Report #23-UM-128

NSTSCE

National Surface Transportation Safety Center for Excellence

Do Real-time and Post Hoc Feedback Reduce Teen Drivers' Engagement in Secondary Tasks?

Lesheng Hua • Gayatri Ankem • Alexandria Noble • Peter Baynes • Charlie Klauer • Tom Dingus

Submitted: August 2, 2023

Technology
Impairment
Mobility
Infrastructure

Housed at the Virginia Tech Transportation Institute
3500 Transportation Research Plaza • Blacksburg, Virginia 24061

ACKNOWLEDGMENTS

The authors of this report would like to acknowledge the support of the stakeholders of the National Surface Transportation Safety Center for Excellence (NSTSCE): Zac Doerzaph from the Virginia Tech Transportation Institute; John Capp from General Motors Corporation; Terri Hallquist, from the Federal Motor Carrier Safety Administration; Mike Fontaine from the Virginia Department of Transportation and the Virginia Transportation Research Council; and Melissa Miles from State Farm Insurance.

Additionally, we would like to thank Dr. Bruce Simons-Morton for his collaboration and support of the Supervised Practice Driving Study database, which is also used in the analyses in this report.

The NSTSCE stakeholders have jointly funded this research for the purpose of developing and disseminating advanced transportation safety techniques and innovations.

EXECUTIVE SUMMARY

In 2020, 2,800 teens in the United States between the ages of 13 and 19 were killed in motor vehicle crashes (Centers for Disease Control and Prevention, 2023). The purpose of this study is to assess if there is an additional benefit to the driver feedback system implemented in the Driver Coach Study (Klauer et al., 2017) on secondary task reduction and if the same trends of parental involvement are observed.

The data used in this study were drawn from two previously completed naturalistic driving studies involving teenage drivers. The *Driver Coach Study* recruited 90 teen-parent dyads and presented the teen driver with feedback on their driving performance for the first 6 months (Klauer et al., 2017). Parents were able to review a website that provided information on the feedback that their teen received. The Driver Coach Study data were compared to the *Supervised Practice Driving Study*, which observed 88 teenage drivers during naturalistic driving in the same geographic location who did not receive feedback.

Novice driver secondary task engagement was recorded. Parental involvement was examined by tracking which teen/parent groups checked the website and which did not. Results suggest that teen drivers who received feedback were overall less likely to engage in secondary tasks as well as less likely to multitask than those teen drivers who did not receive feedback. Additionally, females generally engaged in secondary tasks more often than males. Teen drivers whose parents logged in to the feedback website also reduced their engagement in some secondary tasks but not all. Unfortunately, no significant reduction in cell phone use was observed between teen drivers who received feedback and those who did not. Overall, the results suggest that further research should be conducted, as monitoring and feedback for teen drivers does reduce overall secondary task engagement.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

CNC	crash and near-crash
DCS	Driver Coach Study
NDS	naturalistic driving study
SPDS	Supervised Practice Driving Study
VTTI	Virginia Tech Transportation Institute

CHAPTER 1. INTRODUCTION

In 2020, 2,800 teens in the United States between the ages of 13 and 19 were killed in motor vehicle crashes (Centers for Disease Control and Prevention, 2023). In an analysis of the month-to-month variation in the crash involvement of new drivers, Mayhew et al. (2003) found that crash rates decline dramatically during the first 6 months of independent licensure. However, Simons-Morton et al. (2015) found that despite the decline over time, crash and near-crash (CNC) rates were four times higher among teenagers than adults. Contributing factors associated with this elevated crash rate for teen drivers compared to adult drivers include general inexperience, secondary task engagement, and risky driving behavior (Simons-Morton et al., 2017; Williams, 2003).

Novice drivers are not as well versed as adults in navigating complex intersections, anticipating hazards, or performing other strategic driving tasks (Fisher et al., 2017; Pradhan et al., 2013), and make critical errors while driving in recognition, decision, and performance (Curry et al., 2011; McKnight & McKnight, 2003). Recognition errors include inadequate surveillance, inattention, internal distractions (such as interaction with handheld electronic equipment), and external distractions, and these account for 46.3% of all teen driver errors (Curry et al., 2011). According to the National Highway Traffic Safety Administration (2019), 23% of all distracted driving fatalities involved drivers between the ages of 15 and 19. It is postulated that crashes due to distracted driving are in fact much higher than what is evident from government statistics, as driver behaviors are not reliably reported (Beanland et al., 2013; Braitman et al., 2008; Carney, McGehee, & Harland, 2015; Curry et al., 2011; Stutts et al., 2001). Naturalistic driving studies (NDSs) offer a novel solution to obtaining objective measures of the distracted driving behavior of teens while they drive their own cars.

NDSs of teenage drivers led by the Virginia Tech Transportation Institute (VTTI) have already provided insight into the rates and consequences of secondary task engagement for novice teenage drivers, including elevated CNC involvement (Klauer et al., 2014), longer glance time away from the forward roadway (Simons-Morton et al., 2014), and increased prevalence of high-risk secondary task engagement over the first 18 months of licensure (Klauer et al., 2014). The current state of knowledge on teen distracted driving clearly indicates that there is an urgent need for interventions to reduce the disproportionate public health burden from teen distracted driving. One proposed solution consists of providing teen drivers with real-time feedback on their driving performance and their parents with post hoc feedback on their teen's driving performance. In-vehicle data recorders with event-triggered video have been assessed in several studies and show promise of reducing the frequencies of some high-risk driving behaviors. Systems with real-time driver feedback paired with delayed event feedback provided to parents have been shown to reduce the frequency of high g-force events such as sudden acceleration, braking, and turning (Simons-Morton, 2007).

The purpose of the Driver Coach Study (DCS) (Klauer et al., 2017) was to test whether teenage drivers could benefit from receiving real-time and post hoc feedback on their driving performance. Ninety newly licensed teens had their vehicles instrumented with a data acquisition system and received driving feedback in the form of a light and a tone when a potentially risky driving behavior was detected. Driving behaviors such as swerving, speeding, changing lanes without a turn signal, hard braking, and hard turning events triggered feedback. Participants received feedback for 6 months. Results from the DCS indicated that real-time and post hoc feedback produced a significant reduction in the rate of CNC involvement, *but only when parents logged in to the website*. If parents did not log in to the website to review the coachable events, the real-time feedback did not improve CNC rates.

The objectives of this study were to assess (1) if there is additional benefit to the driver feedback system implemented in the DCS whereby reductions in secondary task engagement are also observed and (2) if the same trends of parental involvement are observed. While the direct measure of interest, secondary task engagement, was not a behavior that resulted in direct feedback with the DCS system, we hypothesized that engaging in secondary tasks often resulted in high-g force events that became coachable events. Once teenagers learn that secondary task engagement results in coachable events which are viewable by their parents (on the post hoc feedback website), they may alter their behavior (e.g., reduce their frequency of texting while driving). Thus, real-time and post hoc feedback may not only reduce those high-risk driving events as detected by excessive kinematic signatures, but also some of the distracted driving behaviors that may lead to such events. Thus, this project is designed to understand if real-time and post hoc feedback on high g-force events subsequently reduces secondary task engagement.

CHAPTER 2. APPROACH

This study was an extra analysis of two previously conducted naturalistic teen driving studies: the DCS and the Supervised Practice Driver Study (SPDS). Both studies collected continuous audio, multi-camera video, and driving performance data from 182 novice teen driver-parent dyads (90 dyads in the SPDS plus 90 dyads in the DCS). For more details on data collection for these studies, readers are referred to the DCS report (Klauer et al., 2017) and Gershon et al. (2018).

To answer the research question, we compared the prevalence of secondary task engagement among newly licensed teens who received both real-time and post hoc feedback via an in-vehicle device (DCS) and those who received none (SPDS). We estimated prevalence by observing the presence of any secondary task engagement using control segments that were randomly selected and stratified by hours of driving. Trained data coders watched the videos during these control segments and recorded the presence of secondary tasks, among other variables.

The prevalence of teen driver engagement in secondary tasks associated with increased risk of CNC involvement for teenage drivers was also assessed using the risk calculations presented in Guo et al. (2017). High-risk secondary tasks include manually texting, browsing, dialing, talking, and reaching for a cell phone, all of which require both visual attention and some physical manipulation. Additionally, tasks such as talking to passengers, operating other in-vehicle devices, reaching for objects, and external distractions are high-risk secondary tasks, all of which also involve some level of eyes-off-road time and/or some physical manipulation.

DESCRIPTION OF DATASET

As mentioned above, data from two previously completed NDSs involving teenage drivers, the DCS and the SPDS, were used in this analysis. Both studies used similar recruitment methods and had similar inclusion criteria (e.g., the same geographical region of Southwestern Virginia; possession of learner's permit for less than 2 weeks). For details, see Table 1 andFigure 1.

Table 1. Overview of DCS and SPDS Studies

	DCS	SPDS
Participants	92 newly licensed teen driver/ parent dyads Data from 89 teens used in this analysis	90 newly licensed teen driver/ parent dyads Data from 88 teens used in this analysis
Age at recruitment (years)	15.5 and 16.1 at the recruitment	15.5 and 16.1 at the recruitment
Driving status at recruitment	Teens had received their learner's permit	Teens had received their learner's permit
Data collection	June 2013–August 2015 Data were collected from 15 months up to 22 months (9 months of learner's permit plus up to 7 months)	January 2011–August 2014 Data were collected from 15 months up to 22 months (9 months of learner's permit plus up to 12 months)

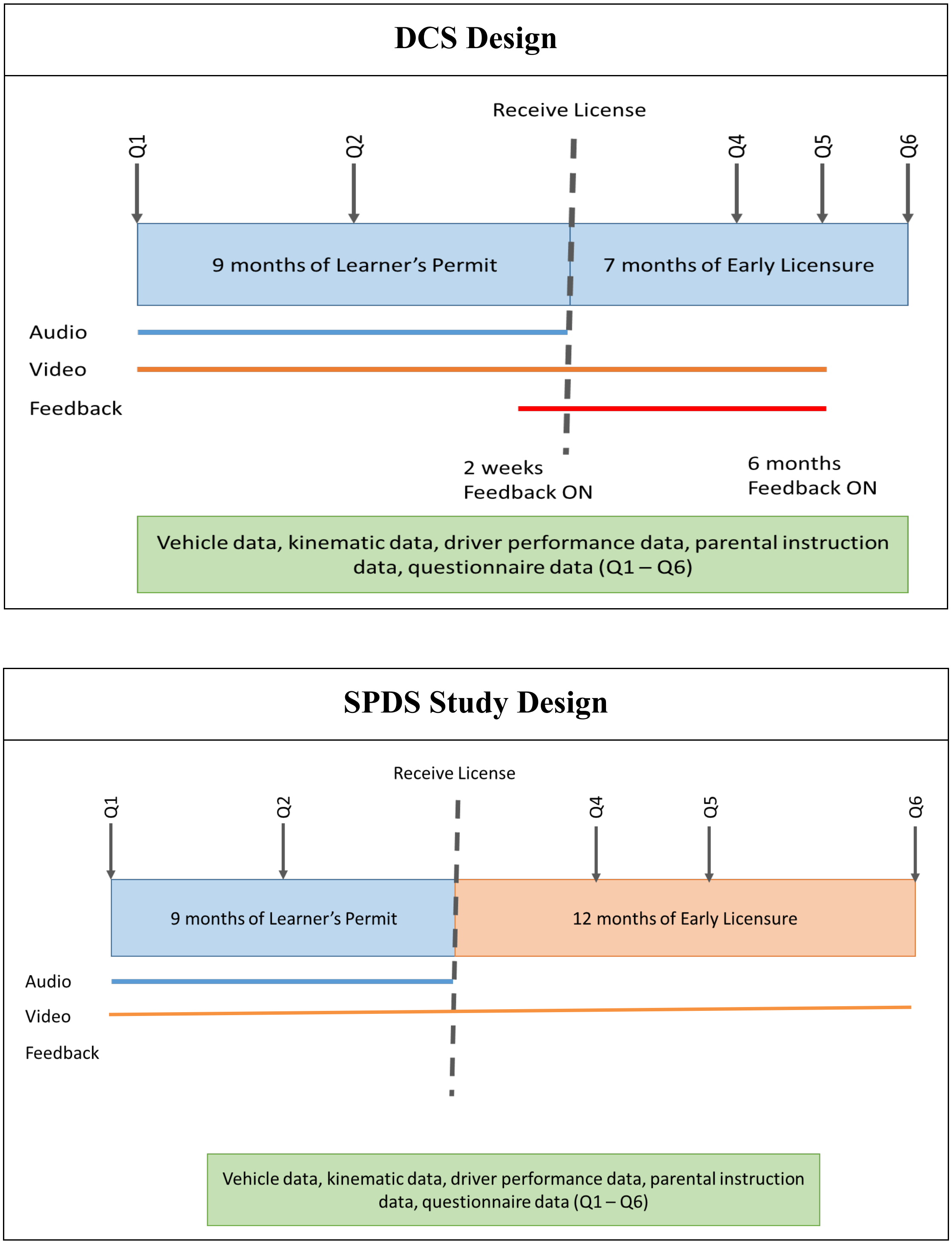

Figure 1. Illustration. Overview of DCS (feedback group) and SPDS (control group) study designs.

CONTROL SEGMENT SAMPLE SELECTION

For assessing the prevalence of secondary task engagement, 6-second baseline segments (driving segments without any CNC event) were randomly selected and stratified across the participants based on miles traveled. VTTI has successfully used this strategy in previous NDSs to produce stable estimates of the prevalence of driver behaviors (Guo, 2019).

CODING PROCESS TO IDENTIFY SECONDARY TASK ENGAGEMENT

The data coding was completed using Hawkeye, a VTTI proprietary web-based software application that allows for events to be identified in the data stream. Data coders were trained to use an *a priori* developed formal protocol. The same formal protocol was used for both SPDS and DCS data coding. Using Hawkeye, these highly trained data coders were able to review the four channels of video for the SPDS and the two channels of video for the DCS. Figure 2 shows an image of the video views as seen in VTTI's reduction software.

Figure 2. Screen capture. Quad split of all four video views available in the two databases: upper left, driver face; upper right, forward view; lower left, over the shoulder view; lower right, rear-view. ***Note that driver was a VTTI employee, not a participant.***

The video allowed the data coders to record a battery of variables for each 15-second control segment using drop-down menus. Key information that was recorded for each control segment included any observable distractions, any driver behavior and/or driver errors, time of day, roadway type, weather conditions, seat belt use, and sequence of events for CNCs. For the purpose of this analysis, we utilized data coders' observations for up to three unique secondary tasks per control segment.

INTER- AND INTRA-RATER RELIABILITY

An inter- and intra-rater reliability test, comprised of 20 randomly selected control segments, was administered to the data coders. This test was given to measure both the accuracy among data coders as a group and individual precision to that of a highly experienced data reductionist, also known as a "gold standard." This test was administered three times throughout the course of the study: twice during the data coding and once near the study's conclusion. The results from inter-rater tests indicated that the four trained coders were 86% accurate to the gold standard across the entire reduction. Additionally, the overall intra-rater test combined with quality assurance indicated that trained coders were 89% accurate to the gold standard across the entire reduction.

ANALYTIC APPROACH

While teens are known to engage in a wide variety of secondary tasks, this analysis was primarily interested in understanding the prevalence of engagement in *high-risk* secondary tasks. High-risk secondary tasks were determined by Guo et al. (2017), whose work identified those secondary tasks that increase CNC risk for novice drivers.

The high-risk secondary tasks that were included for this analysis were divided into secondary tasks associated with cell-phone use (Table 2) and non-cell-phone-related secondary tasks (Table 3). It is important to note that for any one observation of a whole task (e.g., talking on a cell phone) a combination of subtasks, such as reaching for a cell phone, dialing the cell phone, and talking on the cell phone, may be observed.

Table 2. Cell-phone-related Tasks

Group Name	Subtasks/Reduced Driver Behaviors
Cell phone talking	Cell phone talking/listening, handheld
	Cell phone talking/listening, hands-free
Cell texting	Cell phone, texting
Cell handheld dialing	Cell phone, dialing handheld
	Cell phone, dialing handheld using quick keys
Cell browsing	Cell phone, browsing
Cell reaching	Cell phone, Locating/reaching/answering
Cell phone – visual-manual	Any subtask within: • Cell phone texting • Cell phone handheld dialing • Cell phone browsing • Cell phone reaching • Cell phone, other
All cell phone tasks	The engagement of any cell phone task listed above with the addition of cell phone, other and cell phone, holding

Table 3. Non-cell-phone-related Tasks

Group Name	Subtasks/Reduced Driver Behaviors
External distraction	Looking at an object external to the vehicle
	Looking at pedestrian
	Looking at previous crash or incident
	Looking at animal
	Distracted by construction
	Other external distraction
Interact with passenger	Passenger in adjacent seat – interaction
	Passenger in rear seat – interaction
	Child in adjacent seat – interaction
	Child in rear seat – interaction
Reaching	Reaching for object, other
	Reaching for food-related or drink-related item
	Reaching for personal body-related item
	Reaching for cigar/cigarette
	Moving object in vehicle
	Object in vehicle, other
Operate in-vehicle devices	Adjusting/monitoring climate control
	Adjusting/monitoring radio
	Adjusting/monitoring other devices integral to vehicle
	Inserting/retrieving CD or similar

The prevalence of high-risk secondary task engagement by driver group is reported with respect to the percentage of baselines observed. Where applicable, a logistic regression was used to determine if teens who did not receive feedback (SPDS) were more likely to engage in secondary tasks than teens who did receive feedback (DCS). Secondary task engagement by parental login was also conducted for the DCS teens to assess whether parental login impacted teen secondary task engagement. DCS participants were divided into two groups of parental logins: if the parent logged in to the website at least once, then they were assigned to the DCS-login group; the rest were assigned to the DCS-no login group.

CHAPTER 3. RESULTS

For these analyses, control segments were restricted to the first 6 months of driving after provisional licensure. This method produced 364 baselines for the DCS and 485 baselines for the SPDS. The average number of trips for each driver is listed in Table 4. Each trip duration is 6 seconds in the SPDS and 21 seconds in the DCS. Males accounted for 40% of the trips in the DCS and 46% in the SPDS study. To assess the impact of parent feedback on teen distracted driving behavior, we analyzed the prevalence of overall secondary tasks and five subtask groups.

Table 4. Description of Data

Study	First 6 Months of Independent Driving Baselines	Number of Trips per Driver		Gender	
		Mean	SD	Male	Female
DCS	364	4.0	2.76	147	217
SPDS	485	6.6	4.1	224	261

DCS VS. SPDS SECONDARY TASK ENGAGEMENT

Sometimes, teens would engage in several secondary tasks concurrently or serially. For example, when talking with passengers, drivers may have also been dancing or eating. Those behaviors were coded as secondary task one, two, and three. Drivers were engaged in secondary tasks in over half of baselines in the two studies (57.5% in SPDS, 50.5% in DCS). In the SPDS, 14.23% of cases involved a secondary task two and, in the DCS, 9.89% of cases involved a secondary task two. Only1.65% of cases in the SPDS and 1.92% of cases in the DCS presented three secondary tasks together. See Figure 3 for a visual representation.

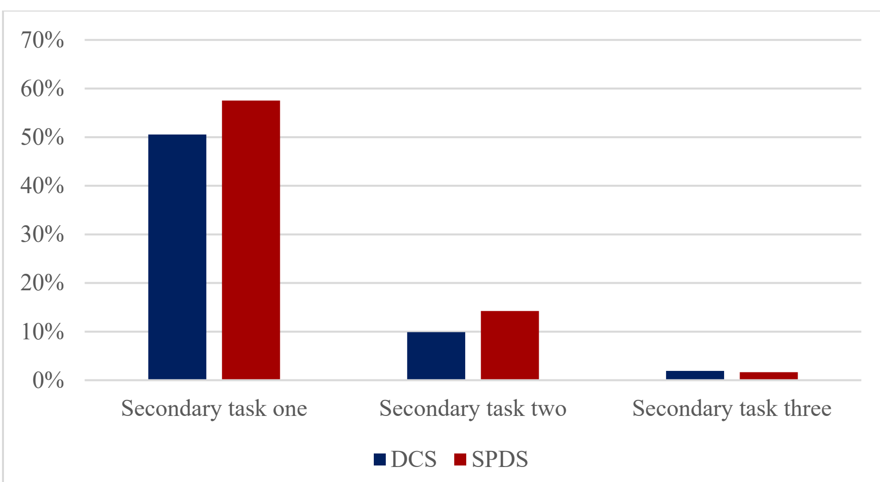

Figure 3. Bar graph. Secondary task engagements in the DCS and SPDS.

Because we only focused on one variable, engagement in secondary task, we employed MedCalc statistics software to calculate the odds ratios. The odds ratio calculation used the comparison between the odds of the DCS (Yes secondary task/No secondary task) and the odds of the SPDS (Yes secondary task/No secondary task). Teens enrolled in the SPDS were significantly more likely to engage in secondary tasks than teens in the DCS cohort, as shown by the odds ratios presented in Table 5. Additionally, the prevalence of multitasking was much lower for teens in the DCS with parent feedback compared to teens in the SPDS. In secondary task three, there was no significant difference between the two studies.

Table 5. Odds Ratios for Secondary Task Engagement vs. No Secondary Tasks

Secondary Tasks	Prevalence		Yes Secondary Task		No Secondary Task		Odds Ratio Estimates (DCS Reference Group)			
	DCS	SPDS	DCS	SPDS	DCS	SPDS	OR	LL	UL	*P*
Single Secondary Task	0.505	0.575	184	279	180	206	1.32	1.008	1.74	**0.0435**
Multiple Secondary Tasks	0.193	0.272	43	77	180	206	1.565	1.02	2.39	**0.0382**
Overall secondary tasks	0.558	0.771	227	356	180	206	1.37	1.056	1.777	**0.0176**

DCS vs. SPDS SUBTASKS ENGAGEMENT

We grouped secondary tasks into five subtasks:

1. Cell-phone related
2. External distraction
3. Interact with passenger
4. Reaching
5. Operate in-vehicle devices

The "cell-phone related" group included all types of cell-phone tasks, such as holding, talking, texting, and browsing. The "external distraction" group included looking at objects external to the vehicle, other external distractions, and unknown. The "interact with passenger" group included interaction with passengers and children in the vehicle and talking or singing with an unknown audience. The "reaching" group included removing, dancing, eating, drinking, biting, combing, reaching, and moving activities. Adjusting or monitoring devices in the vehicle was considered to be in the "operate in-vehicle devices" group.

This subdivision leaves only non-specific eye-glance cases. In the SPDS study, non-specific internal glance indicated the driver was in a drowsy/fatigued situation instead of experiencing an external distraction. In the DCS, non-specific, internal-glance cases were "check glances" and included actions such as checking rear view mirrors, left-right mirrors, or speed. Moreover, the eye-glance durations were less than 2 seconds, and the number of cases was less than three. Thus, cases involving non-specific internal glances were not classified into a secondary task group but rather as no secondary task.

As seen in Figure 4, the prevalence of each group showed that teens' secondary behaviors were different in the two studies. Odds ratios of each subgroup were calculated, comparing the frequency of each subtask group versus no secondary task cases. The DCS was the reference group. Frequency counts for each group used a combination of secondary tasks one, two, and three. For example, the driver might be holding the cell phone in secondary task one and browsing the cell phone in secondary task two. Holding and browsing were observed at the same time, so we consider the two actions as one count. Even though all secondary tasks were classified into five groups, the total number of non-secondary tasks did not change for each dataset. The frequency of no subtask corresponding to each subtask group still used the same number of no secondary tasks in each dataset. The prevalence of each group is listed in Table 6. The most frequently observed secondary behavior was interaction with passengers. External distraction was the second most common secondary behavior, and cellular phone and reaching for object were the third most common.

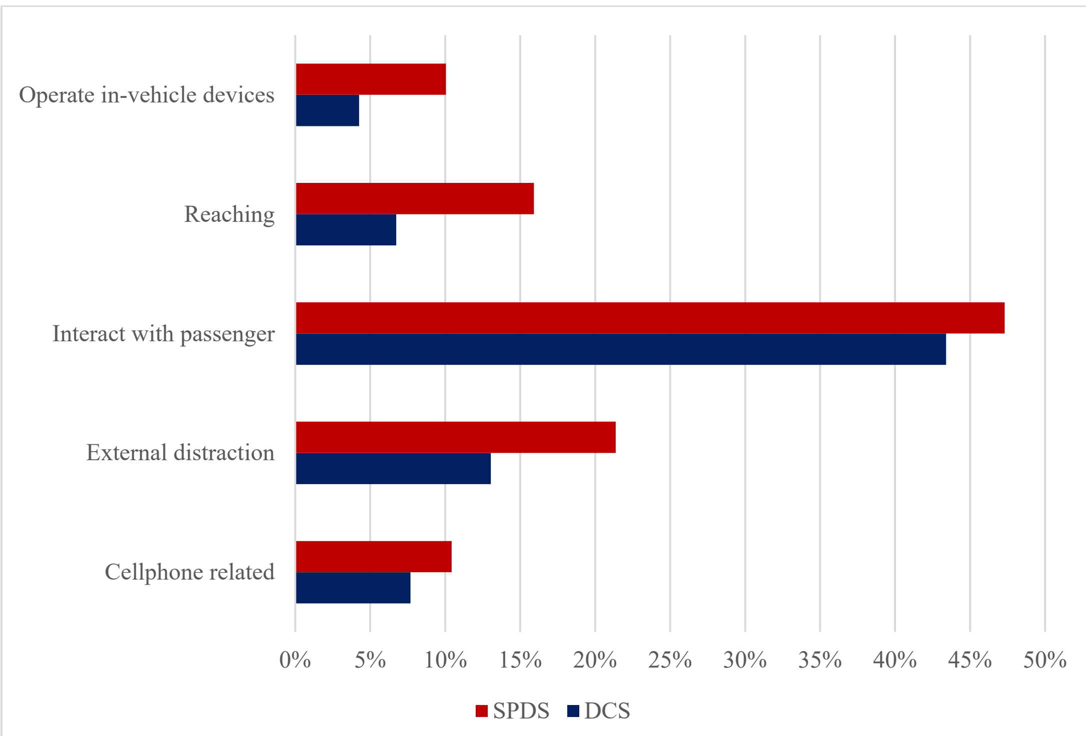

Figure 4. Bar graph. Prevalence of each subtask group in the SPDS and DCS.

Odds ratios in Table 6 indicated that teens enrolled in the SPDS were significantly more likely to engage in reaching for objects, look at external objects, and operate in-vehicle devices than teens in the DCS cohort. There were no significant differences between the two studies in cell-phone-related tasks and interaction with passengers. The National Safety Council (Sanders, 2004) has suggested that three or more passengers in the car will result in 4 times greater risk than when a teen is driving alone. In the two studies, each trip had at least one passenger. In the DCS, there were 475 front seat passengers and 20 rear seat passengers in all cases, while there were 687 front seat passengers and 62 passengers in the SPDS. Though the number of passengers in the two studies was significantly different, this did not cause a significant difference in interaction with passengers between the DCS and SPDS.

Table 6. Odds Ratios for Each Group

Group name	Prevalence		Yes Subtasks		No Subtasks		Odds Ratio Estimates (DCS Reference Group)			
	DCS	SPDS	DCS	SPDS	DCS	SPDS	OR	LL	UL	*p*
Cell-phone related	7.69%	10.43%	15	24	180	206	1.398	0.712	2.747	0.331
External distraction	**13.04%**	**21.37%**	**27**	**56**	**180**	**206**	**1.81**	**1.098**	**2.991**	**0.02**
Interact with passenger	43.40%	47.31%	138	185	180	206	1.171	0.870	1.578	0.298
Reaching	**6.74%**	**15.92%**	**13**	**39**	**180**	**206**	**2.621**	**1.357**	**5.066**	**0.004**
Operate in-vehicle devices	**4.26%**	**10.04%**	**8**	**23**	**180**	**206**	**2.512**	**1.097**	**5.755**	**0.0294**

DCS vs. SPDS GENDER

In the SPDS, females were observed to have generally higher rates of secondary behaviors than males, except for external distraction. Males' engagement in cell-phone-related tasks was much lower than females (odds ratio = 0.375, $p = 0.0458$). In the DCS, females also had higher rates of reaching behavior, cell-phone behavior, and interaction with passengers than males. The largest difference between males and females was in the subtask "interact with passenger," for which females had 21% more exposure in cases than males.

A logistic regression model and the frequency procedure in SAS 9.4 data analysis software were utilized to calculate the odds ratios for assessing the association between gender, feedback groups, and subtasks. When ignoring the gender variable, drivers' engagements in cell-phone-related tasks and interaction with passengers were not significantly different between the two studies. Odds ratios in Table 7 show that the chi-square statistic for males was significant in the interaction with passengers and reaching subtasks. Males with parental feedback were more likely to reduce the frequency of engagement in reaching activities and interaction with passengers than those without feedback. There was a significant association between feedback for females and operating in-vehicle devices. Females with parental feedback were more likely to reduce their frequency of operating in-vehicle devices than females without parental feedback.

The odds ratio of cell-phone-related tasks in the two studies was not significant. Teens' attitudes to cell phones in both studies were similar and teens did not reduce the frequency of cell-phone use even when parents provided guidance or feedback. Also, the difference between females and males in cell-phone use was not significant.

Table 7. SPDS vs. DCS in Gender

	Yes Subtasks				No Subtasks				
Group name	**DCS**		**SPDS**		**DCS**		**SPDS**		**Chi-Square**
	Male	Female	Male	Female	Male	Female	Male	Female	*p*
Cell-phone related	5	10	6	18	86	94	97	109	>0.9
External distraction	16	11	30	26	86	94	97	109	0.136 (male) 0.0616 (female)
Interact with passenger	38	100	85	100	86	94	97	109	**0.0049 (male)** 0.4580 (female)
Reaching	4	9	17	22	86	94	97	109	**0.0146 (male)** 0.0712 (female)
Operate in-vehicle devices	3	5	5	18	86	94	97	109	0.5982 (male) **0.0244 (female)**

SECONDARY TASK ENGAGEMENT BY PARENTAL LOGIN STATUS

In the DCS, the post hoc feedback component was delivered to both parents and teens via a website, thus enabling parental involvement. Odds ratios were calculated to assess the relationship between secondary task engagements and whether parents logged in to the website to observe the post hoc feedback. Odds ratios showed that the prevalence of all secondary task engagements for teens whose parents logged in to the web was not significantly different from that for teens whose parents did not log in.

We employed MedCalc statistics software to calculate the odds ratios for whether parents logged in to website in DCS compared with SPDS. Odds ratios of each subgroup compared the frequency of "yes subtasks" to "no subtasks" cases. A DCS parent login(yes) was the reference group. The odds ratios in Table 8 show that the subtask engagement frequency of teens whose parents logged in was significantly less than that of teens in the SPDS for external distraction and reaching. Compared with the SPDS, cell-phone use frequency in teens whose parents logged in was not significantly reduced in the DCS.

Table 8. Task Engagement by Parent Login vs. SPDS

Group name	Yes Subtasks			No Subtasks			Odds Ratio Estimates (DCS Reference Group)			
	DCS Login		SPDS	DCS Login		SPDS	OR	LL	UL	*p*
	Yes	No		Yes	No					
Cell-phone related	7	8	24	111	69	206	1.847	0.77	4.422	0.168
External distraction	**15**	**12**	**56**	**111**	**69**	**206**	**2.011**	**1.087**	**3.72**	**0.0259**
Interact with passenger	84	54	185	111	69	206	1.187	0.839	1.677	0.332
Reaching	**6**	**7**	**39**	**111**	**69**	**206**	**3.5**	**1.44**	**8.529**	**0.005**
Operate in-vehicle devices	5	3	23	111	69	206	2.47	0.917	6.699	0.074

CHAPTER 4. DISCUSSION

There was a significant difference between the DCS and SPDS groups concerning overall secondary task engagement. The assessment of teen driver engagement in secondary tasks showed that teens in the SPDS engaged in secondary tasks more frequently than teens in the DCS. Additionally, teen drivers in the SPDS were also more likely to multitask than were teen drivers in the DCS. The subtasks of secondary tasks that achieved statistical significance were external distraction, reaching, and operating in-vehicle devices. These results suggest that teen drivers with monitoring and feedback devices in their vehicles were less likely to engage in secondary tasks overall and less likely to perform multiple secondary tasks than teen drivers without monitoring and feedback devices in their vehicles.

One primary goal of this study was to understand the prevalence of engagement in *high-risk* secondary tasks. Previous studies have shown that the estimated prevalence of cell-phone use ranges from 6.29% to 10.4% (Guo et al., 2017). In this study, the prevalence of cell-phone use is 7.69% in the DCS and 10.43% in the SPDS, lower than that of other secondary tasks except for operating in-vehicle devices. Guo et al. (2017) pointed out that driving experience and age influence risk management skills. For 15.5–16-year-old teen drivers, skill deficits and inexperience may limit teen driver engagement in high manual and cognitive demand tasks, such as texting or operating devices while driving. As driving experience increases, the risk and prevalence of cell-phone use for teen drivers also continues to increase over time, reaching a peak during young adulthood (Guo et al., 2017).

Unfortunately, teens with monitoring and feedback devices did not reduce engagement in cell-phone-related tasks or interaction with passengers. Thus, providing feedback on kinematic risky driving was not found to reduce prevalence of cell-phone use among teen drivers.

In this study, the prevalence of interaction with passengers is the highest among all secondary tasks. Females were more likely than males to interact with passengers, operate in-vehicle devices, and reach for objects. The results were consistent with the study by Goodwin et al. (2012). Parental feedback significantly reduced males' engagement in interact with passengers and reaching.

CHAPTER 5. CONCLUSIONS

The overall goal of this project was to determine whether monitoring and feedback for kinematic risky driving can also reduce engagement in secondary tasks for teen drivers. The results indicated that monitoring and feedback does generally reduce overall secondary task engagement. We did not find this to be true for specific, higher risk, visual-manual tasks, such as cell-phone use. Additionally, we also found that parental feedback from parents who used the monitoring and feedback site did not modify teen drivers' cell-phone-use behavior. The effect of gender was also insignificant. This may be due to the low prevalence of cell-phone use and attitudes toward the cell phone. Teens may have a stronger attachment to their cell phones, and thus may be less concerned about parents finding out that they were interacting with their cell phone while driving. The significant effects of parental feedback on the external distraction, reaching, and operating in-vehicle devices demonstrated that parental feedback can significantly reduce engagements in visual-manual tasks. Visual-manual tasks increase risk more than cognitive tasks do (Guo et al., 2017); thus, reducing engagements in visual-manual tasks could lead to a greater decrease in driving risks. Parental feedback is an effective method to mitigate teen driving risks.

Some limitations of this study include small sample sizes of teen drivers, with all drivers located in Southwest Virginia. Additionally, project resources limited the number of baseline control samples that could be coded. While cell-phone tasks were among the most prevalent secondary tasks, they still only represented ~5% of all coded events, which also may have limited the statistical power of these analyses. Additional research should be conducted with teens from a broader range of geographic locations and with a greater number of additional samples.

These results do provide confirming evidence that monitoring and feedback devices can have a positive safety impact on teen drivers. Additional research should be conducted to more fully investigate how these systems can be more broadly deployed and provide useful and effective feedback for teen drivers and their parents to save teen drivers' lives across the US and beyond.

REFERENCES

Beanland, V., Goode, N., Salmon, P. M., & Lenné, M. G. (2013). Is there a case for driver training? A review of the efficacy of pre- and post-license driver training. *Safety Science*, *51*(1), 127–137. https://doi.org/10.1016/j.ssci.2012.06.021

Braitman, K. A., Kirley, B. B., Mccartt, A. T., & Chaudhary, N. K. (2008). Crashes of novice teenage drivers: Characteristics and contributing factors. *Journal of Safety Research*, *39*(1), 47-54. https://doi.org/10.1016/j.jsr.2007.12.002

Caird, J. K., Johnston, K. A., Willness, C. R., Asbridge, M., & Steel, P. (2014). A meta-analysis of the effects of texting on driving. *Accident Analysis and Prevention*, *71*, 311–318. https://doi.org/10.1016/j.aap.2014.06.005

Carney, C., Mcgehee, D., & Harland, K., et al. (2015, March). *Using naturalistic driving data to assess the prevalence of environmental factors and driver behaviors in teen driver crashes*. AAA Foundation. https://iro.uiowa.edu/esploro/outputs/9983557190702771

Centers for Disease Control and Prevention. (2017). *Teen drivers: Get the facts*. https://www.cdc.gov/motorvehiclesafety/teen_drivers/teendrivers_factsheet.html

Curry, A. E., Hafetz, J., Kallan, M. J., Winston, F. K., & Durbin, D. R. (2011). Prevalence of teen driver errors leading to serious motor vehicle crashes. *Accident Analysis and Prevention*, *43*(4), 1285–1290. https://doi.org/10.1016/j.aap.2010.10.019

Durbin, D. R., McGehee, D. V., Fisher, D., & McCartt, A. (2014). Special considerations in distracted driving with teens. *Annals of Advances in Automotive Medicine*, *58*, 69.

Fisher, D. L., Caird, J. K., Horrey, W. J., & Trick, L. M. (Eds.). (2017). *Handbook of teen and novice drivers: Research, practice, policy, and directions*.

Gershon, P., Ehsani, J. P., Zhu, C., Sita, K. R., Klauer, S. G., Dingus, T. A. & Simons-Morton, B. (2018). Crash risk and risky driving behavior among adolescents during learner and independent driving periods. *Journal of Adolescent Health*, *63*(5), 568–574.

Goodwin, A. H., Foss, R. D., Harrell, S. S., & O'Brien, N. P. (2012). *Distracted driving among newly licensed teen drivers*. AAA Foundation for Traffic Safety.

Guo, F. (2019). Statistical methods for naturalistic driving studies. *Annual Review of Statistics and Its Application*, *6*, 309–328.

Guo, F., Klauer, S. G., Fang, Y., Hankey, J. M., Antin, J. F., Perez, M. A., … Dingus, T. A. (2017). The effects of age on crash risk associated with driver distraction. *International Journal of Epidemiology*, *1*(46), 258–265. https://doi.org/10.1093/ije/dyw234

Klauer, S. G., Ankem, G., Guo, F., Baynes, P., Fang, Y., Atkins, W., … Dingus, T. (2017). *Driver Coach Study: Using real-time and post hoc feedback to improve teen driving habits*. https://vtechworks.lib.vt.edu/bitstream/handle/10919/81096/STSCE_DriverCoachFinalReport_Final.pdf?sequence=1&isAllowed=y

Klauer, S. G., Guo, F., Simons-Morton, B. G., Ouimet, M. C., Lee, S. E., & Dingus, T. A. (2014). Distracted driving and risk of road crashes among novice and experienced drivers. *New England Journal of Medicine*, *370*(1), 54–59. https://doi.org/10.1056/NEJMsa1204142

Mayhew, D. R., Simpson, H. M., & Pak, A. (2003). Changes in collision rates among novice drivers during the first months of driving. *Accident Analysis and Prevention*, *35*(5), 683–691. https://doi.org/10.1016/S0001-4575(02)00047-7

McCartt, A. T., Hellinga, L. A., & Bratiman, K. A. (2006). Cell phones and driving: Review of research. *Traffic Injury Prevention*, *7*(2), 89–106. https://doi.org/10.1080/15389580600651103

McKnight, A. J., & McKnight, A. S. (2003, November). Young novice drivers: Careless or clueless? *Accident Analysis and Prevention*, *35*, 921–925. https://doi.org/10.1016/S0001-4575(02)00100-8

National Highway Traffic Safety Administration. (2019). *Distracted driving in fatal crashes, 2017*. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812700

Pradhan, A. K., Li, K., Ehsani, J. P., Ouimet, M. C., Klauer, S. G., & Simons-Morton, B. G. (2013). Measuring young drivers' behaviors during complex driving situations. *Proceedings of the Seventh International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design*.

Sanders, M. H. (2004). *Teen driver: A family guide to teen driver safety.* National Safety Council.

Simons-Morton, B. G., Ehsani, J. P., Gershon, P., Klauer, S. G., & Dingus, T. A. (2017). Teen driving risk and prevention: Naturalistic driving research contributions and challenges. *Safety*, *3*(4), 29.

Simons-Morton, B. G. (2007). Parent involvement in novice teen driving: Rationale, evidence of effects, and potential for enhancing graduated driver licensing effectiveness. *Journal of Safety Research*, *38*(2), 193–202. https://doi.org/10.1016/j.jsr.2007.02.007

Simons-Morton, B. G., Guo, F., Klauer, S. G., Ehsani, J. P., & Pradhan, A. K. (2014). Keep your eyes on the road: Young driver crash risk increases according to duration of distraction. *Journal of Adolescent Health*, *54*(5), S61–S67. https://doi.org/10.1016/j.jadohealth.2013.11.021

Simons-Morton, B. G., Klauer, S. G., Ouimet, M. C., Guo, F., Albert, P. S., Lee, S. E., … Dingus, T. A. (2015). Naturalistic teenage driving study: Findings and lessons learned. *Journal of Safety Research*. https://doi.org/10.1016/j.jsr.2015.06.010

Stutts, J., Reinfurt, D., Staplin, L., & Rodgman, E. (2001). *The role of driver distraction in traffic crashes*. AAA Foundation for Traffic Safety.

Williams, A. F. (2003). Teenage drivers: Patterns of risk. *Journal of Safety Research*, *34*(1), 5–15. https://doi.org/10.1016/S0022-4375(02)00075-0