Mitigating Teen Driver Distraction: In-vehicle Feedback based on Peer Social Norms

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Birsen Donmez*, Maryam Merrikhpour, and Mehdi Hoseinzadeh Nooshabadi

Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, ON, Canada

***Corresponding author**: 5 King's College Rd., Toronto, ON, Canada, M5S 3G8, email: donmez@mie.utoronto.ca, telephone: +1 (416) 978-7399; fax: +1 (416) 978-7753.

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Abstract

Objective: To investigate the efficacy of in-vehicle feedback based on peer social norms in mitigating teen driver distractions.

Background: Distraction is a significant problem among teen drivers. Research into the use of in-vehicle technologies to mitigate this issue has been limited. In particular, there is a need to study whether social norms interventions provided through in-vehicle feedback can be effective. Peers are important social referents for teens; thus, normative interventions based on this group is promising. Socially proximal referents have a greater influence on behavior; thus, tailoring peer-norm feedback based on gender may provide additional benefits.

Method: 57 teens completed a driving simulator experiment while performing a secondary task in three between-subject conditions: (a) post-drive feedback incorporating same-gender peer norms, (b) post-drive feedback incorporating opposite-gender peer norms, and (c) no feedback. Feedback involved information based on descriptive norms (what others do).

Results: Teens' self-reported frequency of distraction engagement was positively correlated with their perceptions of their peers' engagement in and approval of distractions. Feedback based on peer norms was effective in reducing distraction engagement and improving driving performance, with no difference between same- and opposite-gender feedback.

Conclusion/Application: Feedback based on peer norms can help mitigate driver distraction among teens. Tailoring social norms feedback to teen gender appears to not provide any additional benefits. Longer-term effectiveness in real-world settings should be investigated.

Keywords: Teenage driver distraction; Normative feedback; Gender; In-vehicle information systems; Driving simulator

Precis

This research investigated the efficacy of interventions based on peer norms to mitigate teen driver distractions. A driving simulator experiment conducted with 57 teens showed that social norms feedback based on peer norms was effective in reducing distraction engagement and improving driving performance among teens.

Introduction

Distraction is a significant problem among teen drivers. In 2017, 15- to 19-year-old drivers constituted 3.9% of all U.S. drivers (Federal Highway Administration, 2019) but 9% of distracted drivers involved in fatal crashes (National Highway Traffic Safety Administration, 2019). While the teen crash risk associated with distraction is already alarming, there is also a growing concern due to new mobile and interactive technologies, both carried in and incorporated within the vehicle.

Although in-vehicle technologies can be a source of distraction, they can also be utilized to provide drivers with feedback and direct their attention back to the road (Lee, 2007, 2009). Previous studies suggest that providing feedback during (i.e., real-time feedback) and after (i.e., post-drive feedback) driving could be effective countermeasures to mitigate distraction and improve performance (Donmez, Boyle, & Lee, 2007, 2008; Lee, McGehee, Brown, & Reyes, 2002). However, only a limited number of studies have been conducted in this area, and one important factor that is yet to be explored systematically is whether social norms feedback can be leveraged within in-vehicle systems to mitigate teen driver distraction. As noted by Lee and Strayer (2004, p. 586), "..social norms governing acceptable risks – specifically, whether it is socially acceptable to use a cell phone while driving – may have the largest effect on driving safety".

Social norms interventions have been successfully used to target behavioral changes in various domains (Allcott, 2011; Haines, Barker, & Rice, 2003; Perkins, Linkenbach, Lewis, & Neighbors, 2010). According to the Social Norms Theory (Perkins & Berkowitz, 1986), individuals choose to engage in a particular behavior based on their perceptions of others' behavior (i.e., descriptive norms) or approval (i.e., injunctive norms). The overestimation of the prevalence/permissiveness of negative behaviors is common and can lead to increased engagement in those behaviors. Social norms interventions aim to correct these overestimations and reduce negative behaviors by providing accurate social norms information. However, to the best of our knowledge, social norms feedback to mitigate driver distraction has only been investigated in two studies (Merrikhpour & Donmez, 2017; Roberts, Ghazizadeh, & Lee, 2012), only one of which focused on the teen problem (Merrikhpour & Donmez, 2017).

Roberts et al. (2012) conducted a simulator experiment with 36 participants between the ages of 25 and 50 years to evaluate two different systems: post-drive feedback incorporating social norms information and real-time feedback. Post-drive feedback included a post-drive report with feedback on participants' driving performance and distraction level observed in the recently completed drive, as well as a comparison between participants' and their peers' distracted driving behavior. Real-time feedback included visual and auditory warnings based on glance behaviors to alert drivers when they were distracted. Post-drive feedback increased eyes-on-road time and decreased unsafe off-road glances compared to no feedback, whereas real-time feedback was not found to generate such benefits (Lee et al., 2013; Roberts et al., 2012). Although these results provide evidence that post-drive feedback incorporating social norms information can be effective to reduce driver distraction, it is unclear whether these benefits would also materialize for teen drivers.

In a more recent driving simulator study, our research group investigated the effectiveness of social norms feedback to mitigate teen driver distraction by focusing on parents as the social referent (Merrikhpour & Donmez, 2017). The experiment had four between-subject conditions. In the social norms feedback condition, teens were presented with post-drive feedback, which provided a report at the end of each drive on their distracted driving behavior, comparing their distraction engagement to their parent's engagement. In the post-drive feedback only condition, teens were provided with just the report on their distracted driving behavior without information on their parents. The other two conditions were real-time feedback provided in the form of auditory warnings based on eyes off road-time, and no feedback that was implemented as control. Although the teens were told that the information presented to them was based on their parent's behavior, artificial data was used instead to control for potential variances among the parents. Findings indicated that both social norms feedback and real-time feedback reduced distraction engagement and improved driving performance, with social norms feedback outperforming real-time feedback. No major benefit was observed for the post-drive feedback only condition, suggesting that the addition of social norms information to post-drive feedback made a significant difference in effectiveness.

During adolescence, there is a shift from family to group life, and teens turn increased attention to peer social cues (Allen & Brown, 2008; Blos, 1962; Gifford-Smith, Dodge, Dishion, & McCord, 2005). Peer norms have been shown to affect teen driver behaviors. The Naturalistic Teenage Driving Study showed that teens who reported to have more risk-taking friends had significantly higher rates of crashes/near crashes and risky driving (Simons-Morton et al., 2011). Further, in a driving simulator study, Simons-Morton et al. (2014) found that male teens, who were exposed to a risk-accepting confederate peer, exhibited more high-risk driving behaviors compared to those who were exposed to a risk-averse confederate peer. Particular to driver distraction, both Carter et al. (2014) and Beck and Watters (2016) found that teens' perception of their peers' engagement in driver distraction is predictive of their own self-reported distraction engagement. Further, Carter et al. (2014) found that teens may overestimate their peers' frequency of engagement in driver distractions.

In the current study, we evaluated the efficacy of in-vehicle feedback based on peer descriptive norms (i.e., what peers do). We hypothesized that teens overestimate distraction engagement among their peers, and that providing teens with peer norm feedback can mitigate their distraction behaviors. In addition, we investigated the effects of tailoring feedback based on teen's gender. Based on the Social Comparison Theory (Festinger, 1954), which states that socially proximal comparison referents (e.g., same age, same gender) have a greater influence on behavior, we hypothesized that social norms feedback based on same-gender peer norms would be more effective than one based on opposite-gender peer norms.

Three between-subject feedback conditions were evaluated in a driving simulator experiment: (a) post-drive feedback incorporating same-gender peer norms, (b) post-drive feedback incorporating opposite-gender peer norms, and (c) no feedback as control. As reported above, Merrikhpour and Donmez (2017) found that post-drive feedback became effective with the inclusion of social normative information, but was not effective without. Therefore, in the current study, we chose not to include a fourth condition to test post-drive feedback only (without normative information), but assumed that if feedback types tested in our study are effective, the effectiveness can be attributed to the introduction of the social norms component to post-drive feedback. Questionnaires were also administered to collect data on teens' distraction engagement and the associated social norms.

Methods

A 2x3x5 mixed factorial design was used, with driver gender (male, female) and feedback type (same-gender peer norm, opposite-gender peer norm, and no feedback) as between-subjects factors, and experimental drive (d1 to d5) as a within-subject factor. Each participant completed five drives in the simulator while performing a self-paced visual-manual secondary task. No feedback was provided during drive 1, the baseline drive, which was identical across all feedback types. Drives 2 to 5 differed across the feedback types, with feedback being present for the same- and opposite-gender peer norm conditions, and not being present for the no feedback condition. The teens who were assigned to a social norms feedback condition were presented with post-drive normative feedback after each experimental drive. Therefore, drives 2 to 5 were feedback drives (i.e., undertaken after receiving feedback).

Participants

To be eligible for the experiment, teens needed to have at least a Class G2 license (allowing independent driving with restrictions) or equivalent in Ontario, Canada, and to be able to drive without the use of corrective lenses to ensure good eye tracking data.

Forty-six participants were recruited: 19 for same-gender feedback, 21 for opposite-gender feedback, and 6 for no feedback. Data from the 11 participants who completed the no feedback condition in our previous study that was conducted a year earlier (Merrikhpour & Donmez, 2017) were added to the no feedback condition of the current study as the experimental design and procedures for these conditions across the two studies were exactly the same. To further justify this merge, the experimental data for the two groups were compared and no significant differences were observed. Thus, the current study had a total of 57 participants (Table 1).

Table 1. Demographic information of the teens across the three feedback types

			% age group			**% years of G2 licensure**		
Feedback Type	**N**	**% male**	17	18	19	≤1	>1, ≤2	>2
Same-gender peer norm	19	47.4	0	52.6	47.4	10.5	52.6	36.8
Opposite-gender peer norm	21	47.6	4.8	61.9	33.4	19	47.6	33.4
No feedback	17	58.8	11.8	29.4	58.8	11.8	64.7	23.5
Overall	57	50.9	5.3	49.1	45.6	14	54.4	33.4

All teens were compensated C$25 for their participation, including a C$5 bonus. To provide motivation for secondary task engagement, C$5 was presented to participants as a potential bonus based on secondary task performance; all participants received the full amount regardless of performance. Both studies received approval from the University of

Toronto Research Ethics Board (#31322). Informed consent was obtained from each participant.

Apparatus

A NADS MiniSim™ Driving Simulator with three 42-inch monitors creating a 130° horizontal and 24° vertical field of view and a dashboard mounted FaceLAB™ 5.1 Eyetracker were used to collect data at 60 Hz (Figure 1). A 10.6-inch touchscreen Microsoft Surface™ Pro 2 was used for the presentation of the self-paced secondary task as well as feedback.

Figure 1: University of Toronto NADS MiniSim™ driving simulator with (a) eye-tracking cameras and (b) in-vehicle display

Experimental Tasks

All five drives were identical and each drive took on the average 6.2 minutes (SD = 0.35). Participants were instructed to follow a lead vehicle on a 2-lane rural road and to maintain the speed limit of 50 mph (~80 kph). They were informed that the lead vehicle may occasionally brake; however, they were not informed about when and how frequently. Within each drive, there were eight lead vehicle braking events at a rate of 0.4 g (3.9 m/s^2). The lead vehicle speed was programmed to adjust to obtain a gap time of 2.2 s at the onset of lead vehicle braking. These particular deceleration rate and gap time values were chosen during pilot testing to induce a response right away without imposing an emergency.

The self-paced visual-manual secondary task developed by Donmez et al. (2007) was adopted, which has been shown to degrade driving performance in the simulator, particularly in response to lead vehicle braking. A self-paced task was used as the objective of the study was to assess changes in distraction engagement through feedback; a task paced by the experimenters would not have been appropriate. Participants were asked to select a match with the phrase “Discover Project Missions” from a list of 10 phrases presented on the Microsoft Surface display. The task was available throughout an entire drive. The participants initiated the task by touching a start button. Participants then scrolled through a list of closely related phrases, for a phrase that had either “Discover” first, “Project” second, or “Missions” as the third word. The phrases were presented two at a time, and participants could view the list of 10 phrases by scrolling using up and down arrows. Each phrase submission was followed by another set of phrases. Participants were instructed that the task would be available at all times and they could choose to engage in the task at their own pace that they felt comfortable. They were also instructed to prioritize safety and to drive as they would in their own vehicle.

Feedback Designs

Same-gender and opposite-gender peer norm feedback consisted of a post-drive report presented to the teens, which provided a comparison of their distracted driving behavior to that of their same-gender and opposite-gender peers, respectively (Figure 2). The teens were told that the information presented to them was based on the average driving behavior of 30 same/opposite-gender 17- to 19-year old teens who participated in the same study. However, same normative information had to be presented for both feedback conditions in order to have experimental control. Thus, this information had to be artificial (Table 2).

We first tested the artificial data from our previous study used to represent parental behavior (Merrikhpour & Donmez, 2017). During pilot testing, it became clear that the teens in the current study did not find this earlier data credible as they expected higher distraction levels for their peers. In the end, we utilized teen behavior data recorded in our earlier study to create the artificial data in our current study (~ 25th percentile point was adopted). The teens were debriefed at the end about this deception, and none indicated any suspicion.

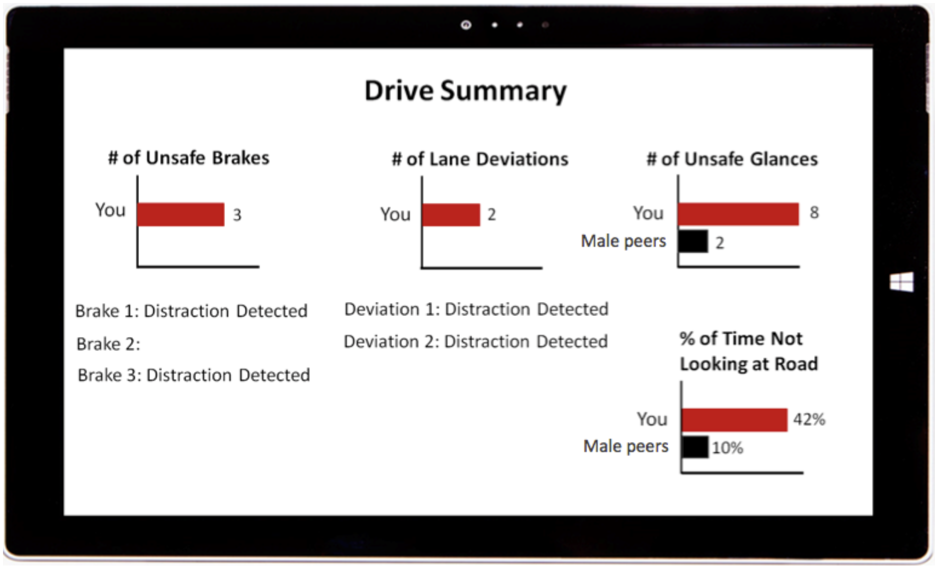


Figure 2: Same/opposite-gender peer-norm feedback

Table 2. Artificial peer data used for comparison in same- and opposite-gender peer-norm feedback

Drive Number	**# of Unsafe Glances**	**% Time Not Looking at the Road**
d1	5	21
d2	3	18
d3	2	10
d4	0	6
d5	0	5

Peer norm feedback presented detailed performance and attention measures using bar graphs (Figure 2). Driving performance graphs presented information on unsafe braking and lane deviation. The criteria for unsafe braking and lane deviation were empirically determined for the particular experiment design and simulator used in this study. Maximum deceleration equal to or greater than 0.6 g (5.9 m/s^2) or a minimum time to collision equal to or shorter than 1.5 s was used to determine when an unsafe braking occurred; while lane deviation was defined as straying from the intended lane either into the adjacent lane (i.e., the tire coming into contact with the lane marker) or off the road (i.e., the tire coming into contact with the shoulder). Teens were informed about the criteria, although they did not know the specific thresholds.

Attention to driving graphs provided a comparison between teen and peer unsafe glances (glances over 2 seconds on the secondary display) and percentage of the time not looking at the roadway. The 2-second threshold was chosen as Klauer et al. (2006) showed that glances away from the road over 2 seconds can double the risk of a crash. Information about teen's distraction status prior to each driving error (i.e., unsafe braking and lane deviation) was also provided. The phrase "distraction detected" was presented when either a single long glance (>2 seconds) on the secondary display was detected within 5 seconds prior to the driving error or when the driver's eyes were on the secondary display for a total of 3 seconds in a 5-second moving window.

Procedure

After signing the informed consent document, teens completed a pre-experiment questionnaire, which is described in detail below, to assess their self-reported distraction engagement and their perceived norms. The eye-tracker was then calibrated and the teens completed a practice drive identical to experimental drive 1 (the baseline), while practicing the secondary task. The range of angular errors in calibration was recorded to be between 0.5° and 1°. Although we did not record the exact calibration accuracy for this experiment, in an earlier study using the same calibration procedure, we found angular error to have an average of 0.9° (SD: 0.4°) (D'Addario & Donmez, 2019). At the end of the last experimental drive, teens who experienced feedback completed a widely-used system acceptance questionnaire (Van Der Laan, Heino, & De Waard, 1997).

Distraction Engagement and Driving Performance Measures and Analysis

Table 3 presents the measures used to assess distraction engagement and driving performance. For distraction engagement, in addition to the glance measures that had been presented as post-drive feedback to the participants (i.e., rate of glances longer than 2 seconds and percent time looking at the display), we also analyzed number of manual interactions with the secondary display. The driving performance measures assessed lateral control and brake response performance as defined in SAE J2944 Operational Definitions of Driving Performance Measures and Statistics (SAE, 2015).

Table 3. Simulator measures

Distraction Engagement	**Driving Performance**
Glances to secondary display:	*Lateral control*:
Rate of glances > 2 s (per minute)	Standard deviation of lane position (SDLP)
% time looking at display (during the drive)	
	Brake response:
Manual engagement with secondary display:	Accelerator release time (ART)
Number of manual interactions (during the drive)	Brake transition time (BTT)
	Maximum deceleration
	Minimum time to collision (TTC_{min})

In order to control for the inflation of Type I error, two repeated measures Multivariate Analyses of Variance (MANOVAs) were conducted using the general linear model framework (SAS GLM procedure): one for distraction engagement measures (percent time looking and number of manual interactions) and one for driving performance measures (all five). All independent variables (i.e., gender, feedback type, and drive number) as well as their interactions (both two- and three-way) were included in MANOVAs, with gender and feedback type introduced as between-subjects factors, and drive number introduced as a within-subject factor. The significant main and interaction terms from these MANOVAs were selected to be used as independent variables in follow-up univariate analyses, again conducted using the general linear model framework. Within these univariate models, significant terms were explored through model contrasts.

Rate of glances >2 s was not included in the MANOVA analysis given the highly non-normal nature of this dependent variable, which warranted a generalized linear model approach rather than a general linear model approach. To analyze rate of glances > 2 s (per minute) to the secondary display, a negative binomial model was built (SAS GENMOD procedure). Repeated measures were accounted for using generalized estimating equations.

Questionnaire Measures and Analysis

System acceptance questionnaire data that was collected at the end of the experiment from same- and opposite-gender feedback groups was analyzed through repeated measures ANOVA, with gender as a between-subject factor and feedback type as a within-subject factor, their interaction was also investigated.

The pre-experiment questionnaire was developed by the authors to assess self-reported driver distraction engagement and related social norms. A variety of distraction tasks were adopted from the survey reported in Carter et al. (2014) to provide a wide range of tasks that teens may engage in while driving (Table 4). For analysis, the initial set was narrowed to 12 tasks, excluding those that around 90% of the teens reported to never or rarely engage in (last five items in Table 4).

Teens were instructed to answer survey questions in the context of a scenario depicted in an image provided to them, with the following script: “We ask you to answer questions in the context of the scenario depicted below, a two-lane rural road where traffic conditions are low and there is good weather.” Further, teens were asked to answer according to their actual experiences rather than what they thought their experience should be.

Table 4. Distractions utilized in the questionnaires

Distractions
1- Talking on a hand-held cell phone while driving
2- Talking on the phone using a hands-free device (e.g., Bluetooth headset)
3- Reading a text message on a hand-held device (e.g., cell phone) while driving
4- Responding to a text message on a hand-held device (e.g., cell phone) while driving
5- Having a text message conversation involving several texts in a row on a hand-held device (e.g., cell phone)
6- Manually entering an address into a navigation app on a smartphone that is NOT mounted inside the vehicle while driving
7- Manually entering an address on a built-in or mounted navigational system while driving
8- Adjusting the audio system using controls on the console
9- Chatting with passengers if there are any while driving
10- Eating something messy like a taco while driving
11- Drinking a hot beverage while driving
12- Grooming (e.g., combing hair, applying makeup, flossing teeth) while driving
13- Updating or checking social media such as Facebook, Twitter, or Instagram while driving
14- Playing digital games such as Angry Birds, Farmville, or Words with Friends
15- Watching online videos
16- Reading emails on a hand-held device (e.g., cell phone)
17- Reading extended text such as book, magazine, and e-book, or the web

Self-reported distraction engagement and *perceived distraction engagement* were assessed for each distraction through the following question: “On average, how often do you think you (male teens your age, female teens your age) have engaged in each of the following tasks over the last year while driving in an environment similar to the image above?” (1= never, 2= rarely, 3= sometimes, 4= often, 5= very often, NA = don’t use this technology). *Perceived distraction approval* (perceived injunctive norms) was assessed for each distraction through the following question: “On average, how much would male (female) teens your age approve or disapprove if you engage in each of the following tasks while driving in an environment similar to the image above?” (1= strongly disapprove, 2= disapprove, 3= neutral, 4= approve, and 5= strongly approve, NA = I don’t use this technology).

The internal consistency of each measure met the well-established threshold of 0.7 for Cronbach’s alpha (Nunnally, 1978), and ranged from 0.84 to 0.87. For the purpose of scoring, responses were averaged across the different distractions for each teen. The questionnaire data for those 11 participants who were added from our previous study, was excluded in the analysis reported in this paper, as when they were given this questionnaire a distinction of peer gender was not made in the questions. Paired t-tests and Wilcoxon Signed Rank tests (non-parametric alternative when the normality assumption is violated) were conducted to compare teens' self-reported distraction engagement to their perception of how frequently their peers engage in distractions. Further, gender effects were explored through independent t-tests and Wilcoxon Rank Sum tests (non-parametric alternative). Pearson and Spearman (non-parametric alternative) correlation analyses were conducted to assess the relationship between teen distraction engagement and perceived peer norms.

Results

Distraction Engagement and Driving Performance

MANOVA results are presented in Table 5. For distraction engagement measures, gender, feedback type, drive number, and feedback type and drive number interaction were found to be significant. For driving performance measures, the findings were similar with feedback type and drive number effects, except gender was not significant.

Table 5. MANOVA results (significant p-values in bold; α = .05)

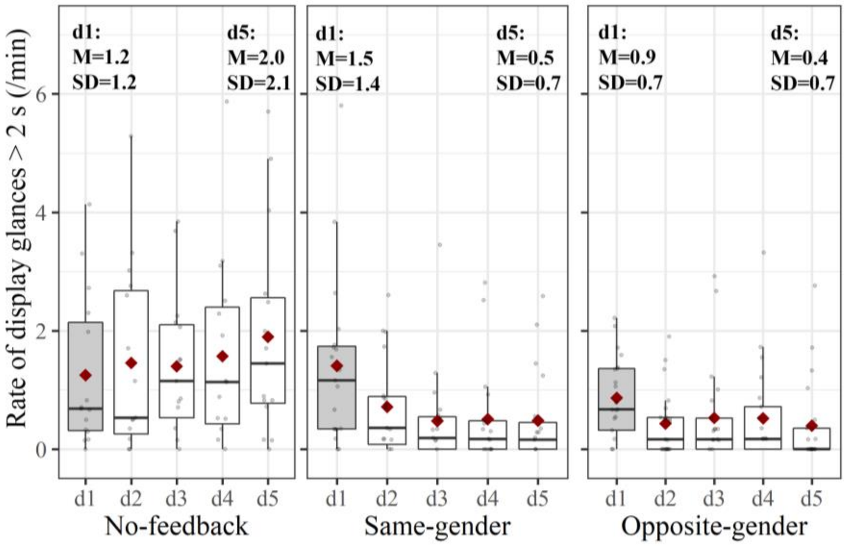
Independent Variables	Wilks' Λ	F-value	p-value
Distraction Engagement Measures: *% time looking + Number of manual interactions*			
Gender	0.861	F(2, 49) = 3.96	**.03**
Feedback type	0.819	F(4, 98) = 2.57	**.04**
Drive number	0.782	F(8, 398) = 6.49	**<.0001**
Gender*Feedback type	0.991	F(4, 98) = 0.11	.98
Gender*Drive number	0.987	F(8, 398) = 0.32	.96
Feedback type*Drive number	0.761	F(16, 398) = 3.63	**<.0001**
Gender*Feedback type*Drive Number	0.942	F(16, 398) = 0.76	.73
Driving Performance Measures: *SDLP + ART + BTT + Max deceleration + TTCmin*			
Gender	0.889	F(5, 45) = 1.12	.36
Feedback type	0.813	F(10, 90) = 0.98	.46
Drive number	0.639	F(20, 607.9) = 4.40	**<.0001**
Gender*Feedback type	0.740	F(10, 90) = 1.46	.17
Gender*Drive number	0.891	F(20, 607.9) = 1.07	.37
Feedback type*Drive number	0.701	F(40, 800.5) = 1.70	**.005**
Gender*Feedback type*Drive Number	0.885	F(40, 800.5) = 0.57	.99

The independent variables used in the univariate models presented in Table 6 were selected according to the MANOVA findings. For driving performance measures, Table 6 reports only SDLP and maximum deceleration, as the other three measures did not reveal any significant results. Further, for the rate of glances > 2 s, only significant effects obtained from the negative binomial model are reported.

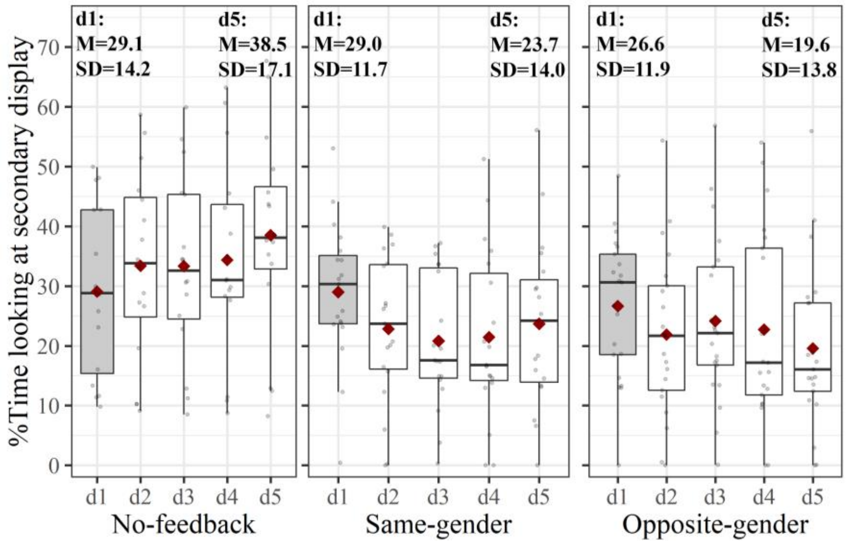
Table 6. Univariate analysis results (significant p-values in bold; α = .05)

Independent Variables		**F / χ^2-value**	**p-value**	η_p^2
Distraction Engagement Measures				
Rate of glances > 2 s	Feedback type	$\chi^2(2) = 10.74$	**.005**	
	Drive number	$\chi^2(4) = 19.43$	**.0006**	
	Feedback type*Drive number	$\chi^2(8) = 52.59$	**<.0001**	
% time looking at display	Gender	F(1, 52) = 7.01	**.01**	0.45
	Feedback type	F(2, 52) = 3.42	**.04**	0.45
	Drive number	F(4, 212) = 1.64	.17	0.03
	Feedback type*Drive number	F(8, 212) = 7.29	**<.0001**	0.22
Number of manual interactions	Gender	F(1, 53) = 5.96	**.02**	0.39
	Feedback type	F(2, 53) = 2.92	**.06**	0.39
	Drive number	F(4, 216) = 3.90	**.004**	0.07
	Feedback type*Drive number	F(8, 216) = 4.09	**.0001**	0.13
Driving Performance Measures				
SDLP	Feedback type	F(2, 53) = 2.30	.11	0.25
	Drive number	F(4, 204) = 6.11	**.0001**	0.11
	Feedback type*Drive number	F(8, 204) = 4.27	**<.0001**	0.14
Maximum deceleration	Feedback type	F(2, 53) = 2.76	.07	0.14
	Drive number	F(4, 208) = 18.07	**<.0001**	0.26
	Feedback type*Drive number	F(8, 208) = 3.01	**.003**	0.10

The relevant data distributions are presented in Figure 3. It appears that in the no feedback condition, distraction engagement increased as the teens completed more drives, whereas the opposite effect was observed for the normative feedback conditions. Statistical findings reported below support these data trends. Although there was a monetary incentive to encourage participant engagement in the secondary task, two of the 57 participants did not start the task at all in any of the drives, having 0 number of manual interactions with the display. Those who engaged had almost 100% success rate in finding the correct phrase for the secondary task (M: 98%, SD: 2.9%), and thus this metric assessing secondary task performance was not analyzed.



(a)



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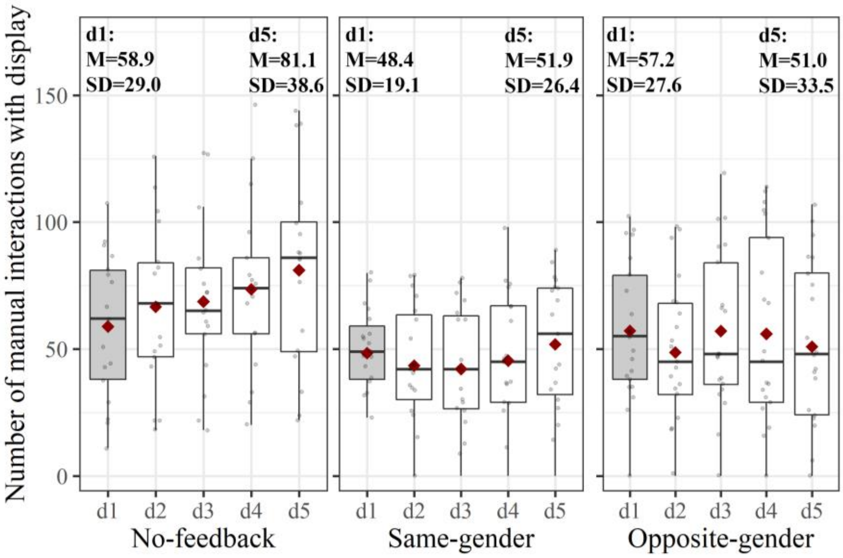

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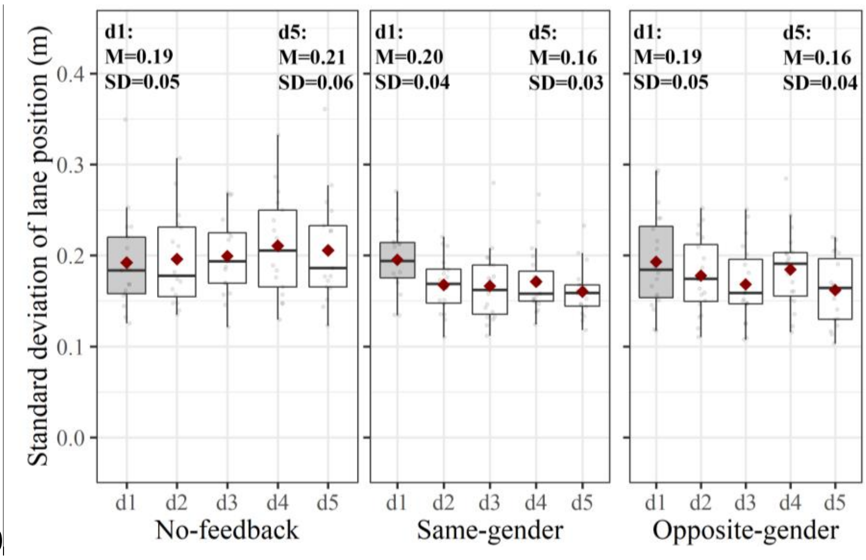

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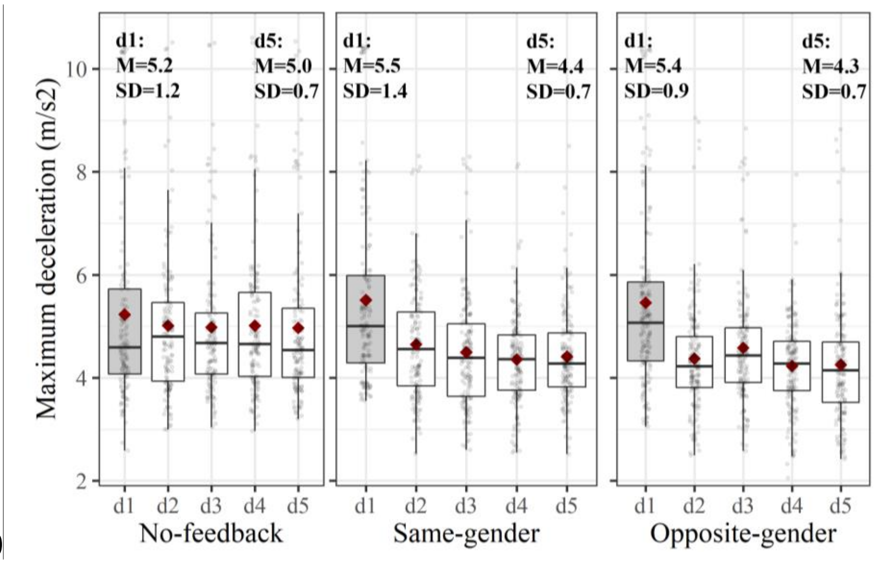

(e)

Figure 3. Interactions with the secondary display and driving performance: (a) rate of glances >2 s per minute, (b) % time looking, (c) number of manual interactions, (d) standard deviation of lane position, (e) maximum deceleration. The boxplots present the data points (gray circles), the first and the third quartiles, the median, the mean (red diamond), and potential outliers; d1 highlighted with shading is the baseline drive; d2 to d5 are feedback drives. The mean and the standard deviation values for d1 and d5 are also presented.

Model contrast results comparing same-gender and opposite-gender feedback to no feedback are presented in Table 7. When same-and opposite-gender feedback were compared to each other, no differences were observed, therefore, these contrasts are not reported. Further, there were no significant differences across the three conditions during the baseline drive (drive 1), supporting that there were no inherent differences among the teens who completed the different between-subjects conditions.

Table 7. Model contrast results assessing significant interaction effects of feedback type and drive number (significant p-values in bold; α = .05)

		Rate of glances >2 s		**% time looking at display**		**Number of manual interactions**		**SDLP**		**Maximum deceleration**	
Contrast	**Drive #**	$\chi^2(1)$	p-value	t(212)	p-value	t(216)	p-value	t(204)	p-value	t(208)	p-value
Same-gender feedback vs. No feedback	1: baseline	0.23	.63	0.15	.88	-0.87	.38	0.68	.50	0.77	.44
	2	3.66	.06	-2.13	**.03**	-2.18	**.03**	-1.82	.07	-1.32	.19
	3	6.14	**.01**	-2.56	**.01**	-2.52	**.01**	-2.28	**.02**	-1.82	.07
	4	6.54	**.01**	-2.64	**.009**	-2.70	**.008**	-2.41	**.02**	-2.38	**.02**
	5	10.52	**.001**	-3.07	**.002**	-2.80	**.005**	-2.54	**.02**	-2.01	**.045**
Opposite-gender feedback vs. No feedback	1: baseline	1.38	.24	-0.37	.71	0.03	.98	0.04	.96	0.93	.35
	2	9.68	**.002**	-2.40	**.02**	-1.69	.10	-1.54	.12	-2.25	**.03**
	3	5.95	**.01**	-1.88	.06	-1.02	.31	-2.12	**.04**	-1.48	.14
	4	6.64	**.01**	-2.42	**.02**	-1.65	.10	-1.47	.14	-3.02	**.003**
	5	12.04	**.0005**	-4.05	**<.0001**	-2.97	**.003**	-2.80	**.0006**	-2.76	**.006**

Compared to no feedback, same-gender feedback resulted in a lower rate of display glances > 2 s in drives 3 to 5, and a shorter percent time spent looking at the display and fewer number of manual interactions with the display in drives 2 to 5. Opposite-gender feedback had similar results, with drive 2 also being significant for rate of glances > 2 s, whereas drive 3 being non-significant for percent time looking at the display and only drive 5 being significant for number of manual interactions. As for driving performance, compared to no feedback, SDLP was lower in drives 3 to 5 for same-gender feedback, and drives 3 and 5 for opposite-gender feedback, and maximum deceleration was lower for drives 4 and 5 for same-gender feedback, and drives 2, 4, and 5 for opposite-gender feedback.

Investigating the significant main effect of gender for distraction engagement measures, we found that females spent less time looking at the secondary display compared to males, $t(52) = -2.56$ $p = .01$, and had fewer manual interactions with the display, $t(53) = -2.44$, $p = .02$.

Overall, the findings presented above indicate that both same- and opposite-gender peer norm feedback mitigated teen driver distraction and improved driving performance. Although some effects did not materialize immediately during early exposure to feedback (i.e., in drive 2 or the first feedback drive), after repeated exposure (i.e., in drive 5 or the last feedback drive), both feedback types proved to provide benefits. Contrary to our hypothesis, there were no clear differences between same- and opposite-gender feedback types.

Feedback Acceptance

Figure 4 presents the model estimated means and 95% confidence intervals for the two-scales of the system acceptance questionnaire. In general, feedback was well accepted as indicated by the 95% confidence intervals excluding zero for the estimated mean usefulness and satisfaction scores. The repeated measures ANOVA did not result in any significant gender or feedback type effects.

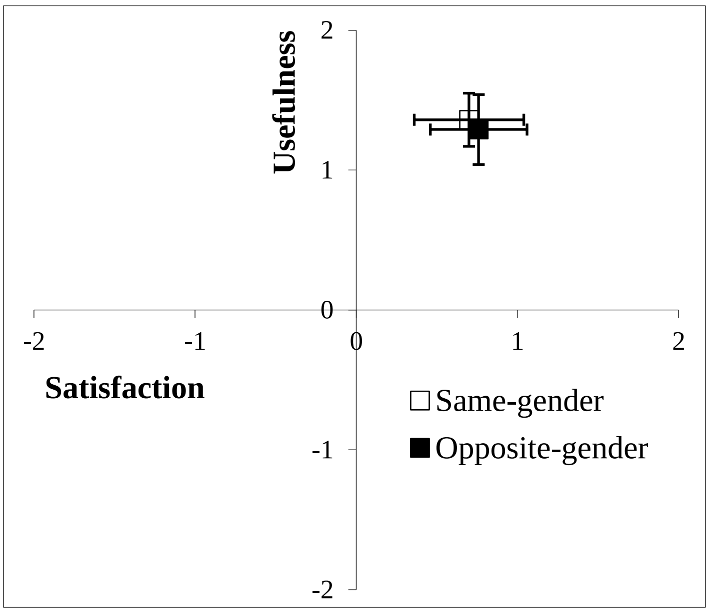

Figure 4. Acceptance of feedback (model estimated means and 95% confidence intervals)

Self-reported Distraction Engagement and Perceived Norms

Table 8 presents the scores for pre-experiment questionnaire responses. Given that these scores were calculated as averages over 12 distractions, they are continuous variables; further, most were found to meet the normality assumption and hence were analyzed with t-tests and Pearson correlations; those that did not meet the normality assumption were analyzed with non-parametric alternatives (i.e., Wilcoxon Signed Rank test for paired observations, Wilcoxon Rank Sum test for independent observations, and Spearman's Rho). Both female and male teen participants reported that both their female peers (female participants: $t(22)=8.56$, $p<.0001$; male participants: $V=4$, $p=.0002$) and male peers (female participants: $t(22)=7.83$, $p<.0001$; male participants: $V=0$, $p<.0001$) engaged in distractions more often compared to themselves. These results suggest either potential overestimation of peers' distraction engagement behavior, or underreporting of teens' own distraction engagement, or both. Moreover, teens' self-reported distraction engagement was in general positively correlated with their perceptions of what their peers did and approved of (Table 9). No significant effects for teen driver gender and peer gender were found for either the perceived descriptive or injunctive norms, and no significant difference was found between female and male teens' self-reported distraction engagement.

Table 8. Descriptive statistics (mean and standard deviation) on pre-experiment questionnaire responses

Teen gender	**Self-reported engagement M (SD)**	**Perceived peer engagement M (SD)**		**Perceived peer approval M (SD)**	
		Female	Male	Female	Male
Female	2.30 (0.68)	3.35 (0.73)	3.26 (0.66)	3.26 (0.57)	3.30 (0.55)
Male	2.51 (0.65)	3.39 (0.56)	3.32 (0.53)	3.12 (0.51)	3.11 (0.5)

Table 9. Correlations between teens' self-reported distraction engagement and their perceived norms (r: Pearson correlation coefficient; ρ: Spearman correlation coefficient)

	Self-reported distraction engagement		
Perceived norms	All participants n=48	Females n=23	Males n=25
Perceived descriptive norms			
Female peer engagement	r =.52***	r =.66***	ρ =.60**
Male peer engagement	r =.54**	r =.61**	ρ =.67**
Perceived injunctive norms			
Female peer approval	ρ =.55***	ρ =.39, p<.1	r =.48*
Male peer approval	ρ =.57***	ρ =.37, p<.1	r =.53**

*p<.05, **p<.01, ***p<.001

Discussion

We investigated whether feedback based on peer social norms can mitigate teen driver distraction, and if tailoring feedback based on teen gender provides additional benefits. Two feedback types were compared to no feedback: post-drive feedback incorporating same-gender peer norms and opposite-gender peer norms. Questionnaires were used to assess whether misperceptions exist among teens regarding their peers' distraction engagement. Teens in our study reported their distraction engagement to be lower than what they perceived their peers to do, and hence they may have been overestimating their peers' engagement in distracting activities or underreporting their own engagement. Regardless of the reasons for this discrepancy, we found that providing these teens with in-vehicle feedback based on peer norms was effective in reducing their distraction engagement and improving their driving performance and that teens considered such normative feedback to be both useful and satisfactory. The average rate of display glances longer than 2 seconds (i.e., long risky off-road glances) decreased from 1.5 and 0.9 per minute in the baseline drive to 0.5 and 0.4 per minute in the last feedback drive, with same- and opposite-gender feedback respectively. These findings extend previous research on social norms feedback aimed to mitigate driver distraction (Merrikhpour & Donmez, 2017; Roberts et al., 2012). In an earlier study, our group found normative feedback based on parental norms to also be effective in mitigating teen driver distraction (Merrikhpour & Donmez, 2017); however, it is currently unclear which social referent (i.e., parent or peer) is more effective in this context. Further research is warranted.

Teens' self-reported engagement in distractions was found to be positively correlated with their perceived descriptive and injunctive norms associated with their peers. Overall, the observed positive correlations are consistent with the results of Carter et al. (2014), but extend their findings through the consideration of peer gender: teens' self-reported distraction engagement was not correlated more with their same-gender peer norms compared to their opposite-gender peer norms. Although previous research on social norms (Festinger, 1954) suggests that tailoring feedback based on gender may provide additional benefits, our study did not find any differences between the two feedback types tested, a result supported by our questionnaire data. It is possible that same-gender peers are not perceived to be a more proximal reference group by teens than their opposite-gender peers. Future research should explore potentially more proximal reference groups, such as close friends. A difference might be expected here given earlier research; Korcuska and Thombs (2003) showed that college students' alcohol use is better explained by the behavior of best friends than typical students. It is important to note that close friends and parents may impact teen driver distraction not only through subjective norms, but by being a source of distraction (De Gruyter, Truong, & Nguyen, 2017; LaVoie, Lee, & Parker, 2016). For example, a national survey in the U.S. found that teen drivers are most likely to talk to their parents on their cell-phone, whereas they are most likely to text their friends (LaVoie et al., 2016). The effectiveness of social normative feedback can be enhanced by targeting teens' close social networks, not just the teens themselves.

There was no significant gender effect on teens' self-reported distraction engagement, although a difference was observed in the simulator with females spending less time looking at the secondary display and having fewer manual interactions. When it comes to teen driver distraction, literature is not conclusive about gender differences. In a survey study, Barr et al. (2015) found that male high school students reported higher levels of engagement in driver distraction compared to females, whereas in a naturalistic driving study, Foss and Goodwin (2014) showed that females were twice as likely as males to be using an electronic device and more than three times as likely to be observed using a hand-held cell phone. Several other studies reported no association between gender and teen driver distraction engagement (Beck & Watters, 2016; Bernstein & Bernstein, 2015; Bingham, Zakrajsek, Almani, Shope, & Sayer, 2015; Carter et al., 2014; Hill et al., 2015). Further research is needed on gender differences to better inform feedback design for teen driver distractions.

The medium used for our study, i.e., the simulator, is a potential limitation for the generalizability of our findings. For example, teens may not have deemed the engagement behavior demonstrated in the simulator by their peers to be representative of real-world behavior. In the future, the effectiveness of social norms feedback needs to be investigated in the real-world and with longer exposure to feedback. Another limitation of our study is that part of our no-feedback condition data was collected in a separate study although identical procedures were used and no significant differences were found between newer and older data. Further, the reliability of self-reported data is a limitation that applies to our questionnaire findings.

Finally, we utilized artificial data for peer norms, which may not have been representative of what the participants considered their peers to do despite the fact that none of the teens indicated any suspicion about this deception. Although both feedback types were found to be effective, the way that feedback was operationalized in our study, in particular this element of deception, is not appropriate for real-world application; credibility of feedback would be important for adoption. To overcome this issue, feedback can be designed to represent good behaviors (e.g., of safer teens) rather than the average behavior of peers, and can mainly target teens who are detected to engage in distractions frequently, for example, through different in-vehicle technologies. These teens can then be provided with feedback revealing where their behaviors fall with respect to the behaviors of safer teen drivers. Overall, although our simulator study shows that teens change their distraction engagement behaviors based on social normative in-vehicle feedback, further research is needed to identify how such feedback should be fine-tuned for real-world implementation.

Key Points

- A driving simulator experiment was conducted to evaluate the efficacy of peer-based social norms feedback in mitigating teen driver distraction. Questionnaires were administered to collect data on teens' distraction engagement and the associated social norms.
- Feedback based on peer norms was effective in reducing distraction engagement and improving driving performance of teen drivers, and was also found to be useful and satisfactory.
- Tailoring feedback to teen gender did not provide additional benefits as no significant difference was observed between same- and opposite-gender peer norm feedback types.
- Questionnaire results revealed that teens perceived themselves to engage in distractions less frequently than their peers.

References

Allcott, H. (2011). Social norms and energy conservation. *Journal of Public Economics*, *95*(9–10), 1082–1095. https://doi.org/10.1016/j.jpubeco.2011.03.003

Allen, J. P., & Brown, B. (2008). Adolescents, peers and motor vehicles: The perfect storm? *American Journal of Preventive Medicine*, *35*(3), 289–293.

Barr, G. C., Kane, K. E., Barraco, R. D., Rayburg, T., Demers, L., Kraus, C. K., … Kane, B. G. (2015). Gender differences in perceptions and self-reported driving behaviors among teenagers. *The Journal of Emergency Medicine*, *48*(3), 366-370.e3. https://doi.org/10.1016/j.jemermed.2014.09.055

Beck, K. H., & Watters, S. (2016). Characteristics of college students who text while driving: Do their perceptions of a significant other influence their decisions? *Transportation Research Part F*, *37*, 119–128. https://doi.org/10.1016/j.trf.2015.12.017

Bernstein, J. J., & Bernstein, J. (2015). Texting at the light and other forms of device distraction behind the wheel. *BMC Public Health*, *15*, 968.

Bingham, C. R., Zakrajsek, J. S., Almani, F., Shope, J. T., & Sayer, T. B. (2015). Do as I say, not as I do: Distracted driving behavior of teens and their parents. *Journal of Safety Research*, *55*, 21–29. https://doi.org/10.1016/j.jsr.2015.07.007

Blos, P. (1962). *On Adolescence: A Psychoanalytic Interpretation.* Oxford, England: Free Press of Glencoe.

Carter, P. M., Bingham, C. R., Zakrajsek, J. S., Shope, J. T., & Sayer, T. B. (2014). Social norms and risk perception: Predictors of distracted driving behavior among novice adolescent drivers. *Journal of Adolescent Health*, *54*(5), S32–S41.

D'Addario, P., & Donmez, B. (2019). The effect of cognitive distraction on perception-response time to unexpected abrupt and gradually onset roadway hazards. *Accident Analysis & Prevention*, *127*, 177–185. https://doi.org/10.1016/j.aap.2019.03.003

De Gruyter, C., Truong, L. T., & Nguyen, H. T. T. (2017). Who's calling? Social networks and mobile phone use among motorcyclists. *Accident Analysis & Prevention*, *103*, 143–147. https://doi.org/10.1016/j.aap.2017.04.010

Donmez, B., Boyle, L. N., & Lee, J. D. (2007). Safety implications of providing real-time feedback to distracted drivers. *Accident Analysis & Prevention, 39*(3), 581–590. https://doi.org/10.1016/j.aap.2006.10.003

Donmez, B., Boyle, L. N., & Lee, J. D. (2008). Designing feedback to mitigate distractions. In M. A. Regan, J. D. Lee, & K. L. Young (Eds.), *Driver Distraction: Theory, Effects, and Mitigation* (pp. 519–532). Boca Raton, FL: CRC Press.

Federal Highway Administration. (2019). *Highway Statistics 2017* (No. DL 220). Washington, DC.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations, 7*, 117–140.

Foss, R. D., & Goodwin, A. H. (2014). Distracted driver behaviors and distracting conditions among adolescent drivers: Findings from a naturalistic driving study. *Journal of Adolescent Health*, *54*, 50–60.

Gifford-Smith, M., Dodge, K. A., Dishion, T. J., & McCord, J. (2005). Peer influence in children and adolescents: Crossing the bridge from developmental to intervention science. *Journal of Abnormal Child Psychology*, *33*(3), 255–265.

Haines, M. P., Barker, G., & Rice, R. (2003). Using the social norms to reduce alcohol and tobacco use in two midwestern high schools. In H. W. Perkins (Ed.), *The Social Norms Approach to Preventing School and College Age Substance Abuse: A Handbook of Educators, Counselors, and Clinicians* (pp. 235–246). San Francisco: Jossey-Bass.

Hill, L., Rybar, J., Styer, T., Fram, E., Merchant, G., & Eastman, A. (2015). Prevalence of and attitudes about distracted driving in college students. *Traffic Injury Prevention, 16*(4), 362–367. https://doi.org/10.1080/15389588.2014.949340

Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., & Ramsey, D. J. (2006). *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-*

Car Naturalistic Driving Study Data (Technical Report No. DOT HS 810 594; p. 226). Washington, DC: National Highway Traffic Safety Administration.

Korcuska, J. S., & Thombs, D. L. (2003). Gender role conflict and sex-specific drinking norms: Relationships to alcohol use in undergraduate women and men. *Journal of College Student Development*, *44*, 204–216.

LaVoie, N., Lee, Y. C., & Parker, J. (2016). Preliminary research developing a theory of cell phone distraction and social relationships. *Accident Analysis & Prevention*, *86*, 155–160. https://doi.org/10.1016/j.aap.2015.10.023

Lee, J. D. (2007). Technology and teen drivers. *Journal of Safety Research*, *38*(2), 203–213. https://doi.org/10.1016/j.jsr.2007.02.008

Lee, J. D. (2009). Can technology get your eyes back on the road? *Science*, *324*, 4.

Lee, J. D., McGehee, D. V., Brown, T. L., & Reyes, M. L. (2002). Collision warning timing, driver distraction, and driver response to imminent rear-end collisions in a high-fidelity driving simulator. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *44*(2), 314–334. https://doi.org/10.1518/0018720024497844

Lee, J. D., Moeckli, J., Brown, T. L., Roberts, S. C., Schwarz, C., Yekhshatyan, L., … Davis, C. (2013). *Distraction Detection and Mitigation Through Driver Feedback* (No. DOT HS 811 547A). Washington, DC: National Highway Traffic Safety Administration.

Lee, J. D., & Strayer, D. L. (2004). Preface to the special section on driver distraction. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *46*(4), 583–586. https://doi.org/10.1518/hfes.46.4.583.56811

Merrikhpour, M., & Donmez, B. (2017). Designing feedback to mitigate teen distracted driving: A social norms approach. *Accident Analysis and Prevention*, *104*, 185–194. https://doi.org/10.1016/j.aap.2017.04.016

National Highway Traffic Safety Administration. (2019). *Teens and Distracted Driving—2017* (No. DOT HS 812 667). Washington, DC.

Nunnally, J. C. (1978). *Psychometric Theory* (2nd ed.). New York, NY, US: McGraw-Hill.

Perkins, H. W., & Berkowitz, A. D. (1986). Perceiving the community norms of alcohol use among students: Some research implications for campus alcohol education programming. *The International Journal of the Addictions*, *21*(9–10), 961–976.

Perkins, H. W., Linkenbach, J. W., Lewis, M. A., & Neighbors, C. (2010). Effectiveness of social norms media marketing in reducing drinking and driving: A statewide campaign. *Addictive Behaviors*, *35*(10), 866–874. https://doi.org/10.1016/j.addbeh.2010.05.004

Roberts, S. C., Ghazizadeh, M., & Lee, J. D. (2012). Warn me now or inform me later: Drivers' acceptance of real-time and post-drive distraction mitigation systems. *International Journal of Human Computer Studies*, *70*(12), 967–979. https://doi.org/10.1016/j.ijhcs.2012.08.002

SAE. (2015). *Operational Definitions of Driving Performance Measures and Statistics* (No. SAE J2944). https://doi.org/10.4271/J2944_201506

Simons-Morton, B. G., Bingham, C. R., Falk, E. B., Li, K., Pradhan, A. K., Ouimet, M. C., … Shope, J. T. (2014). Experimental effects of injunctive norms on simulated risky driving among teenage males. *Health Psychology*, *33*(7), 616–627. https://doi.org/10.1037/a0034837

Simons-Morton, B. G., Ouimet, M. C., Zhang, Z., Klauer, S. G., Lee, S. E., Wang, J., … Dingus, T. A. (2011). The effect of passengers and risk-taking friends on risky driving and crashes/near crashes among novice teenagers. *Journal of Adolescent Health*, *49*, 587–593.

Van Der Laan, J. D., Heino, A., & De Waard, D. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. *Transportation Research Part C: Emerging Technologies*, *5*(1), 1–10. https://doi.org/10.1016/S0968-090X(96)00025-3

Biographies

Birsen Donmez is an Associate Professor at the University of Toronto, Department of Mechanical & Industrial Engineering and is the Canada Research Chair in Human Factors and Transportation. She received her PhD in industrial engineering from the University of Iowa in 2007.

Maryam Merrikhpour received her PhD from the University of Toronto, Department of Mechanical & Industrial Engineering in 2017.

Mehdi Hoseinzadeh Nooshabadi is a PhD student in Industrial Engineering at the University of Toronto, Department of Mechanical & Industrial Engineering.