAS specifications and features.

Size	6.5" × 5" × 1.75"
Video Channels	Forward roadway (640 × 480) Driver (640 × 480)
Storage	128 GB removable SDHC card
Hardware	GPS: speed, latitude, longitude, heading 3-axis accelerometer: X, Y, Z 3-axis gyroscope: X, Y, Z Magnetometer Cellular modem Microphone (8000 Hz, 8-bit, mono) Infrared (IR) illumination (nighttime video visibility) Incident pushbutton
Key Features	Self-contained, single unit Small installation footprint Single OBD-II cable installation Controller Area Network (CAN) variable collection (speed, RPM, brake, turn signals, etc.) Real-time detection of safety epochs Lane departures Hard turns Hard braking Excessive speed Swerve Epoch and continuous data collection Expandable to work with Wi-Fi, Bluetooth, or CAN modules

The MiniDAS unit was mounted approximately 3 inches from the bottom of the vehicle's windshield, near the vehicle center line. A cable was routed for power and vehicle network data collection between the OBD-II port and the MiniDAS (Figure 1).

Figure 1. Photo. MiniDAS installation location.

The MiniDAS digital video subsystem records views of the forward roadway and the driver's face. Frame numbers are overlaid on the lower left portion of the video feed, allowing for synchronization of the video streams. Figure 2 shows an example of data frames collected from the digital video system on the MiniDAS. Detailed information about the installation and communication specifications of the MiniDAS can be found in the Driver Coach Study final report (Klauer et al., 2017).

Figure 2. Photos. Exemplar video image of driver face view (left) and forward roadway view (right). The driver's face is blurred to protect their privacy.

Under normal driving conditions (12,000-15,000 miles per year), the 128-GB Secure Digital High Capacity (SD) card is capable of collecting 3 to 4 months of video, sensor, and network data before exceeding capacity constraints. Therefore, a VTTI researcher completed an SD card swap every 2 to 3 months for each participant. This SD card swap occurred at a convenient, central location in each participant's general area. The SD card containing data was retrieved from the vehicle, and a new SD card was installed in the MiniDAS. At this time, the researcher checked the data to ensure that proper collection was taking place. Participants were paid $20 for each appointment to compensate them for their time. These appointments typically took approximately 30 minutes. If needed, additional appointments were scheduled to remedy data issues, such as nonfunctional camera or audio, poor cellular communication, and improper sensor readings.

DATA

The two main data sources for this project were (1) psychosocial surveys and questionnaires and neurobiological data collected during risk-taking performance tests and (2) driving data. Detailed descriptions of each appear in the sections below.

Psychosocial and Neurobiological Data

The participants in this study were recruited for the NDHRB study at the age of 13 years and subject to a battery of psychosocial surveys and questionnaires that aimed to understand personality measures, impulsivity and self-regulation measures, social support, and health risk behaviors (Kim-Spoon et al, 2019). Additionally, participants completed tasks that involved risk-taking to assess cognitive control, reward learning, risk processing, and intertemporal discounting. Participants completed these surveys, questionnaires, and tasks two times per year over the course of 6 years. As the focus of this study was to understand underlying risk behaviors and how they may relate to risky driving, the research team selected the surveys and questionnaires that were more focused on these areas from the NDHRB study at Wave 4, which is around the time when the subjects received their learner's permit/license and began driving on their own. Brief descriptions of the surveys, questionnaires, and tasks are included below, and more detailed descriptions can be found in the NDHRB study (Kim-Spoon et al, 2019).

- Academic Performance and Health: This survey asks parents and adolescents about the adolescent's average level of academic performance and general health.

- Behavioral Inhibition System and Behavioral Activation System Scales (BIS/BAS): This questionnaire asks parents and adolescents to indicate how true a number of statements are for them related to drive, fun-seeking/impulsiveness, and reward-responsiveness.

- Difficulties in Emotion Regulation Scale (DERS): This questionnaire asks parents and adolescents a series of questions related to how often they regulate their emotions in times of distress.

- Emotion Regulation Questionnaire (ERQ): Similar to DERS, this questionnaire aims to assess emotion regulation strategies, reappraisal and suppression, by having parents and adolescents indicate how much they agree with statements describing emotional experiences and expressions.

- Domain-Specific Risk-Taking Scale (DOSPERT): This questionnaire assesses behavioral intentions or likelihood to engage in risky behaviors in ethical, financial, health/safety, social, and recreational aspects of life. Parents and adolescents indicate how likely they are to engage, how risky they feel, how likely the bad outcome will occur, and how likely the good outcome will occur, with a number of risky activities.

- Parent-Child Relationship Scale (PCR): This questionnaire has parents and adolescents rate negative aspects of their relationship on a 5-point Likert-type scale.

- Parental Monitoring Scale: This measure asks parents and adolescents about parental knowledge, child disclosure, parent solicitation, and parental control.

- Things I Do/Things Your Child May Do: This questionnaire asks parents and adolescents to indicate how often they have engaged in a number of risky behaviors.

- Uncertainty Task (UNC): This task utilizes functional magnetic resonance imaging (fMRI) to understand adolescent brain activity during an economic lottery choice task to understand risk with gambling.

- Youth Behaviors: This questionnaire asks adolescents about previous drug use, how they would respond in situations involving drugs, and sexual activity.

- Barratt Impulsiveness Scale short form: This scale has parents and adolescents respond to a number of questions to indicate their impulsivity with certain tasks.

- Youth Self-Report (YSR): This survey assesses adolescent behavior problems through a number of questions about internalizing and externalizing behaviors.

- Stoplight Task: This task is a behavioral measure of risky decision-making that has adolescents complete a first-person driving task where they want to reach the finish as quickly as possible but also avoid crashing while driving through intersections.

- Multi-Source Interference Task (MSIT): This task has parents and adolescents respond to a target number paired with zeroes, ones, twos, or threes to assess behavioral performance of inhibitory controls.

- Perceived Stress Scale (PSS): This measure has parents and adolescents report how often they have felt stressed recently.

- Sensation Seeking Scale (SSS): This short-form scale asks parents and adolescents questions to measure sensation seeking.

Driving Data

This analysis consists of measures of driving performance with particular relevance to novice driver risk-taking, including kinematic risky driving (KRD) events, eye-glance behavior, secondary task engagement, and seatbelt use.

KRD

KRD was measured by elevated g-force events. G-force events were considered elevated when they exceeded the following thresholds:

- Longitudinal deceleration/hard braking: ≤ −0.45 g
- Longitudinal acceleration/rapid starts: ≥ 0.35 g
- Lateral negative/left turn: ≤ −0.5 g
- Lateral positive/right turn: ≥ 0.5 g
- Yaw rate/swerve: ± 6 degrees per second

Eye-glance Behavior

To assess the difference between driver eye-glance behavior and secondary task engagement, randomly selected control segments were used. Control segments are 21-second driving segments randomly sampled from a point in a trip where a driver was traveling at least 8 km (5 miles) per hour without any crash-related event. Five hundred control segments were randomly sampled and stratified by driver based on hours traveled (Guo & Hankey, 2009; Hankey et al., 2016).

Eye-glance measures were assessed using general linear models with a random driver effect. Four measures of driver eye-glance behavior were used (Table 2).

Table 2. Eye-glance measures.

Glance Measure	Acronym	Description
Total Eyes-off-road Time	TEORT	The summation of all glance durations to all areas of interest other than the road scene ahead during a sample interval in seconds (SAE International, 2017).
Single Longest Off-road Glance	SLG	The duration of the single longest glance away from the forward roadway during the sample interval.
Mean Off-road Glance Duration	MGOR	The average duration of all off-road glances during the 10-second sample interval.
Number of Off-road Glances	NORG	The average number of glances away from the forward roadway during the 10-second sample interval.

Secondary Task Engagement

All secondary task engagement is recorded by trained data coders. Trained coders have up to five tasks that they can code per control segment. Guo et al. (2017) identified the odds of crash involvement for secondary task engagement for four different driver age groups: Teen, Young Adult, Middle, and Senior. Drivers in the NDHRB study data set are similar ages and drive in similar geographic locations to those in the Teen age group for Guo et al.; therefore, observable distractions with significant odds ratios across this group will be considered high risk for this analysis. Table 3 includes a description of the secondary tasks.

Table 3. Secondary task descriptions.

Secondary Task	Disaggregate Tasks
Any Task	If Secondary Task 1 is populated with a task other than "No Secondary Task"
All Cellphone	All cellphone tasks
Visual-Manual Cellphone	All cellphone tasks excluding talking
Talking	Cellphone, talking/listening, handheld
Texting	Cellphone, texting
Dialing	Cellphone, dialing handheld, including using quick keys
Browsing	Cellphone, browsing
Reaching Phone	Cellphone, locating/reaching/answering
Reaching for object in vehicle (non-cellphone)	Reaching for cigar/cigarette Reaching for food-related or drink-related item Interaction with moving object Reaching for object, other Reaching for personal body-related item
External Distraction	Looking at an object external to the vehicle Looking at previous crash or incident Looking at pedestrian Looking at animal Other external distraction
Passenger Interaction	Passenger in adjacent seat – interaction Passenger in rear seat – interaction Child in adjacent seat – interaction Child in rear seat – interaction

Seatbelt Use

For each trip, seatbelt use was observed at three different timestamps during the trip. A total of 5,521 trips were analyzed, although useable data was only available for 5,445 of the trips. Data where seatbelt use was classified as "unknown" or "NA" was removed from the analyses. Table 4 includes definitions for each of the seatbelt use categories. If the driver's seatbelt status changed during the trip, that was also coded.

Table 4. Levels of seatbelt use.

Category	Description
Proper	Seatbelt appropriately buckled
Not Used	Seatbelt was not used
Improper	Improper seatbelt use
Changed	Inconsistent seatbelt usage within a trip file Proper to improper, improper to proper, etc.

CHAPTER 3. RESULTS

This analysis includes data for 17 participants (9 male) who were enrolled in this study on average for 135 days (M = 134.94, SD = 16.8 days). Participants completed an average of 426 trips while enrolled in the study, with an average duration of 14 minutes (M = 14.18, SD = 2.99 minutes). Participants drove approximately 103.8 hours while enrolled in the study (M = 103.77, SD = 43.8 hours).

Results from the driving data will be presented first, followed by correlations between the driving data and the psychosocial/neurobiological data. The driving data will be presented to show general risky driving levels of this population, whereas the correlations will provide more insight into how these two types of data (risky driving and overall risk-taking behavior) are associated.

RISKY DRIVING DATA

KRD

Due to possible equipment issues, one participant has been excluded from the KRD analyses. Table 5 shows a breakdown of the frequency of KRD events by bin ranges.

Table 5. Frequency of all KRD events by type.

Hard Brake (g)			Rapid Start (g)		
Bin Range		***N***	**Bin Range**		***N***
-0.45	-0.499	183	0.35	0.399	252
-0.5	-0.549	94	0.4	0.449	32
-0.55	-0.599	35	0.45	0.499	1
-0.6	-0.649	13			
-0.65	-0.699	3			
-0.7	-0.749	3			
-0.75	-0.799	3			
-0.8	-∞	5			
Hard Left (g)			**Hard Right (g)**		
Bin Range		***N***	**Bin Range**		***N***
-0.5	-0.549	176	0.5	0.549	251
-0.55	-0.599	73	0.55	0.599	102
-0.6	-0.649	28	0.6	0.649	43
-0.65	-0.699	5	0.65	0.699	6
-0.7	-0.749	3	0.7	0.749	3
-0.75	-0.799	1	0.75	0.799	1
-0.8	-∞	1	0.8	∞	0
Left Yaw (deg./s)			**Right Yaw (deg./s)**		
Bin Range		***N***	**Bin Range**		***N***
-6	-6.99	71	6	6.99	85
-7	-7.99	55	7	7.99	37
-8	-8.99	34	8	8.99	28
-9	-9.99	18	9	9.99	21
-10	- ∞	20	10	∞	30

Figure 3 shows that hard braking events with a magnitude between −0.45 and −0.499 g were the most prevalent with 183 events. There were 156 instances where drivers met or exceeded −0.5 g of braking force.

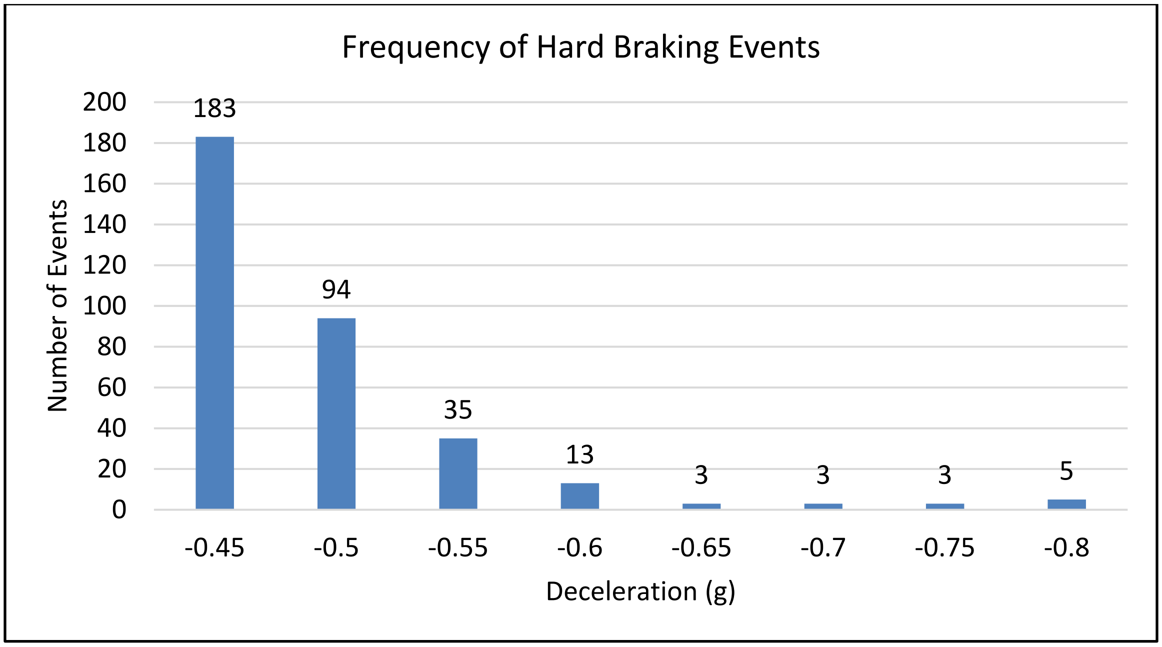

Figure 3. Histogram. Frequency of hard braking events.

There were 285 instances of rapid starts observed in the KRD data (Figure 4). The most frequently occurring value was between 0.35 and 0.399 g.

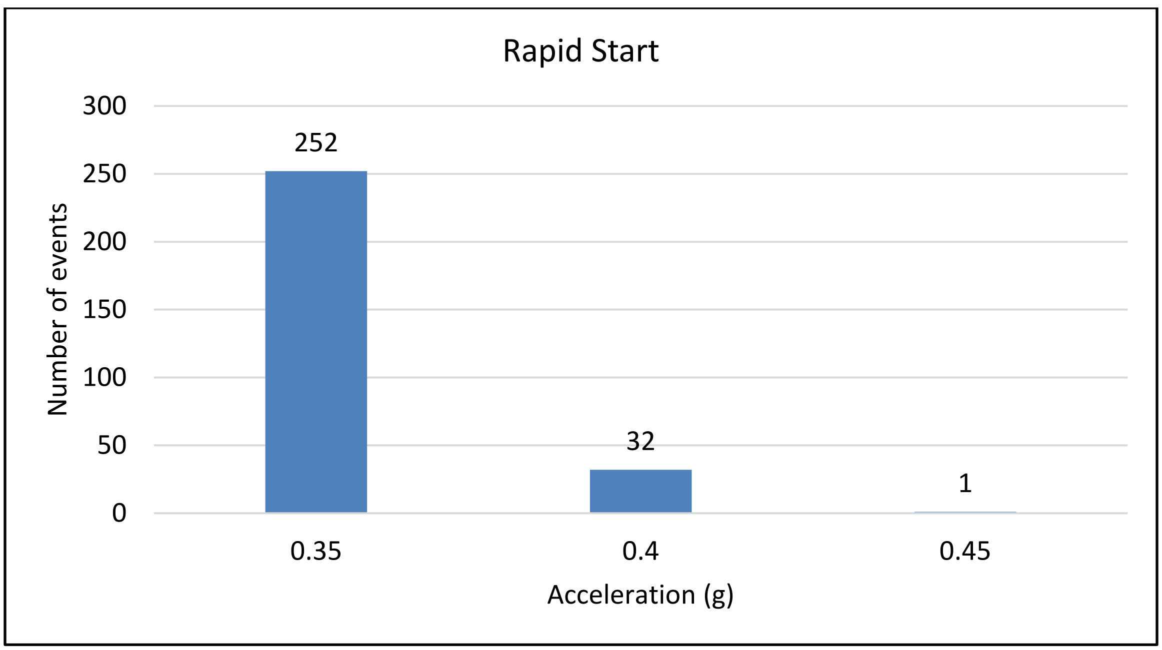

Figure 4. Histogram. Frequency of rapid starts.

Figure 5 shows the frequency of hard cornering KRD events. There were 695 instances of hard cornering observed.

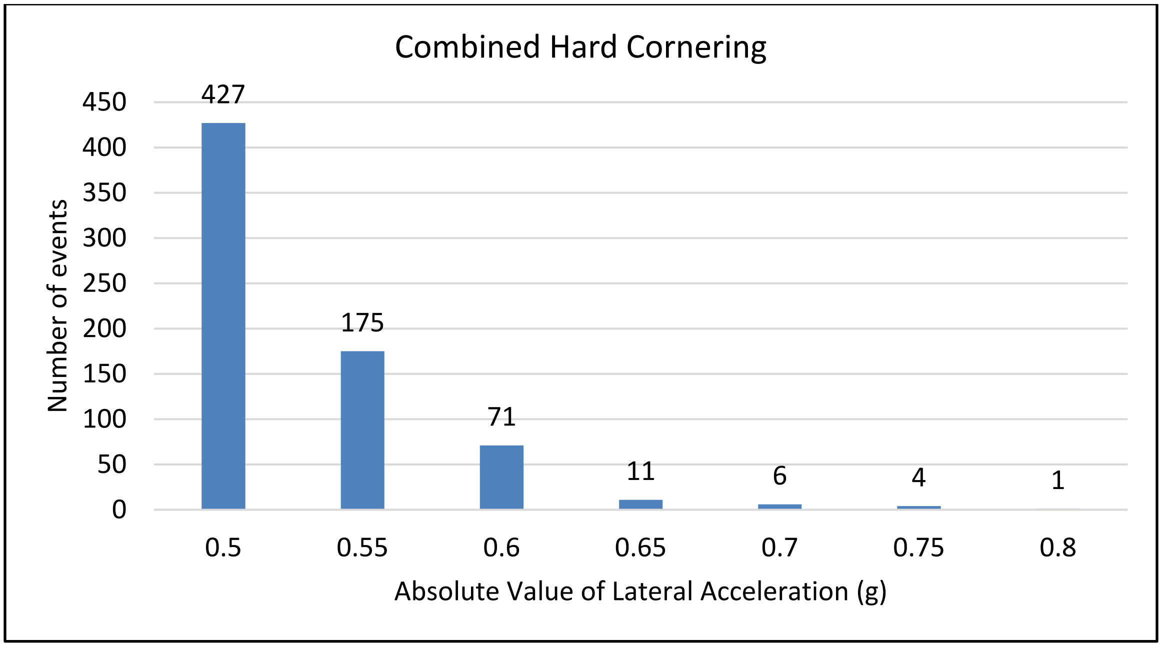

Figure 5. Histogram. Frequency of hard cornering.

Figure 6 shows the frequency of yaw for the left and right directions combined. The most prevalent yaw rate is within the 6-degrees-per-second bin.

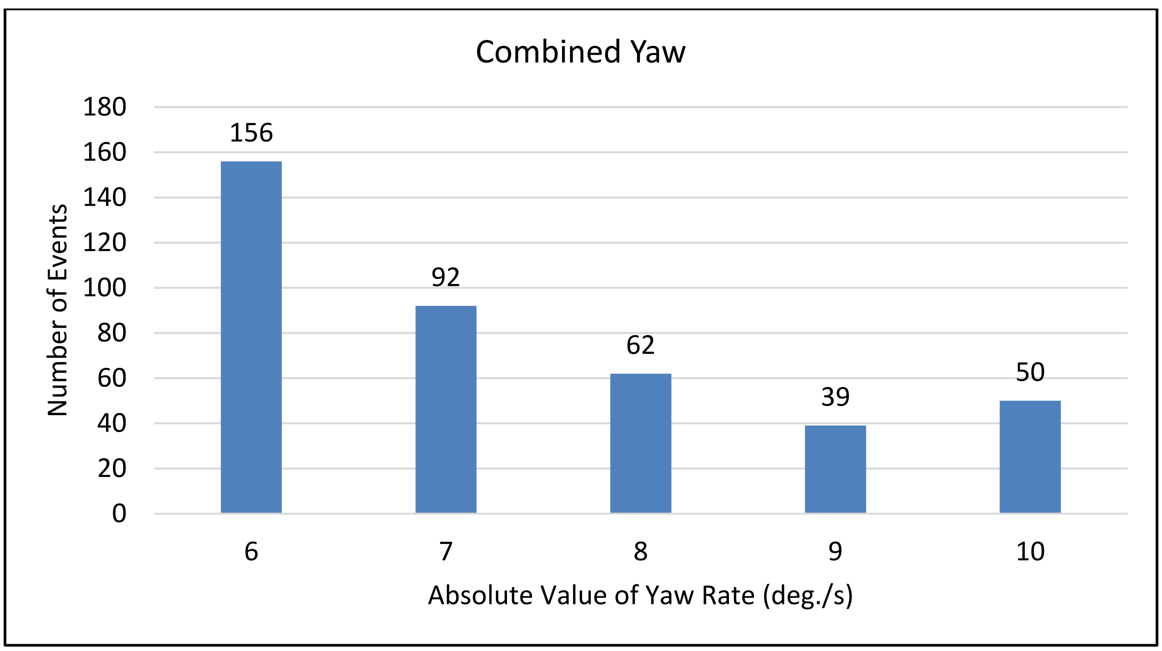

Figure 6. Histogram. Frequency of yaw.

Eye-glance Behavior

Participants' eye-glance behaviors generally appear unremarkable, as summarized in Table 6. Their TEORT lasted approximately 12.5% of the total 21-second control segment duration on average (M = 2.63, SD = 2.46). Participants' MGOR duration was 0.57 seconds, and their SLG away from the roadway was less than 1 second (M = 0.99, SD = 0.86). Participants made an average of 4.09 glances away from the roadway.

Table 6. Aggregate summary of eye-glance measures in seconds.

Variable	*N*	Mean	SD	SE	Min.	Max.
TEORT	500	2.63	2.46	0.11	0	11.49
MGOR	500	0.57	0.38	0.02	0	2.7
SLG	500	0.99	0.86	0.04	0	8.8
NORG	500	4.09	3.39	0.15	0	17

Participant gender was not found to contribute to TEORT ($F[1, 483] = 0.35$, $p = 0.5521$), MGOR ($F[1, 483] = 0.28$, $p = 0.5966$), SLG ($F[1, 483] = 0.00$, $p = 0.9621$), or NORG ($F[1, 483] = 0.26$, $p = 0.6124$). Summary statistics for eye glance by gender are shown in Table 7.

Table 7. Summary eye-glance measures by gender in seconds.

Variable	GENDER	*N*	Mean	SD	SE	Min.	Max.
TEORT	F	249	2.55	2.28	0.14	0	10.8
	M	251	2.71	2.64	0.17	0	11.49
MGOR	F	249	0.56	0.32	0.02	0	2.1
	M	251	0.58	0.44	0.03	0	2.7
SLG	F	249	1.01	0.81	0.05	0	4.9
	M	251	0.97	0.91	0.06	0	8.8
NORG	F	249	3.94	2.94	0.19	0	14
	M	251	4.24	3.79	0.24	0	17

Secondary Task Engagement

Participant secondary task engagement is typical of teen drivers. Table 8 shows the frequency and prevalence of overall and high-risk secondary task engagement for drivers in this study.

Table 8. Observed frequency and prevalence of secondary task engagement.

Secondary Task Categories	*N*	Prev.
Any Task	294	58.8%
All Cellphone	33	6.6%
Visual Manual Cellphone	27	5.4%
Talking	7	1.4%
Texting	3	0.6%
Dialing	2	0.4%
Browsing	14	2.8%
Reaching for cellphone	5	1.0%
External Distraction	28	5.6%
Reaching for object in vehicle (non-cellphone)	1	0.2%
Operating in-vehicle device	29	5.8%
Passenger Interaction	135	27.0%

Seatbelt Use

Participants wore their seatbelts properly 98% of the time on average (Table 9). Improper seatbelt use was most frequently observed during daylight lighting conditions (Table 10) and dry surface conditions (Table 11), although this may be because most driving occurred during these conditions.

Table 9. Prevalence of seatbelt use.

Seatbelt Use	*N*	Prev.
Changed	39	1%
Improper	4	0%
Not used	51	1%
Proper	5,351	98%
Total	**5,445**	**100%**

Table 10. Inappropriate seatbelt use observations by lighting condition.

Lighting Condition	Changed	Improper	Not used	Total
Dark	9	0	11	**20**
Daylight	25	4	34	**63**
Twilight	5	0	6	**11**
Total	**39**	**4**	**51**	**94**

Table 11. Inappropriate seatbelt use observations by surface condition.

Surface Condition	Changed	Improper	Not used	Total
Dry	27	2	37	**66**
Ice	2	0	1	**3**
Unknown	0	0	10	**10**
Wet	10	2	3	**15**
Total	**39**	**4**	**51**	**94**

CORRELATIONS BETWEEN DRIVING DATA AND PSYCHOSOCIAL/NEUROBIOLOGICAL DATA

There were several correlations between the driving data (KRD, eye-glance behavior, secondary task engagement, and seatbelt use) and psychosocial/neurobiological data. The below figures show a few of the highlighted correlations.

Drug Use and KRD

A correlation was found between drug use and overall KRD event rate. Participants who had tried a cigarette before or used marijuana at a younger age were more likely to have higher rates of KRD events (R^2 = 0.4678; Figure 7).

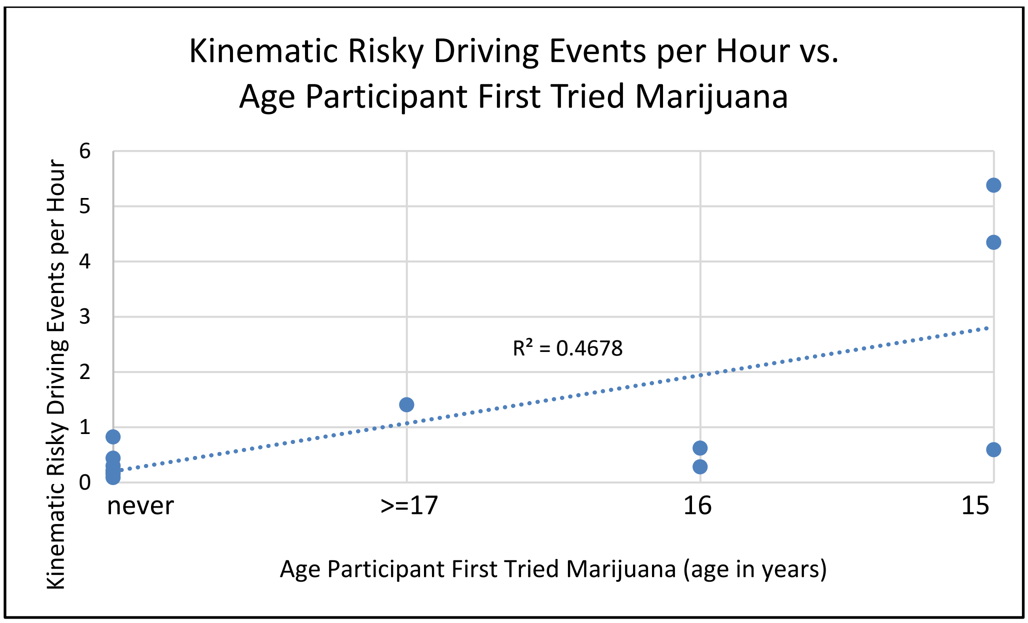

Figure 7. Graph. KRD events and hard cornering events per hour vs. age participant first tried marijuana (age participant first tried marijuana: 1 = never tried marijuana, 2 = 17 years or older, 3 = 16 years old, 4 = 15 years old).

Eye-glance Metrics and Insula Activation and General Health

For eye-glance behaviors, trends were observed between insula activation as well as assessments of general health. Participants who were more willing to take higher risks during the gambling task also had greater TEORT ($R^2 = 0.4963$; Figure 8) and increased NORG ($R^2 = 0.3653$; Figure 9) than those who were more conservative, and participants who assessed that they had poor health also had longer MGOR ($R^2 = 0.3961$; Figure 10) and SLG ($R^2 = 0.7357$; Figure 11).

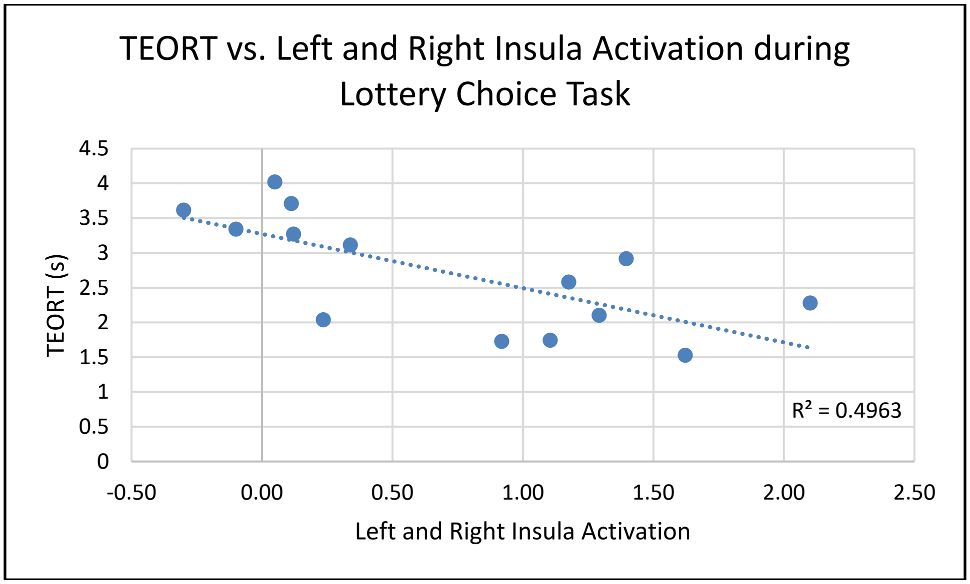

Figure 8. Graph. TEORT vs. left and right insula activation during lottery choice task (higher insula activation indicates greater risk perception).

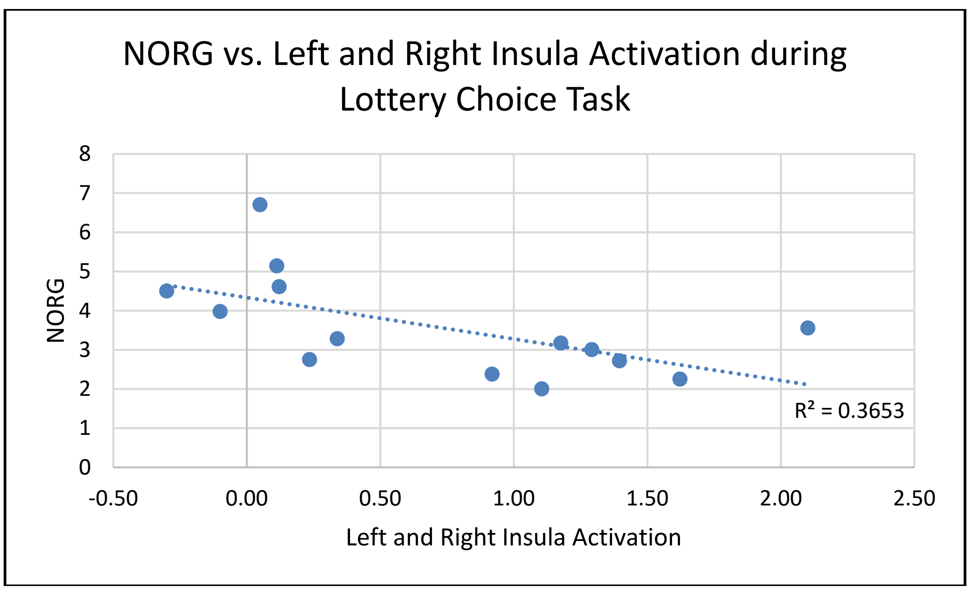

Figure 9. Graph. NORG vs. left and right insula activation during lottery choice task (higher insula activation indicates greater risk perception).

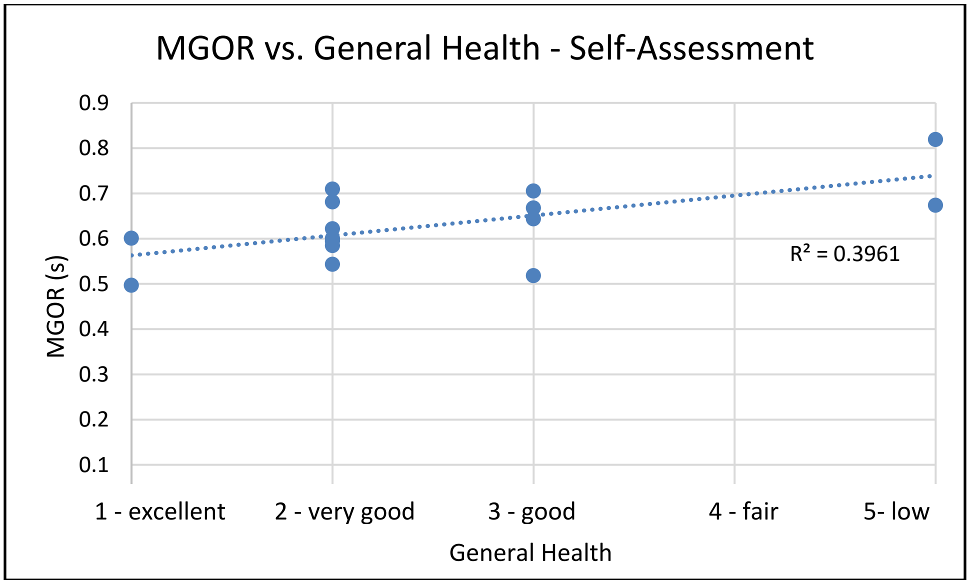

Figure 10. Graph. MGOR vs. general health – self-assessment (general health: 1 = excellent, 2 = very good, 3 = good, 4 = fair, 5 = low).

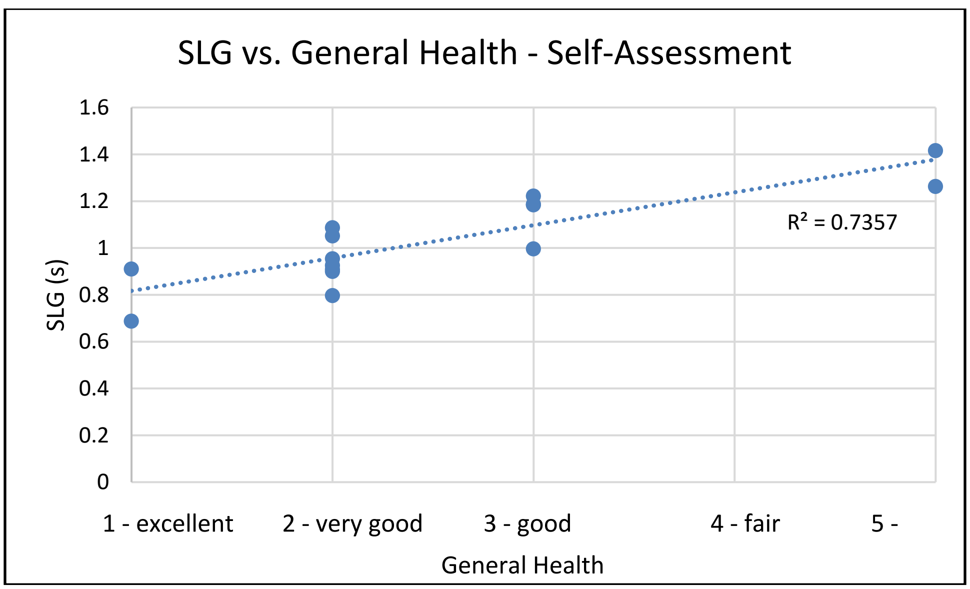

Figure 11. Graph. SLG vs. general health – self-assessment (general health: 1 = excellent, 2 = very good, 3 = good, 4 = fair, 5 = low).

Secondary Task Engagement/Seatbelt Use and DOSPERT Health Safety Risk Report

When looking at certain participant behaviors such as secondary task engagement, cellphone use, and seatbelt use, correlations were identified with scores from the DOSPERT Health Safety Risk Report, insula activation from the lottery task, scores from the Health Risk Composite Report, and self-reported risk scores. Participants who had greater perceptions of risk, or were less likely to take risks, had higher DOSPERT scores, engaged less frequently in secondary tasks (R^2 =

0.6604; Figure 12) or cellphone use (R^2 = 0.4248; Figure 13), and used their seatbelts properly more frequently (R^2 = 0.44; Figure 14).

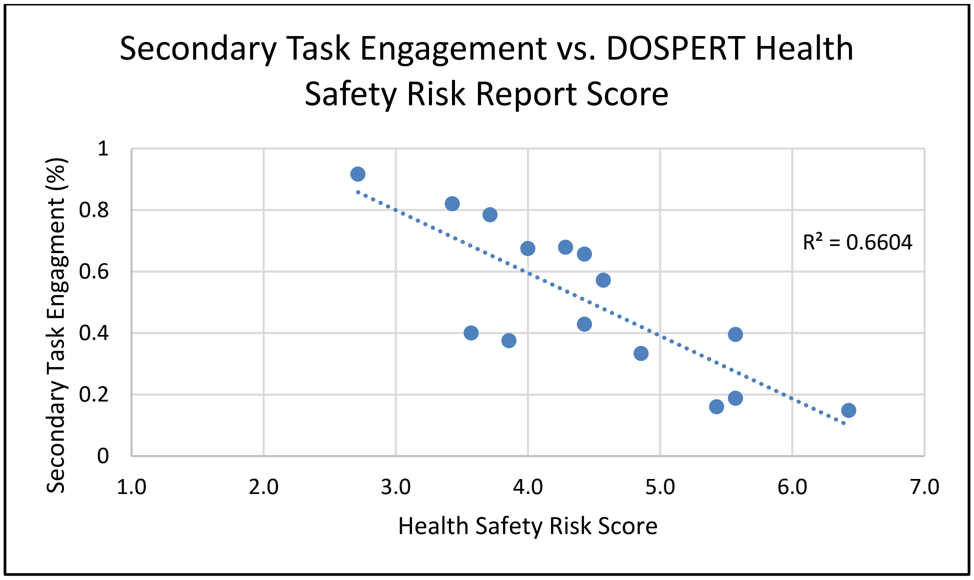

Figure 12. Graph. Secondary task engagement vs. DOSPERT health safety risk report score (higher score indicates less risky behavior).

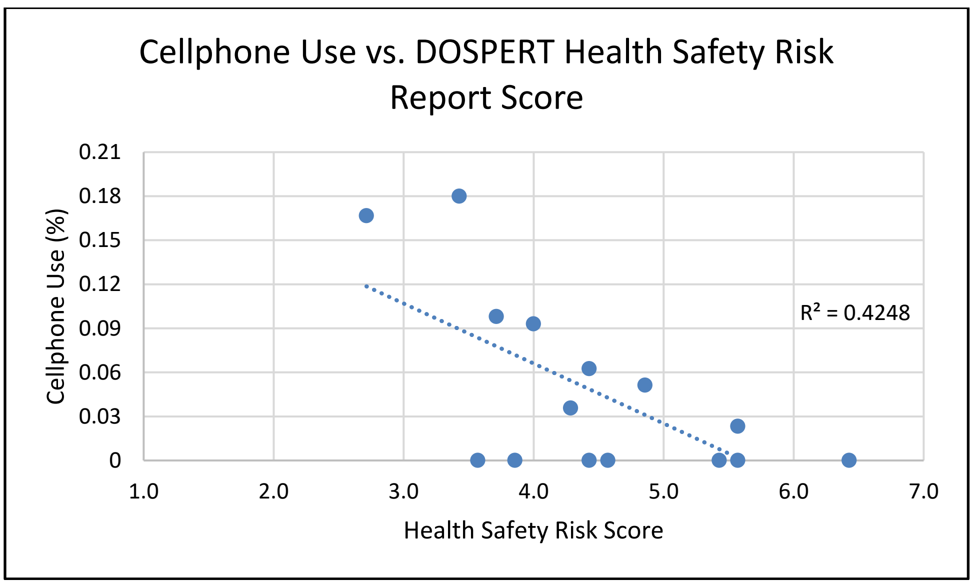

Figure 13. Graph. Cellphone use vs. DOSPERT health safety risk report score (higher score indicates less risky behavior).

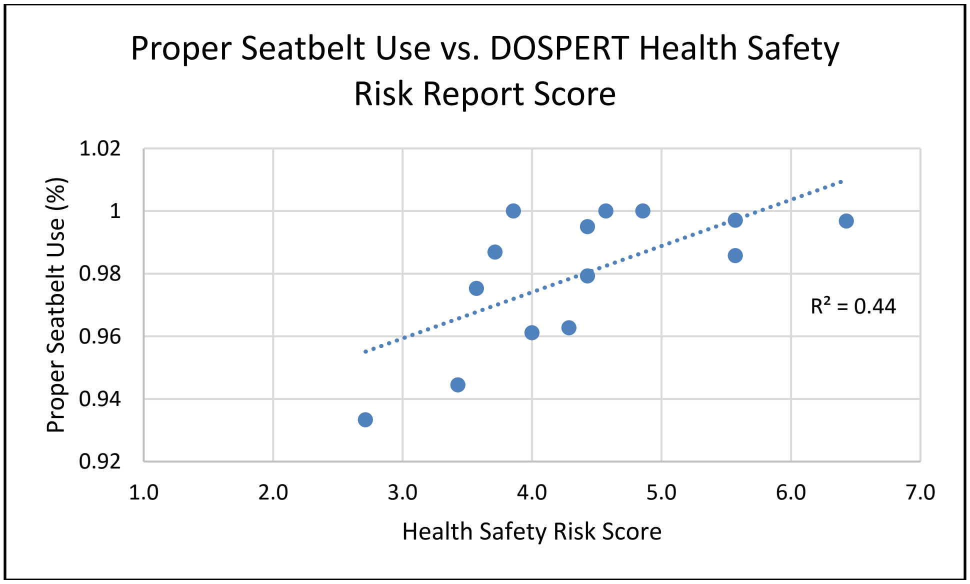

Figure 14. Graph. Proper seatbelt use vs. DOSPERT health safety risk report score (higher score indicates less risky behavior).

Secondary Tasks Engagement/Seatbelt Use and Lottery Choice Task

Similarly, participants with greater risk perceptions measured higher insula activation, engaged less frequently in secondary tasks ($R^2 = 0.4284$; Figure 15) or cellphone use ($R^2 = 0.4936$; Figure 16), and more frequently used their seatbelts properly ($R^2 = 0.397$; Figure 17).

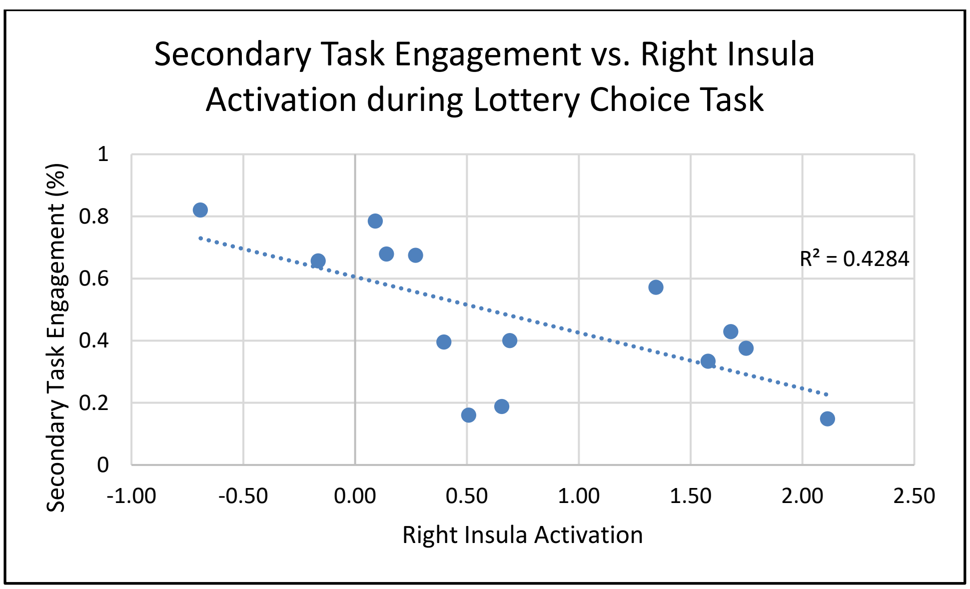

Figure 15. Graph. Secondary task engagement vs. right insula activation during lottery choice task (higher insula activation indicates greater risk perception).

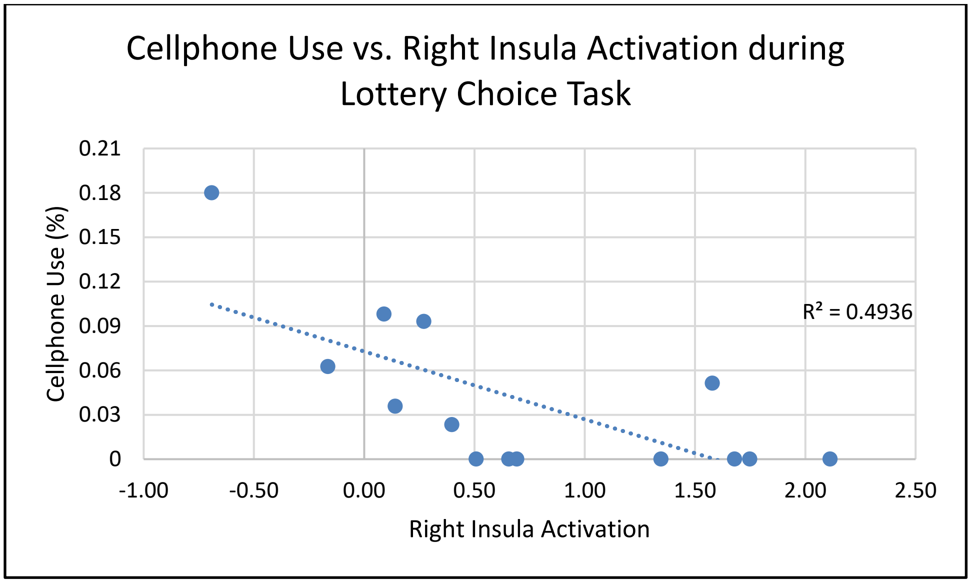

Figure 16. Graph. Cellphone use vs. right insula activation during lottery choice task (higher insula activation indicates greater risk perception).

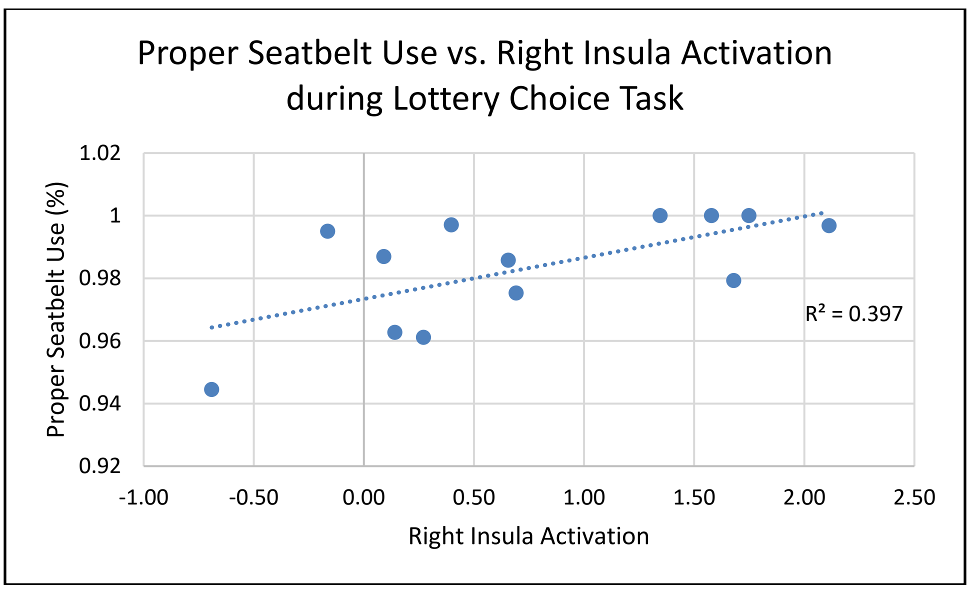

Figure 17. Graph. Proper seatbelt use vs. right insula activation during lottery choice task (higher insula activation indicates greater risk perception).

Cellphone Use/Seatbelt Use and Health Risk Behavior Scores

Participants who recorded lower health risk behavior scores used cellphones less frequently (R^2 = 0.4289; Figure 18) and used their seatbelts more frequently (R^2 = 0.8722; Figure 19).

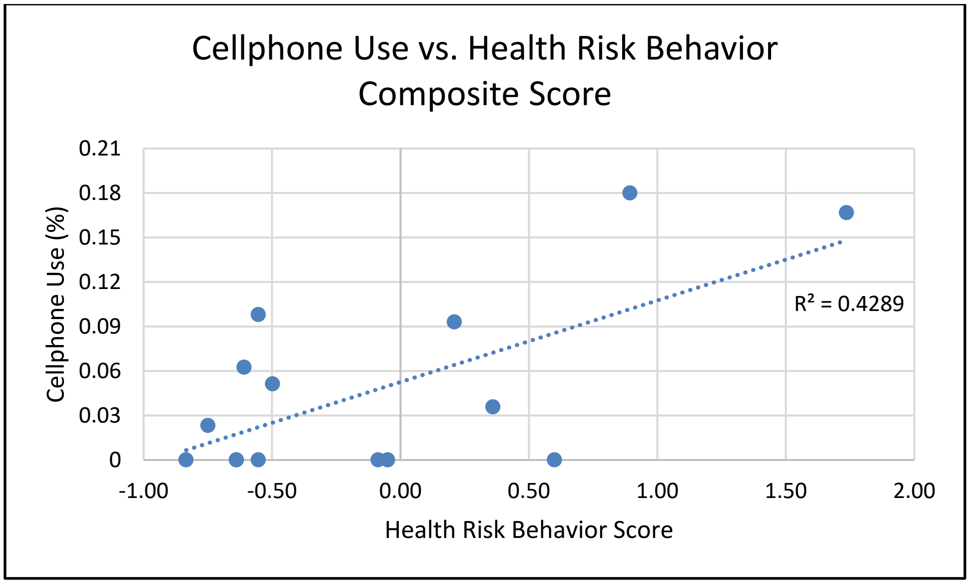

Figure 18. Graph. Cellphone use vs. health risk behavior composite score (higher score indicates lower risk perception).

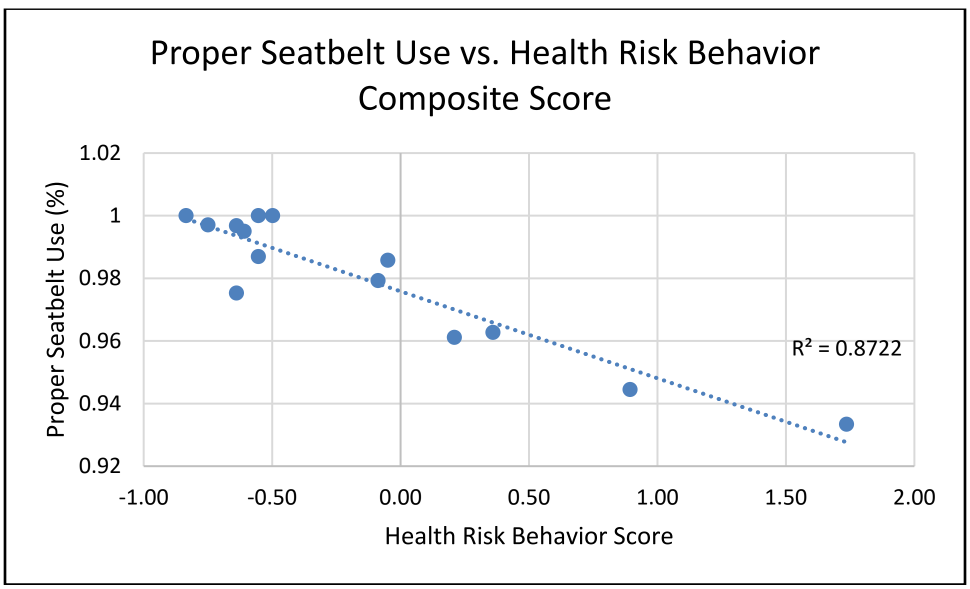

Figure 19. Graph. Proper seatbelt use vs. health risk behavior composite score (higher score indicates lower risk perception).

Cellphone Use/Proper Seatbelt Use and Child Self-reported Risk Scores

Participants who self-reported lower risk scores also used cellphones less frequently (R^2 = 0.6159; Figure 20) and used their seatbelts more frequently (R^2 = 0.7409; Figure 19Figure 21).

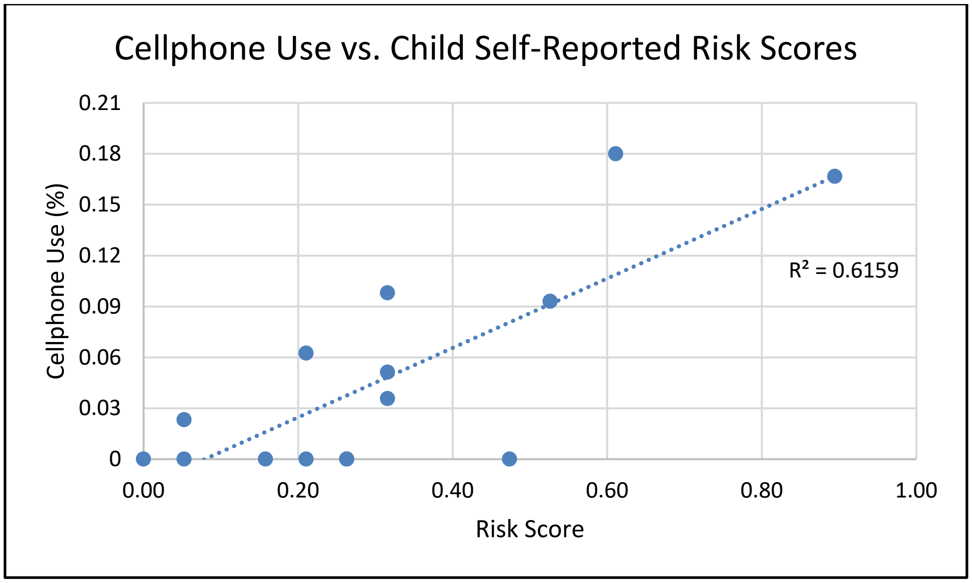

Figure 20. Graph. Cellphone use vs. child self-reported risk scores (higher score indicates more frequent engagement in risky behaviors).

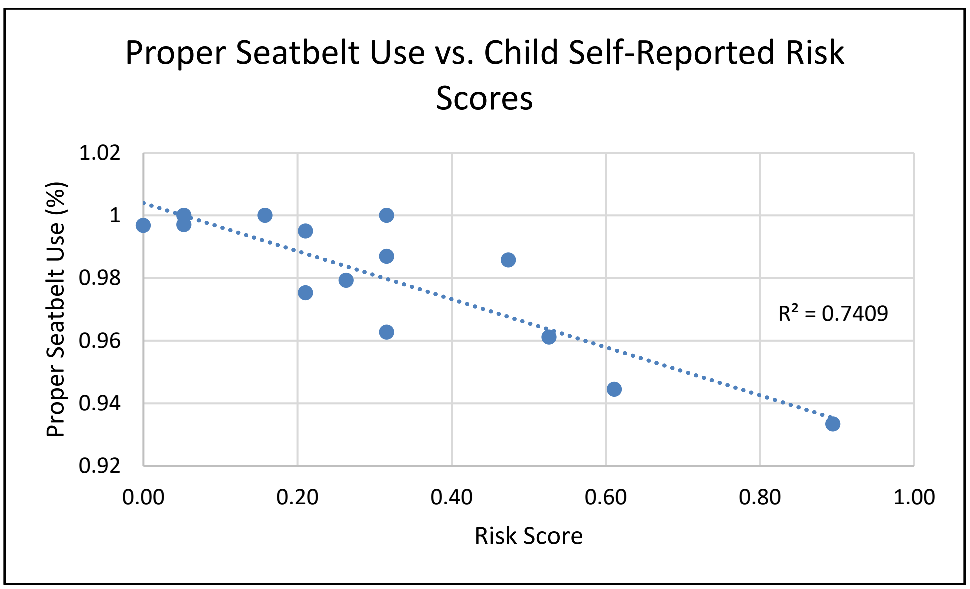

Figure 21. Graph. Proper seatbelt use vs. child self-reported risk scores (higher score indicates more frequent engagement in risky behaviors).

Additional Analyses

There were additional correlations between the driving data and psychosocial/neurobiological data: hard braking events per hour and previous cigarette use (R^2 = 0.63; Youth Behaviors); rapid start events per hour and left insula activation during the gambling task (R^2 = 0.40; UNC); hard cornering events per hour and previous cigarette use (R^2 = 0.58; Youth Behaviors); yaw events per hour and chances to go to college (R^2 = 0.66; Academic Performance and Health); overall KRD events per hour and previous cigarette use (R^2 = 0.61; Youth Behaviors); NORG and ethical risk and health safety risk (R^2 = 0.43 and 0.37, respectively; DOSPERT); secondary task engagement and parent-child relationship scores (R^2 = 0.38; PCR); cellphone use and reported seatbelt use (R^2 = 0.52; Academic Performance and Health); and proper seatbelt rate and reported seatbelt use (R^2 = 0.44; Academic Performance and Health). No other correlations were identified between the data.

CHAPTER 4. DISCUSSION

The results of this pilot study indicated some promising findings for understanding the psychosocial and neurobiological basis of risky driving among adolescents. Many risky behaviors, such as drug and alcohol use, risky sexual behaviors, and gambling, were found to be correlated with unsafe driving measures such as elevated g-force events, secondary task engagement, cellphone use, and improper seatbelt use. Additionally, there were some interesting trends between these measures and assessments of health, academic performance, and relationships with parents. This section will discuss these findings further.

Previous marijuana use was one predictor that was found to be correlated with risky driving behaviors, such as higher rates of elevated g-force events. Additionally, the Health Risk Behavior Composite score included cigarette use, marijuana use, and alcohol use, and teens who indicated that they had previously used these substances had higher scores, had higher rates of using their cellphones while driving, and wore their seatbelts improperly more often. These results very likely indicate that teenagers who are more likely to engage in these risky behaviors are more likely to drive erratically, which is in line with the results from the driving simulator study conducted by Kim-Spoon et al. (2016). Similarly, as previous research has shown, using cellphones while driving is a factor that has been seen to lead to crashes for teens, as it distracts their attention from the forward roadway (Simons-Morton et al., 2015). The inexperience of these young drivers can make it difficult for them to multitask when compared to more experienced, older drivers, and this distraction may lead to elevated g-force events such as veering off the road or having to correct a vehicle drifting out of its lane.

Risky sexual behaviors were also included in the Health Risk Behavior Composite score. Similar to the substance use results, teens who engaged in risky sexual behaviors at a young age also wore their seatbelts less frequently and had higher rates of cellphone use. This very likely ties to a teen's risk perceptions—teenagers who do not perceive the risks of these actions are more likely to continue to engage in them without recognizing the potential consequences. This finding also ties into the DOSPERT health risk safety scores and child self-reported risk scores. Teens who more frequently engaged in risky activities or perceived greater risk with these activities often chose not to use their cellphone while driving and wore their seatbelt nearly all the time.

Participants who were more likely to take risks during the lottery choice task were also observed to have higher rates of engaging in secondary tasks and using their cellphones; these participants also used their seatbelts properly less frequently. Additionally, teens who were more inclined to take risks during the lottery choice task also had higher TEORT and NORG. Previous studies have shown that these are several factors that contribute to the high rates of teen driver crashes and injuries (Hedlund, 2007; Simons-Morton et al., 2015). Teen drivers already struggle with attention allocation, as they need to focus primarily on the driving task because of their inexperience, and additional distractions and eyes-off-road time will continue to contribute to crashes. This highlights the importance of understanding a teen's risk-taking tendencies to predict their driving safety outcomes.

One very interesting finding was that teens who had lower self-perceptions of their general health also had higher SLG and MGOR. This correlation essentially implies that teens who perceive themselves as less healthy tend to look off-road for longer periods of time. Additional investigation into this should be performed, including gathering more details about the questions that were included in the health survey. For instance, adolescents who had lower health scores may have indicated that they do not get enough sleep at night. Previous studies have shown that fatigue is a factor that can contribute to crashes due to less attention awareness and scanning of the road (Meyer & Llaneras, 2022).

Overall, this analysis was limited by the relatively small sample size of 17 participants. While data was collected over a 6-month period, only a small number of safety-critical events or other events of interest occurred that were captured by the MiniDAS, which made it difficult to conduct additional analyses. There may have been more safety-critical events with a larger pool of participants. Similarly, although the number of male and female participants was about equal, there was not enough statistical power in the study to make comparisons between the two groups. As this was a pilot study, future studies should aim to recruit additional participants to conduct more detailed analyses and examine these factors.

Many of these correlations only had a few participants with elevated values on one side of the linear trend. For instance, there were only two teens with cellphone use rates that were much higher than those of the other participants. However, Dingus (2007) found that 10% of the teen drivers were involved in over 50% of the crash events. This result may indicate that most adolescents do try to engage less frequently in risky activities, but it becomes very clear when there is a teen who frequently takes risks as it shows in their driving behaviors and performances. If only 10% of the teen population is causing the teen driving age group to have elevated crash and injury rates, then psychosocial and neurobiological tests and surveys such as the ones included in this study may be good screening methods for identifying higher risk novice drivers.

Overall, this study has shown some very promising findings about the relationship between inherent risky behaviors and risky driving behaviors. Identifying these risks early can potentially provide useful information that can be applied in additional education or training for these high-risk groups of teenagers. Future studies can expand upon the results in this study to better understand which risky behaviors are stronger predictors of risky driving. The next step after that would be to develop solutions that can be implemented to counteract these behaviors.

CHAPTER 5. CONCLUSIONS

While graduated driver licensing programs have been helpful in reducing crash rates for adolescent drivers (Williams, 2007), teen drivers continue to have the highest crash risk among all age groups. The overrepresentation of teen driver crashes is a concern that stakeholders must continue to address. Previous studies have shown that there may be correlations between a variety of types of risky behaviors and unsafe driving behaviors. This pilot study has furthered this research, as it was successful in identifying relationships between risky psychosocial and neurobiological behaviors and risky driving behaviors in teen drivers. By screening new teen drivers using a battery of tests and surveys to elicit data about their risk-taking behaviors, driving outcomes may be better understood. However, identification is only the first step, as solutions for counteracting these behaviors need to be developed, and behavior is a difficult individual factor to change. Future research should continue to study the relationship between risk-taking behaviors and driving performance or behaviors to expand upon the results in this pilot study and create a more detailed and refined model for predicting and deterring risky driving.

APPENDIX A. KRD BY PARTICIPANT

Participant 12 has been excluded from the figures due to possible equipment issues.

Table 12. KRD events by participant.

Participant ID	Hard Brake	Rapid Start	Hard Cornering	Yaw	Grand Total
1	14	1	9	18	42
2	15	61	71	50	197
3	20	71	65	5	161
4	2	0	0	9	11
5	14	3	3	6	26
6	22	1	20	63	106
7	7	3	2	9	21
8	16	6	18	2	42
9	8	2	5	3	18
10	4	1	0	7	12
11	5	19	24	8	56
12	5	3	6	1,733	1,747
13	132	91	325	28	576
14	9	5	9	5	28
15	56	14	128	157	355
16	2	0	2	0	4
17	13	7	12	29	61

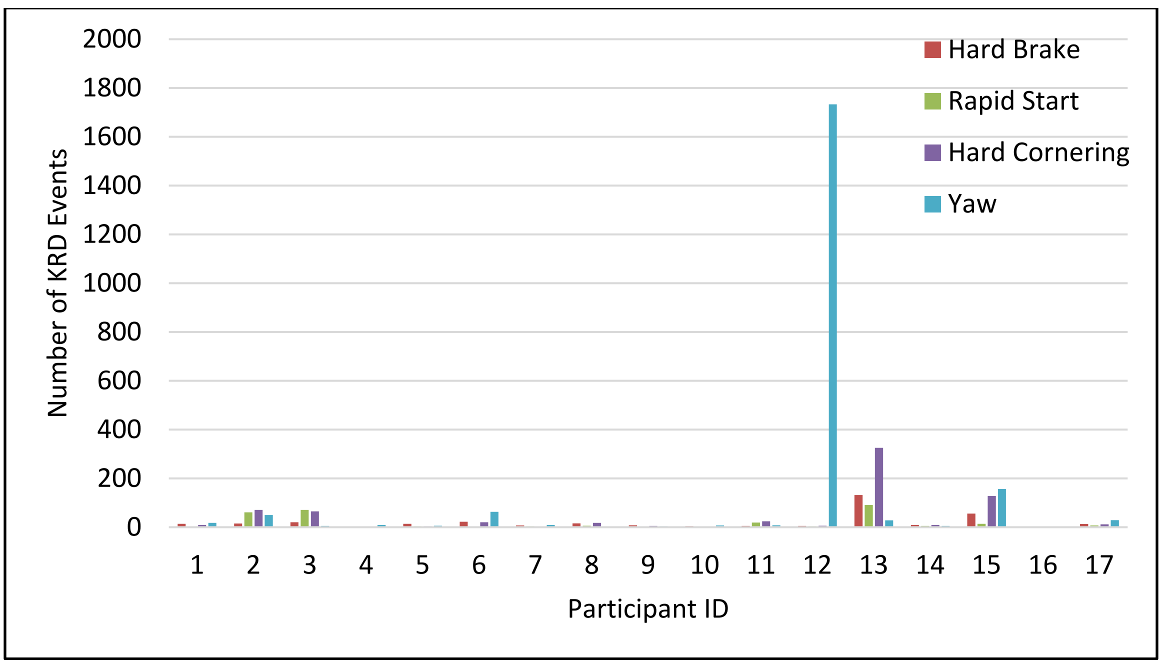

Figure 22. Histogram. KRD events by participant.

Table 13. KRD event rates per hour.

PID	Exposure Hour	Hard Brake	Rapid Start	Hard Cornering	Yaw
1	82.81	0.17	0.01	0.11	0.22
2	62.93	0.24	0.97	1.13	0.79
3	114.62	0.17	0.62	0.57	0.04
4	128.10	0.02	0.00	0.00	0.07
5	174.21	0.08	0.02	0.02	0.03
6	128.67	0.17	0.01	0.16	0.49
7	108.31	0.06	0.03	0.02	0.08
8	140.68	0.11	0.04	0.13	0.01
9	97.53	0.08	0.02	0.05	0.03
10	27.41	0.15	0.04	0.00	0.26
11	94.59	0.05	0.20	0.25	0.08
12	189.24	0.03	0.02	0.03	9.16
13	132.61	1.00	0.69	2.45	0.21
14	99.55	0.09	0.05	0.09	0.05
15	66.01	0.85	0.21	1.94	2.38
16	18.56	0.11	0.00	0.11	0.00
17	98.32	0.13	0.07	0.12	0.29

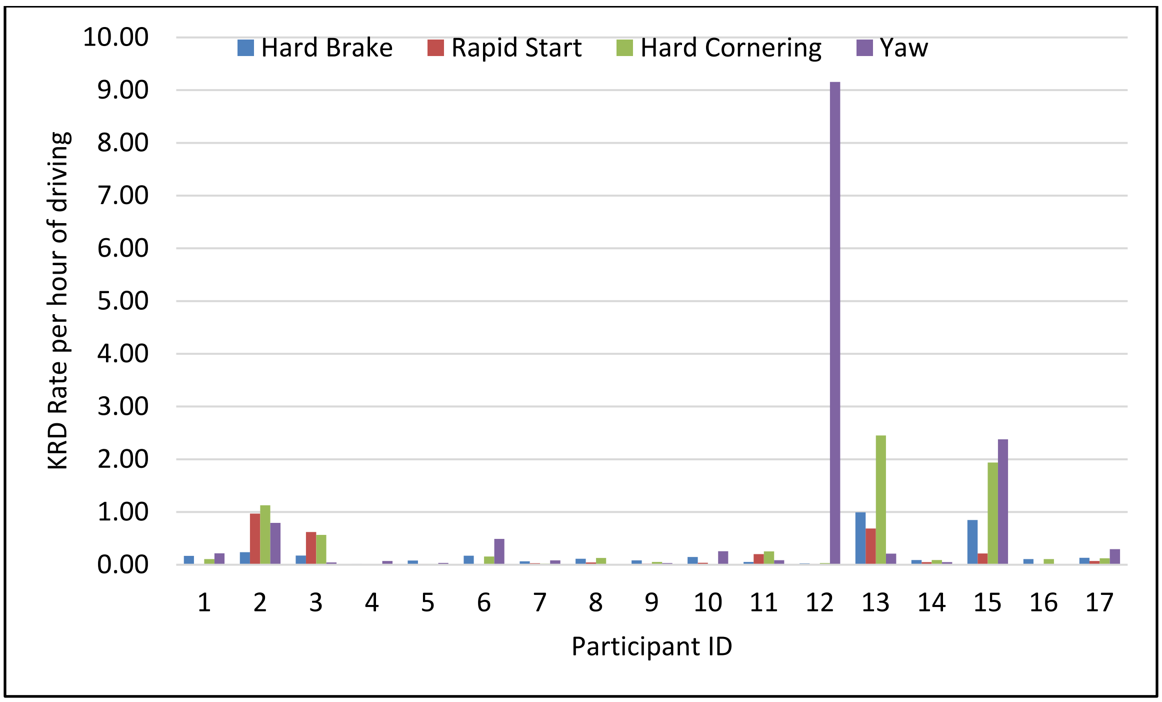

Figure 23. Histogram. Rate of KRD events by participant.

APPENDIX B. EYE-GLANCE BEHAVIOR BY PARTICIPANT

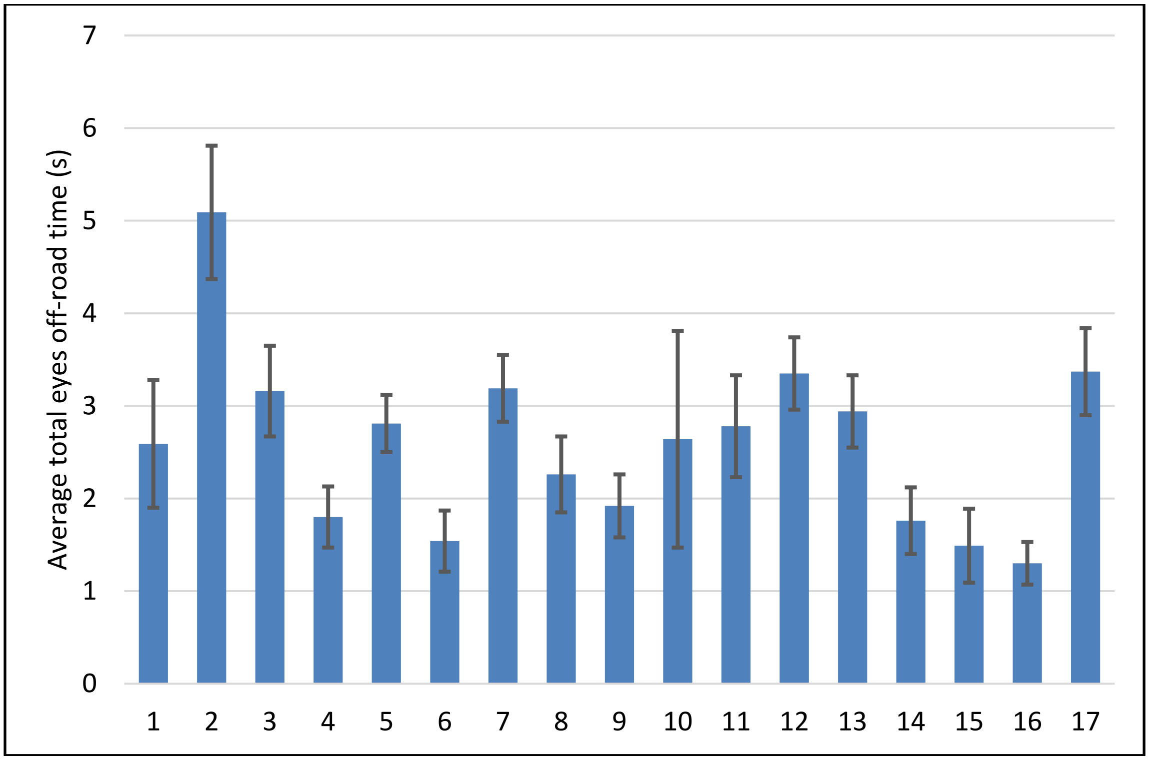

Figure 24. Histogram. Mean TEORT by participant. Error bars represent standard error.

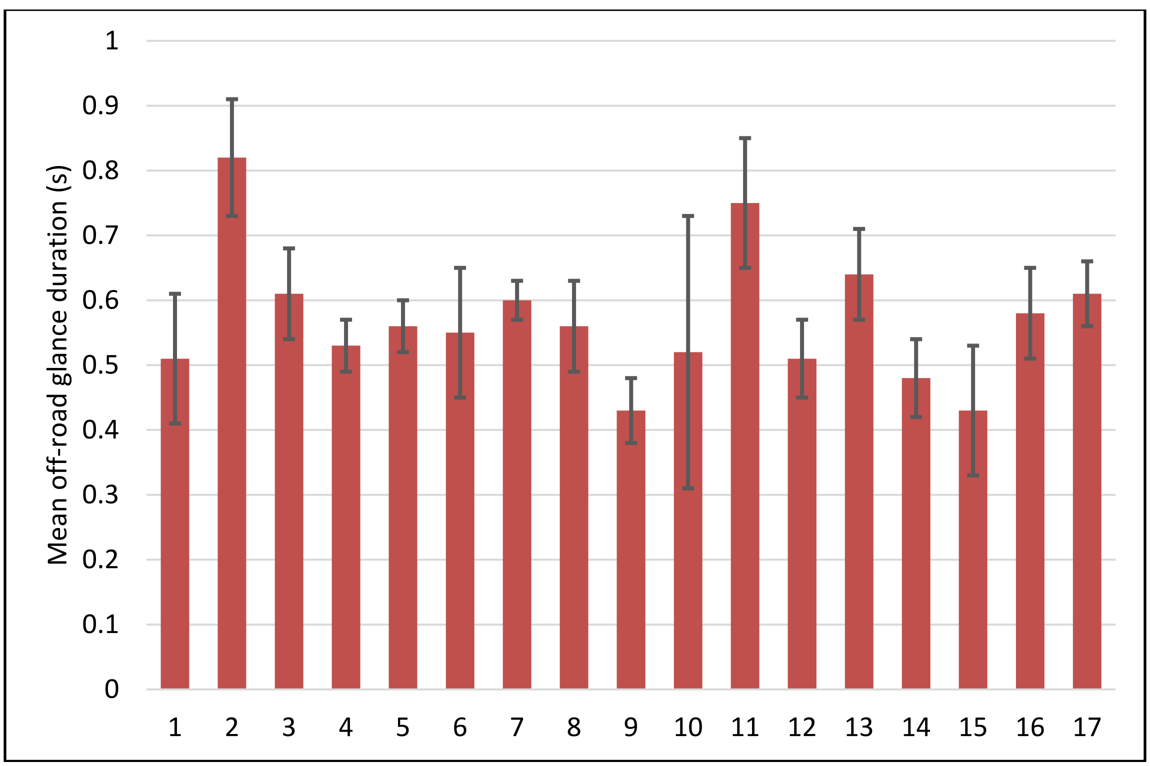

Figure 25. Histogram. Mean MGOR by participant. Error bars represent standard error.

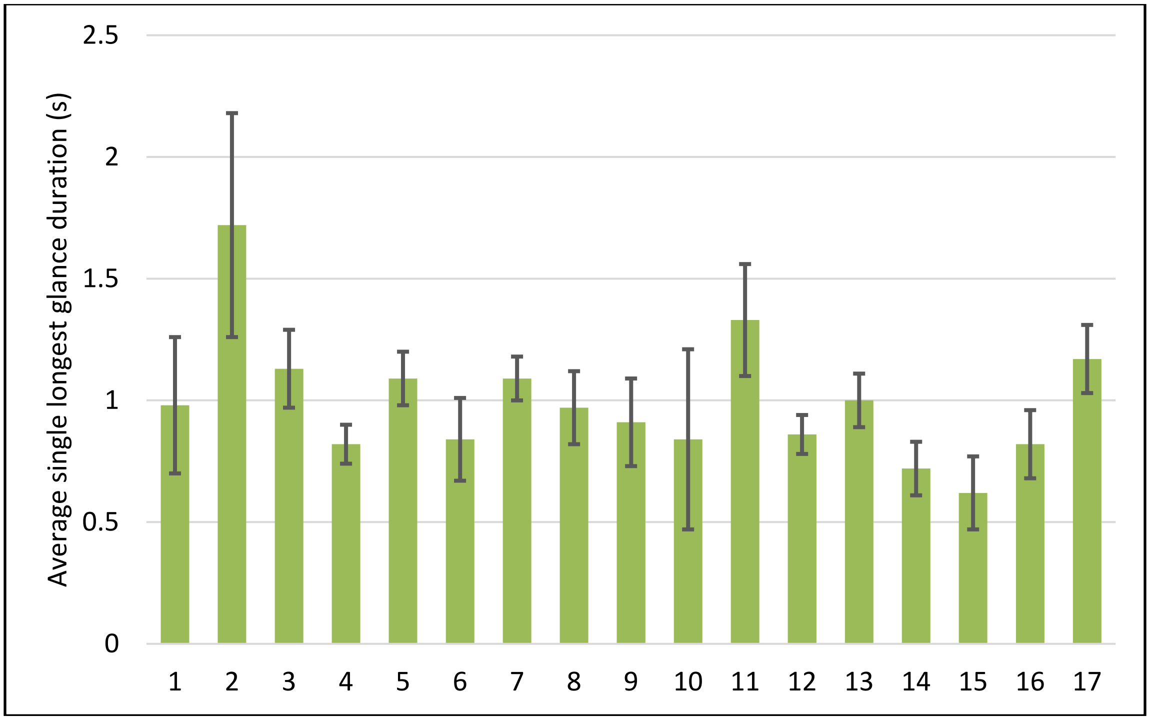

Figure 26. Histogram. Mean SLG by participant. Error bars represent standard error.

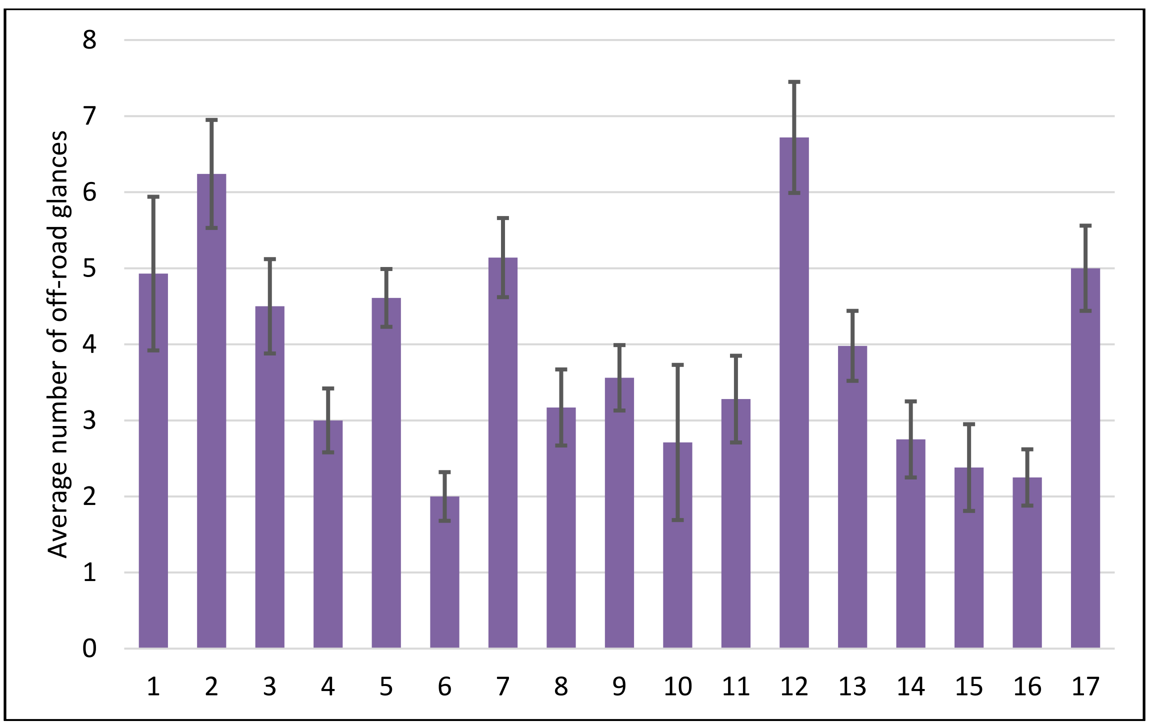

Figure 27. Histogram. Mean NORG by participant. Error bars represent standard error.

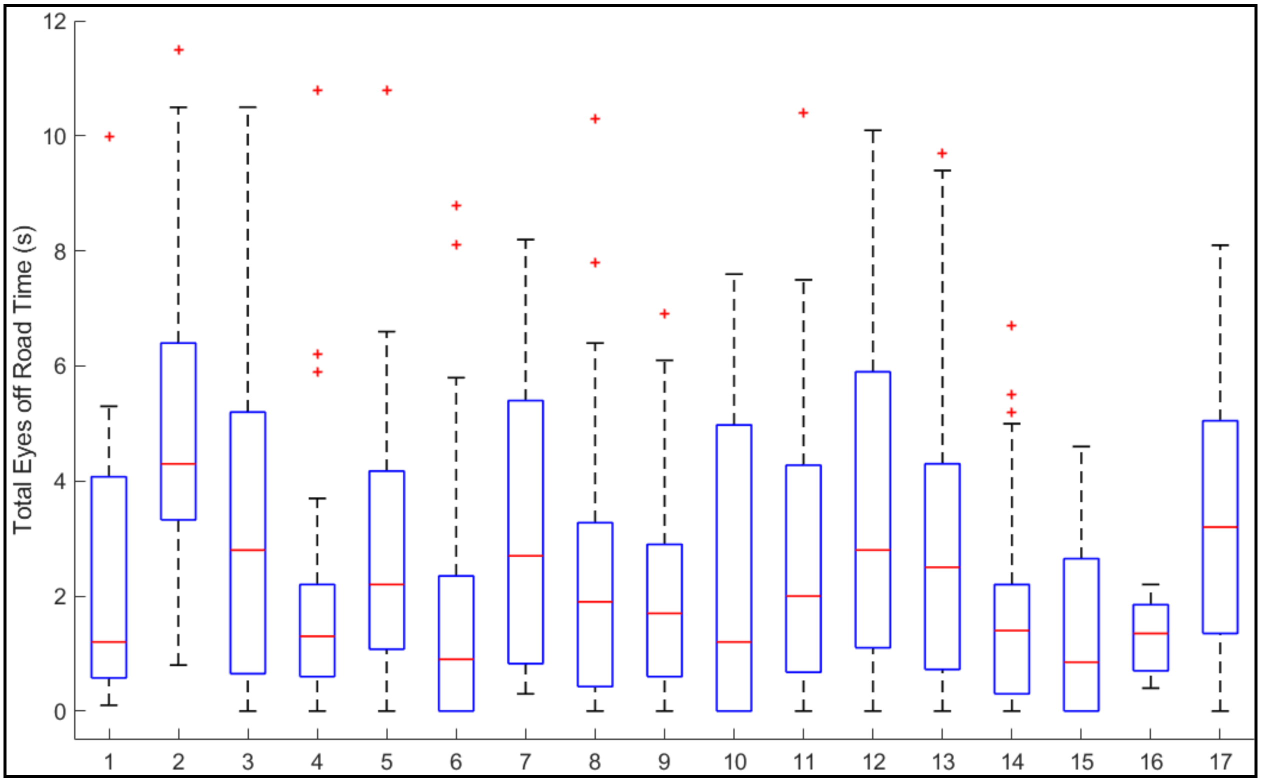

Figure 28. Box-and-whisker plot. TEORT distribution by participant.

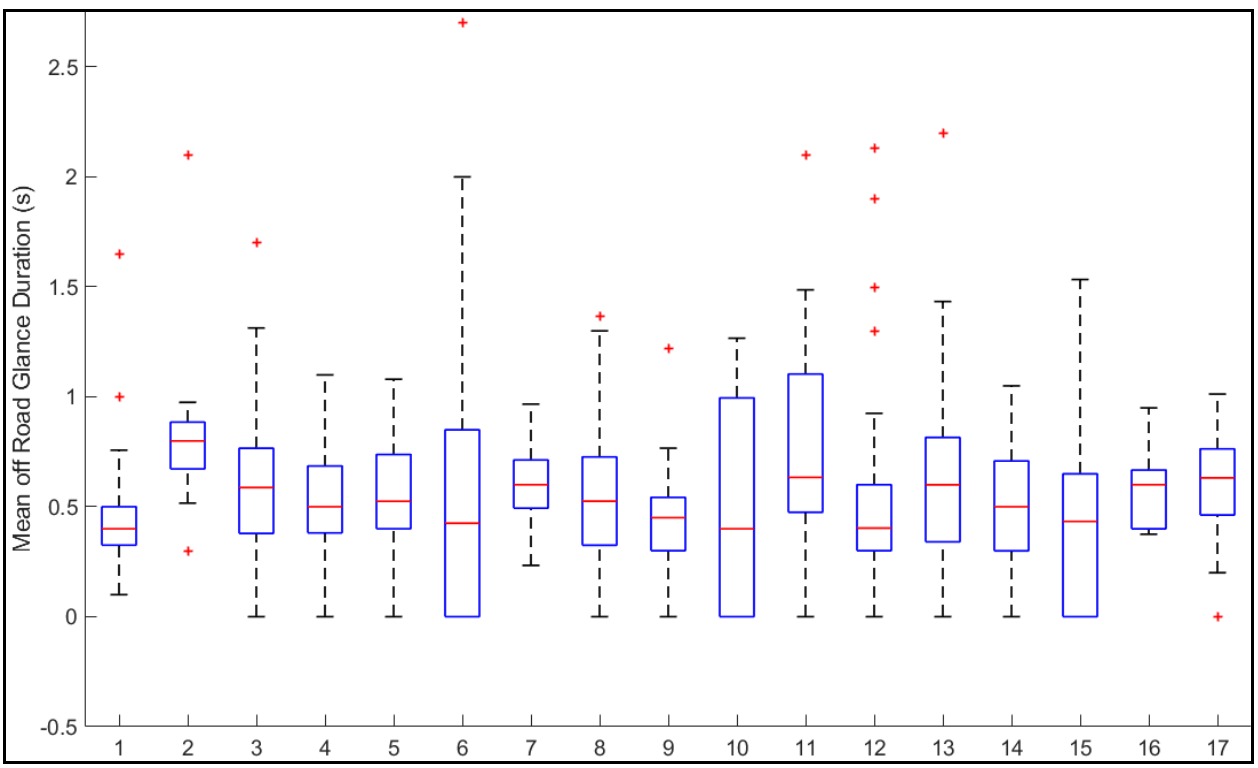

Figure 29. Box-and-whisker plot. MGOR distributed by participant.

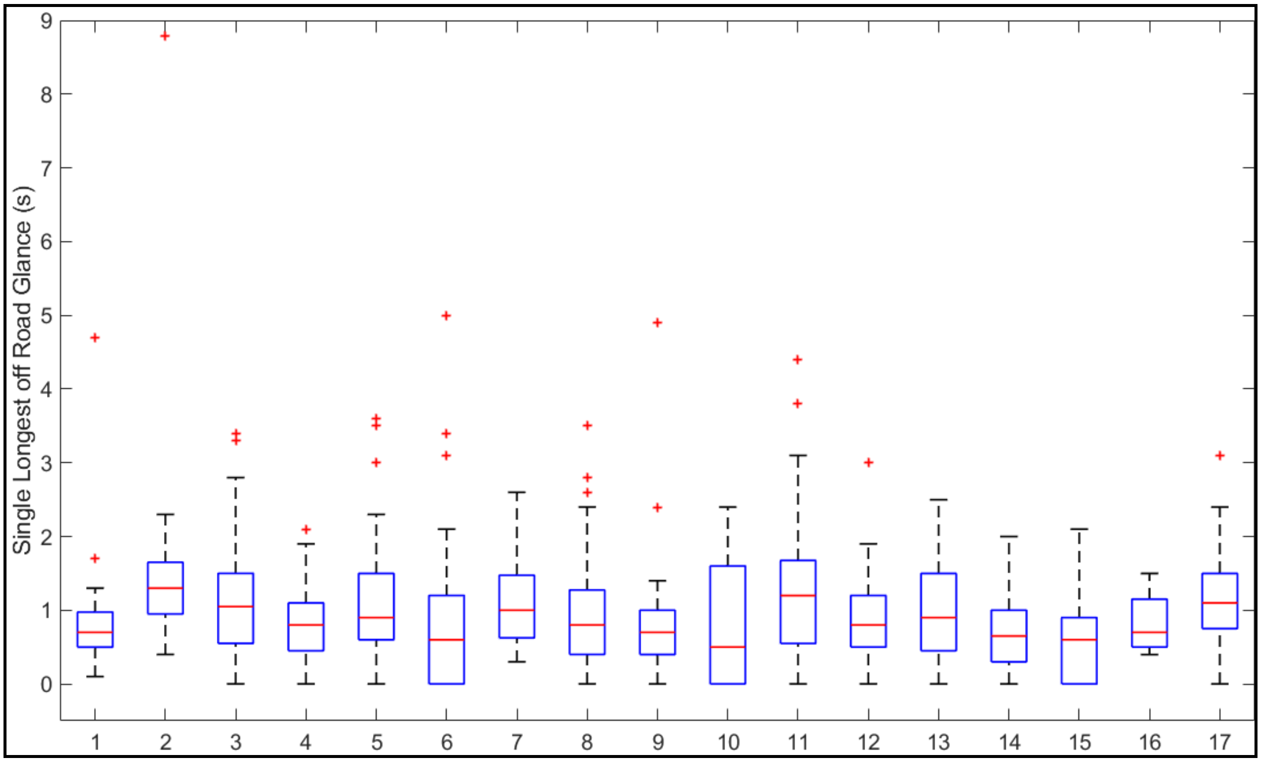

Figure 30. Box-and-whisker plot. SLG distributed by participant.

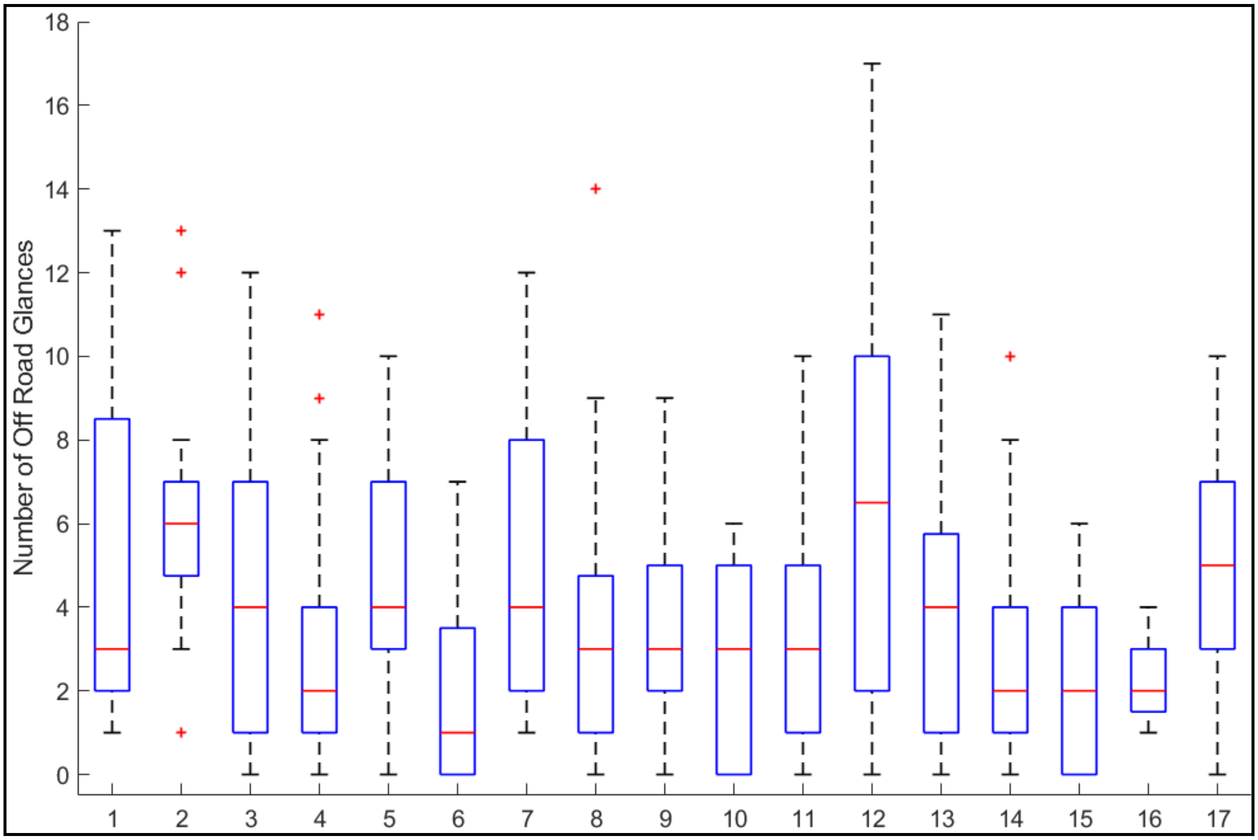

Figure 31. Box-and-whisker plot. NORG distributed by participant.

APPENDIX C. SECONDARY TASK ENGAGEMENT BY PARTICIPANT

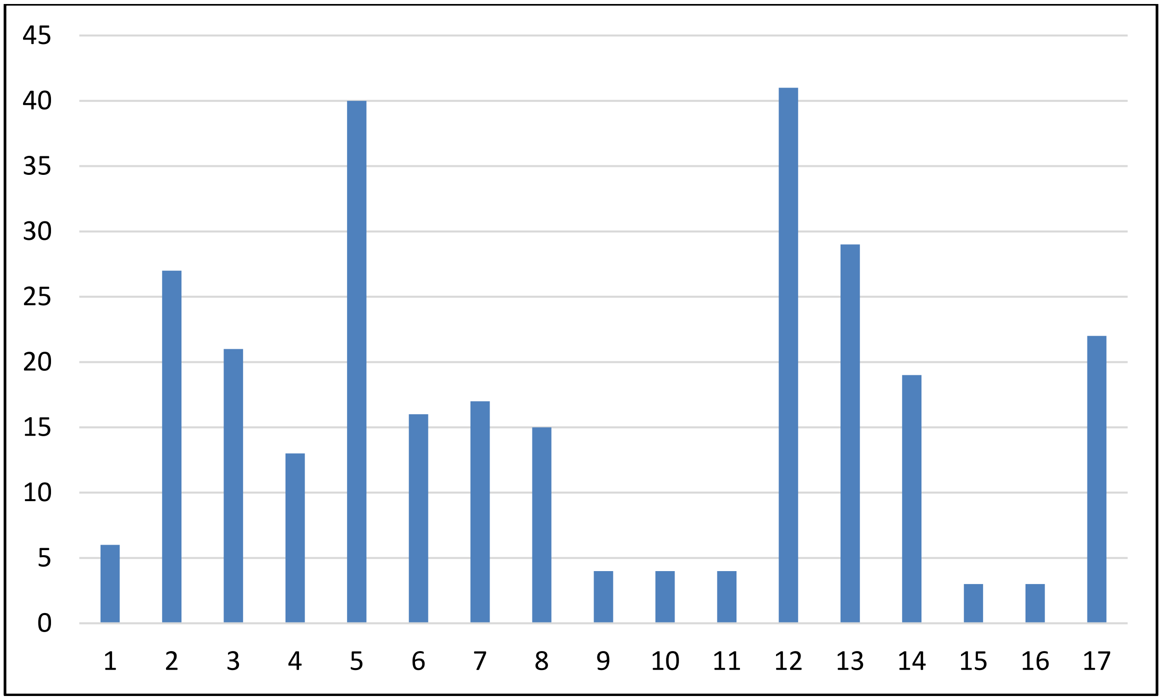

Figure 32. Histogram. Any secondary task by participant.

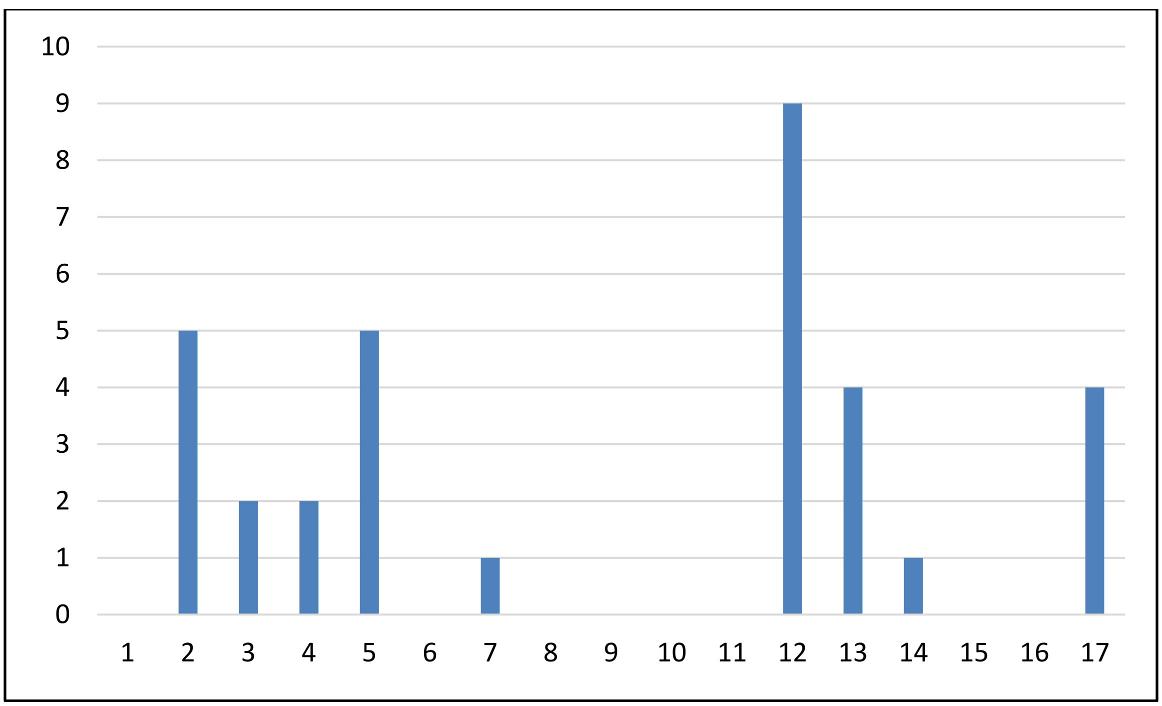

Figure 33. Histogram. All cellphone secondary tasks.

APPENDIX D. SEATBELT USE BY PARTIICPANT

Table 14. Seatbelt use by participant.

PID	Changed	Improper	Not Used	Proper
1	1	1	1	490
2	3	0	1	237
3	1	0	1	398
4	0	0	0	383
5	3	0	5	602
6	0	0	9	355
7	1	1	0	667
8	6	0	5	519
9	0	0	1	308
10	0	0	0	131
11	0	0	0	0
12	2	1	1	68
13	5	0	6	272
14	8	0	7	387
15	0	0	2	138
16	0	0	0	88
17	9	1	12	308

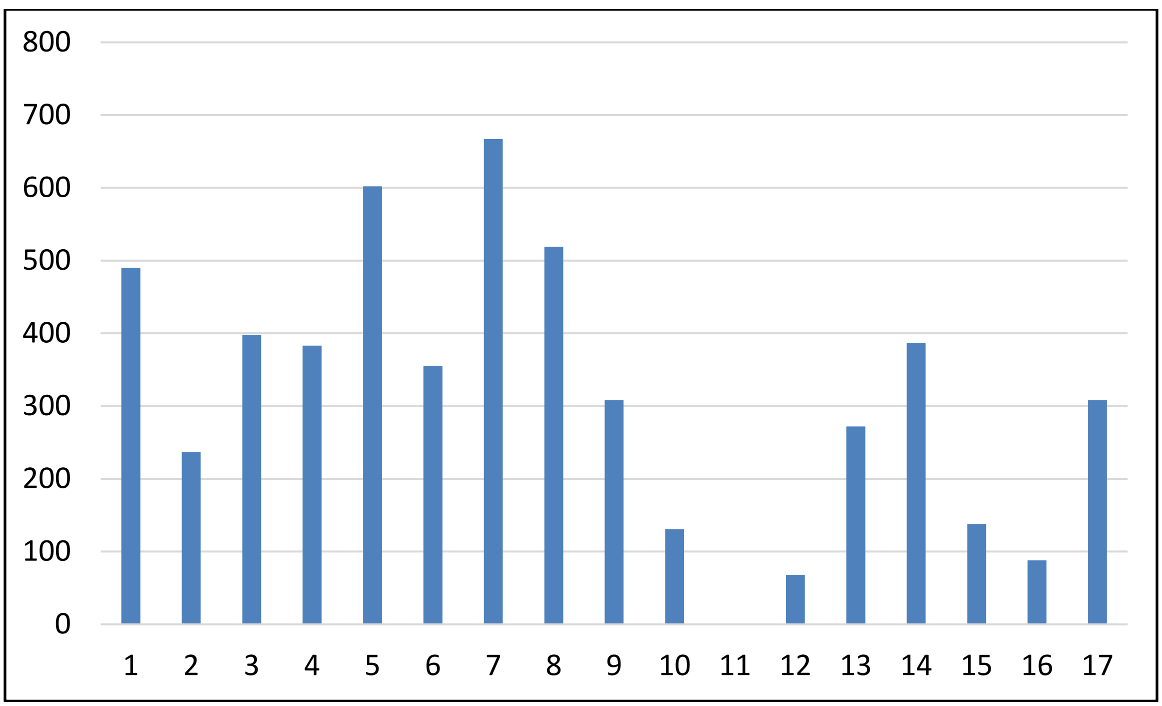

Figure 34. Histogram. Proper seatbelt use by driver (no seatbelt data available for Participant 11).

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