



## **PROPOSED MODEL OF ADOLESCENT RISKY DRIVING: INTEGRATING SOCIAL STRESSORS AND PHYSIOLOGICAL STRESS AS PREDICTORS OF DRIVER BEHAVIOUR**

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**Abstract:** Peer passengers increase the likelihood of fatal collisions among adolescent drivers. Previous research suggests that social acceptance is especially important to adolescents and that peer presence can induce physiological stress, compromising inhibitory control over risk-taking. Despite the evidence for this peer effect, an understanding of the specific mechanisms of how and when peer passengers can influence a young person's driving behaviour is lacking in the literature. Examining the effects of peer influence under different social conditions in a driving simulator will further our understanding of the relationship between young passengers and driving outcomes. Further, physiological stress has not been explored for its effects on driving in young drivers. This study tested the effects of a social stressor on driving behaviour in a driving simulator, including acceleration, speeding, and lateral displacement. Male and female participants between the ages of 16 and 25 were randomized to control and social stressor conditions (peer rejection or acceptance). Participants' cardiovascular stress physiology was measured while completing tasks either alone or partnered, and during a simulated drive. A significant interaction effect emerged with condition, gender, and physiological stress, as well as a significant main effect for condition on acceleration and lateral displacement. Assessing peer effects under different social circumstances while driving contributes to the growing literature on the connection between peer passengers and driving behaviour in young people.

### **1 Introduction**

Motor vehicle collisions are a significant health concern during adolescence. The leading cause of death among adolescents and young adults in North America is unintentional injury, the majority being the result of motor vehicle collisions (Centers for Disease Control and Prevention, 2015; Statistics Canada, 2017). Peer passengers strongly affect young drivers' behaviour by increasing risky driving behaviours and motor vehicle injuries. However, there is currently limited research exploring the social mechanisms that precede risky driving behaviour when young people are driving with a passenger. By comparing different social circumstances in which risky driving might occur (i.e. feeling socially insecure or secure) and measuring individual differences in variables known to influence risky behavior (physiological stress), this study will test currently unexplored connections between peers and risky driving.

This paper presents preliminary analyses of peer passenger effects on driving outcomes and physiological stress as part of an ongoing study on adolescent risky driving behaviour. Following a literature review of peer effects on adolescent and young adult risk-taking behaviour, the experimental

methodology, procedures, measures, and results are described. A discussion of key findings, implications, and plans for future research follows.

## **2 Literature Review**

### **2.1 Peer Effects on Adolescent and Young Adult Risk Behaviour**

Despite the fact that adolescents do not always engage in more risk-taking behavior than adults or children (Defoe, Dubas, Figner, & Aken, 2015), they are significantly more likely to do so when they are in the presence of peers compared to when they are alone (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Gardner & Steinberg, 2005; O'Brien, Albert, Chein, & Steinberg, 2011). Peer presence can be a source of emotional arousal and reward, which can interfere with decision-making (Cowell, 2013; Zelazo & Carlson, 2012). Peers are believed to trigger affective arousal due to increasing neural sensitization to environmental social stimuli in adolescence, which can encourage risk-taking to achieve social goals, such as social dominance (Forbes & Dahl, 2010). Risk-taking activates neural reward pathways in adolescents, with peer presence enhancing this rewarding effect (Chein et al., 2011). Young men, in particular, engage in more risk-taking behaviour when there is a social gain to be had, such as popularity (Voroboyev, Kwon, Moe, Parkkola, & Hämäläinen, 2015) and when the peers explicitly promote risk-taking (Centifanti, Modecki, MacLellan, & Gowling, 2016).

### **2.2 Peers and Physiological Stress**

Social evaluation is a stress-inducing experience in adolescence. After social stressors, adolescents experienced increased physiological stress, as measured by cortisol (Stroud et al., 2009; van den Bos, de Rooji, Miers, Bokhorst, & Michiel Westenberg, 2014) and skin conductance (Somerville, Jones, Ruberry, Dyke, Glover, & Casey, 2013), when compared to younger children. Neuroimaging research also finds decreased activation of neural structures involved in self-regulation and increased activation in affective structures (Sebastian, Viding, Williams, & Blakemore, 2011; Somerville et al., 2013) as well as stronger feelings of self-consciousness and embarrassment (Somerville et al., 2013) when adolescents believed they were being observed by a peer while completing a task. This suggests that social evaluation is physiologically stressful and emotionally arousing, potentially compromising executive functioning (Zelazo & Carlson, 2012).

Fear of social evaluation may be due to concerns about possible rejection. After experiencing social rejection, adolescents demonstrate an attentional bias for social cues that might help them achieve social acceptance, such as peer norms (Jones et al., 2014; Park & Baumeister, 2015; Peake, Dishion, Stromshak, Moore, & Pfeifer, 2013). A possible mechanism that might facilitate re-acceptance is compliance with norms (i.e. risky behaviour) communicated by the rejecting peer. Neuroimaging findings suggest that adolescents who are especially sensitive to rejection (as measured by self-reported rejection sensitivity) may be most susceptible to peer influence (Falk et al., 2014).

### **2.3 Peer Passengers and Driving Behaviour**

Risky driving, or driving behaviours that increase the likelihood of motor vehicle accidents, are more common when young drivers have peer passengers. Driving with peers increases the likelihood of an accident due to distracted driving, excessive speed, and driver error (Ouimet, Pradhan, Brooks-Russell, Ehsani, Berbiche, & Simons-Morton, 2015; Curry, Mirman, Kallan, Winston, & Durbin, 2012; Simons-Morton et al., 2011; Simons-Morton, Lerner, & Singer, 2005). A peer passenger is also associated with reduced visual scanning of the road, diverting the driver's attention from changing road conditions and signage (Pradhan, Li, Bingham, Simons-Morton, Ouimet, & Shope, 2014).

A driver's gender also influences the effect of peer passengers. While adolescent males and females both engage in riskier driving with same-sex passengers compared to driving alone, adolescent males do this more often than do females (Simons-Morton et al., 2005). Moreover, collisions with adolescent female drivers are more likely to be preceded by an interior distractor (e.g. looking around at passengers) while

collisions with male adolescent drivers are more likely to be preceded by exterior distractors, such as other traffic, even with passengers (Curry et al., 2012). Male adolescents tend to experience single-vehicle and head-on collisions more often, while female adolescents experience collisions on the left and right sides of the car (Bingham & Ehsani, 2012). These findings suggest that gender is a key predictor of different driving-related behaviors that increase injury risk and collisions.

### 3 Justification for Current Study and Research Questions.

While previous findings suggest that emotional or physiological arousal and social evaluation are possible mechanisms through which peers may influence behavior, no studies have experimentally manipulated these variables in the context of driving. Directly addressing this identified gap, this study integrates possible mechanisms of peer influence (i.e., social acceptance or rejection and physiological stress) into a proposed model and tests their effects on driving behaviours. The primary research questions include: (1) whether accepting or rejecting social conditions have different effects on risky driving outcomes, and (2) whether driving in a peer’s presence produces a physiological stress. Gender is considered an exploratory variable in both questions.

### 4 Methods and Data Collection

#### 4.1 Driving Scenario

The driving scenario was made using the STISIM driving simulation software with a rural two-lane highway design. The drive was 5 km and driven from south to north during good weather and visibility. Objects and road signs were placed at appropriate locations throughout the drive. The drive began at Point A (0 m) with traffic lights placed at Intersections B (600 m), C (1,100 m), and D (2,100 m), where a yellow light appeared for 4 s prior to a red light for 20 s. Between Point A and Intersection D, driving segments were straight drives with speed limits of 90 km per hour. Segment D-E (2,100 – 3,950 m) had one vertical curve length of 300 m at 70 km per hour. Intersection E occurred 3,950 into the drive and was a green light, requiring the participant to make a left-hand turn into oncoming traffic. The oncoming vehicles had gaps ranging from 0.5 - 2.5 s between them when the participant could choose to turn left or wait until opposing traffic had passed. Finally, segment E-F (3,950 – 5,000 m) had two horizontal curve radii of 300 m each at 70 km per hour. The first horizontal curve to the left began at 4,000 m and the second horizontal curve to the right began at 4,350 m. The scenario ended at Point 5 (5,000 m). The volume of opposing traffic represented approximately 350-400 vehicles per hour on the road. Passing was not permitted and no impeding vehicles were used during the simulation, because we were primarily interested in the influence of interior stimuli (i.e. passengers) on driver behaviour.

The primary outcome variables (driving behaviours) were measured via speeding, acceleration, and lateral displacement. Speed and acceleration were selected because they are frequently implicated as variables that precede collisions with young drivers (e.g. Curry et al., 2012; Ouimet et al., 2015). Lateral displacement was selected because no prior experimental research has measured the extent to which young drivers deviate from the midline of the road. Prior evidence suggests that peer passengers reduce visual scanning, which may distract drivers from attending to their vehicle’s spatial location on the road (Pradhan et al., 2014). The drive was segmented into straight driving and curved sections between intersections (segments B-C, C-D, D-E, and E-F) and intersections (segments C, D, and E) for analyses. Segments A – B and Intersection B of the drive were used as trial drives so participants could adjust to the handling of the car and are excluded from analyses. See Tables 1, 2, and 3 for the means and standard deviations of speed, acceleration, and lateral displacement across experimental conditions, and Section 4.3 for a description of the experimental conditions (independent variables).

Table 1: Mean speed, acceleration, and lateral displacement in 90 km/hour drive segments

	Controls (N = 20) M(SD)	Acceptance (N = 15) M(SD)	Rejection (N = 19) M(SD)
Segment B-C			
Speed	19.41 (3.83)	15.84 (4.43)	17.44 (3.75)

Accel	.10 (0.52)	.55 (0.35)	.36 (0.42)
LD	2.28 (0.36)	2.26 (0.30)	2.25 (0.26)
Segment C-D			
Speed	22.03 (3.65)	21.30 (2.57)	20.68 (3.01)
Accel	0.03 (0.25)	-0.08 (0.14)	0.01 (0.16)
LD	2.27 (0.35)	2.35 (0.34)	2.25 (0.28)

Table 2: Mean speed, acceleration, and lateral displacement in 70 km/hour drive segments

	Controls (N = 20) M(SD)	Acceptance (N = 15) M(SD)	Rejection (N = 19) M(SD)
Segment D-E			
Speed	18.68 (2.48)	19.46 (2.45)	18.67 (1.60)
Accel	0.04 (0.14)	-0.02 (0.07)	-0.01 (0.05)
LD	2.25 (0.35)	2.31 (0.29)	2.23 (0.24)
Segment E-F			
Speed	17.81 (2.14)	17.65 (2.33)	17.66 (1.15)
Accel	0.22 (0.15)	0.19 (0.07)	0.16 (0.06)
LD	2.22 (0.24)	2.28 (0.22)	2.30 (0.16)

Table 3: Mean speed, acceleration, and lateral displacement in intersections

	Controls (N = 20) M(SD)	Acceptance (N = 15) M(SD)	Rejection (N = 19) M(SD)
Intersection C			
Speed	6.53 (6.57)	5.74 (4.54)	6.00 (5.94)
Accel	-0.31 (1.79)	-0.26 (0.71)	-0.43 (0.83)
LD	2.20 (0.30)	2.09 (0.30)	2.04 (0.35)
Intersection D			
Speed	4.36 (2.53)	3.22 (0.25)	3.10 (0.36)
Accel	-0.45 (1.74)	0.16 (0.18)	0.11 (0.16)
LD	1.83 (0.92)	2.11 (0.29)	2.13 (0.25)
Intersection E			
Speed	3.76 (1.63)	4.57 (3.41)	3.25 (0.29)
Accel	-0.23 (0.69)	0.03 (0.14)	0.05 (0.19)
LD	0.30 (1.16)	0.04 (0.98)	-0.43 (0.48)

## 4.2 Participants

A total of 54 participants were recruited from the community and an undergraduate psychology participant pool. Participants were eligible if they were between the ages of 16 and 25 (the minimum age to drive in Ontario and the maximum age to be considered an adolescent, respectively), reported no history of medical, psychiatric, or cognitive conditions that prevent them from driving or interacting with a passenger, and no history of motion sickness or nausea in three-dimension/virtual reality scenarios. The mean age was 19.4 [SD = 2.19]. The sample was 57.4% female and 33.3% Caucasian, 27.8% Asian, 14.8% Southeast Asian, and 24.1% other. A total of 36 participants (66.7%) reported a provisional full or full license status, an average of 2.35 (2.22) years of driving experience, and 7 (13.0%) reported a minor accident or traffic ticket in their driving history. See Table 4 for a breakdown of the sample's demographics and driving history across conditions.

### 4.3 Independent Variables

Using a 3x2 mixed factorial design, all participants were randomized into Control ( $N = 20$ ), Social Rejection (hereafter referred to as *Rej*;  $N = 19$ ) and Social Acceptance (hereafter referred to as *Acc*;  $N = 15$ ) conditions. Controls completed the entire study protocol alone, while *Rej* and *Acc* participants completed the entire study protocol with a peer passenger. The peer passenger role was played by a confederate (a research assistant pretending to be a real participant) and matched to the participant's gender. Conditions were not significantly different from each other on gender, age, years of driving experience, and ethnicity. *Acc* and *Rej* conditions did not differ on their ratings of the confederate's social status or driving behaviour, but as expected, rejected participants felt significantly less accepted by their confederate. See Table 4 for a breakdown of participants' reporting of their perception of the confederate's social status, feelings of social acceptance by the confederate, and perception of the confederate's driving.

Table 4: Sample demographics, driving history, and confederate-related variables

	Controls ( $N = 20$ ) M(SD)	Acceptance ( $N = 15$ ) M(SD)	Rejection ( $N = 19$ ) M(SD)
Age	19.61 [SD = 2.43]	19.73 [SD = 2.19]	18.95 [SD = 1.99]
% Female	55.5%	53.3%	63.2%
% Caucasian	30.0%	40.0%	31.6%
Years of Driving Experience	2.45 (2.62)	2.71 (2.49)	1.97 (1.49)
Peer Status <sup>1</sup>	N/A	13.07 (3.73)	13.10 (2.13)
Social Acceptance <sup>2</sup>	N/A	12.73 (3.03)	8.58 (3.22)
Peer Driving <sup>3</sup>	N/A	7.33 (4.22)	7.21 (2.07)

<sup>1</sup>Participants rated confederates on their physical attractiveness, leadership, dominance, approachability, and desire to spend time with them on a scale of 1-5 after completing Task 1.

<sup>2</sup>Participants rated how well they worked together on tasks, desire to work together again, and how socially accepted they felt by the confederate on a scale of 1-5 after completing Task 2. Accepted and rejected participants significantly differed on their rating of how accepted they felt by the confederate ( $t[32] = 3.830, p = .001$ ).

<sup>3</sup>Participants rated their perception of the confederate's willingness to engage in a range of risky driving behaviours (e.g. not use a seatbelt, drive while impaired, listen to loud music) on a scale of 1-5 after observing the confederate drive and completing their own drive.

### 4.4 Quasi-Experimental Variable: Physiological Stress

Physiological stress was measured via BIOPAC MP-150 (BIOPAC Systems, Inc., Goleta, CA) wearable biopotential recording systems. Heart rate and respiration were measured continuously via sensors on the torso and recorded via AcqKnowledge software (BIOPAC Systems Inc., Goleta, CA). Due to the high rate of non-responsive respiration data, only findings for mean heartbeats per minute are reported below. A lower heart rate has previously been shown to be associated with risk-taking and aggressive/antisocial behaviour broadly (Portnoy & Farrington, 2015). However, heart rate is also positively correlated with adolescents' and young adults' perceived stress during social stressor tasks (Evans, Greaves-Lord, Euser, Tuelen, Franken, & Huizink, 2012), which may in turn affect participants' physiological responsivity. These measures of physiological stress were selected due to the mobile nature of their data collection possibilities, since participants moved around a room during the study, and because other measures (i.e. finger sensors, blood pressure cuffs) can impede drivers' ability to manoeuvre a steering wheel.

Each phase of the experiment (baseline, group tasks, stressor, confederate driving, participant driving) was segmented, allowing for temporal comparisons across the study. The driving phase of the experiment was further segmented by section of the drive (e.g. Segment B-C, Intersection D). See Table

5 for means and standard deviations of heart rate across experimental segments and driving segments between conditions.

Table 5: Mean heart rate in beats per minute (BPM) across experimental and driving segments

	Controls (N = 20) M(SD)	Acceptance (N = 15) M(SD)	Rejection (N = 19) M(SD)
Experimental			
Baseline	91.47 (17.10)	92.93 (15.10)	88.94 (11.10)
Task 1	87.97 (14.77)	92.77 (12.87)	88.85 (10.59)
Stressor	N/A	94.35 (13.86)	87.96 (9.88)
Task 2	N/A	93.55 (12.99)	90.47 (12.79)
Confederate Drive	N/A	100.18 (12.30)	93.77 (13.85)
Participant Drive	84.31 (15.11)	95.47 (11.52)	89.34 (14.11)
Return to Baseline	89.53 (15.04)	103.10 (11.56)	99.51 (17.98)
Driving			
B-C	93.36 (29.16)	92.95 (15.55)	89.22 (10.64)
C	92.75 (28.98)	92.46 (13.74)	89.56 (13.56)
C-D	93.70 (28.12)	93.79 (16.09)	91.70 (13.55)
D	91.26 (29.60)	92.69 (14.80)	88.63 (12.07)
D-E	86.56 (16.25)	92.85 (13.15)	88.08 (9.85)
E	90.50 (13.01)	93.63 (12.47)	88.64 (9.88)
E-F	92.30 (16.70)	92.47 (13.11)	88.91 (11.71)

#### 4.5 Experimental Procedure

Control participants were told that the study is about driver stress and decision-making with or without a passenger. After obtaining consent, the BIOPAC sensors were placed on the participant's torso and they completed a brief driving history questionnaire, including driver's license status, years of driving experience, and any history of collisions while baseline physiological data was collected. They then spent five minutes on a road sign identification task (Task 1) before completing the driving course and then debriefed.

For social condition participants, the confederate was waiting in the lobby of the laboratory building when the participant arrived. Both were told the study is about driver stress and decision-making with or without a passenger and that the confederate has been randomized to be the passenger and the participant to be the driver, but that the confederate would also get to try out the simulator briefly. After obtaining consent, the BIOPAC sensors were placed on the participant and both the participant and confederate completed the driving history questionnaire while baseline physiological measurements were taken. Next, the participant and confederate completed Task 1 together. The confederate agreed more often (Acc condition) or appeared more skeptical (Rej condition) about most of the participant's suggestions. After Task 1, they completed the peer status questionnaire before being told that their next task was to complete a road rules test (Task 2) but that they could work together on it. As the stressor, the confederate then smiled and nodded (Acc condition) or interjected with, "*Uh, actually, could I do this one on my own?*" (Rej condition). After Task 2, the participant and confederate completed the social manipulation check and the confederate completed their simulated drive. The confederate followed a script and drove in a risk-averse (i.e., driving below the speed limit, commenting "*There are a lot of other cars, I should slow down*") or in a risk-accepting (i.e., speeding, commenting "*I better get through this light quickly*") manner. When their trial was finished, the participant took the driver's seat to complete the driving course 2-3 times, depending on the time availability of the simulator. The participant and confederate then completed the peer driving manipulation check and were debriefed.

## 5 Results

### 5.1 Does a peer passenger influence driving outcomes?

Using repeated measures multivariate ANOVA (MANOVA), the effect of a passenger (Rej and Acc conditions) compared to controls was tested on acceleration, speed, and lateral displacement. Driving segments (B-C, C-D, D-E, and E-F) and intersections (C, D, and E) were considered in separate models as within-subjects dependent variables. Condition (control, Rej, and Acc) and gender (male or female) were used as the between-subjects factors. Age and years of driving experience were entered as covariates in both models.

For acceleration in driving segments, Box's *M* test was significant ( $p < 0.001$ ), so Pillai's trace is reported. A Greenhouse-Geiser correction is used since Mauchly's assumption of sphericity was violated. The condition x acceleration interaction [Pillai's trace = 0.404,  $F(2.528, 54.358) = 9.173$ ,  $p < 0.001$ ] was significant, with acceptance and rejection conditions differing from controls. Similarly, a condition x acceleration interaction in intersections approached significance ( $p = .09$ ). For lateral displacement in driving segments, no significant main effects or interactions were found, but a significant condition x lateral displacement interaction was found between acceptance and rejection conditions and controls [Pillai's trace = 0.204,  $F(2.374, 52.223) = 2.504$ ,  $p = .048$ ] on intersections. No significant main or interaction effects were found for speed on driving segments or intersections.

### 5.2 Does a peer passenger influence physiological stress?

Again using MANOVA, the effect of a passenger (Rej and Acc conditions) compared to controls was tested on physiological stress during driving segments and intersections in separate models. Mean beats per minute were considered in separate models as within-subjects dependent variables. Condition (control, Rej, and Acc) and gender (male or female) were used as the between-subjects factors. Age and years of driving experience were entered as covariates in both models.

For physiological stress during driving segments and intersections, Box's *M* test was not significant and the assumption of sphericity was not violated, thus all findings are reported using Wilks' lambda and the assumption of sphericity. For driving segments, a significant condition x gender x heart rate interaction was found [Wilks' lambda = 0.733,  $F(6, 132) = 3.424$ ,  $p = .004$ ], such that female participants' heart rates remained significantly higher across all conditions compared to males, and was higher in the Acc condition (see Figure 1). For intersections, no significant main effects or interactions were found.

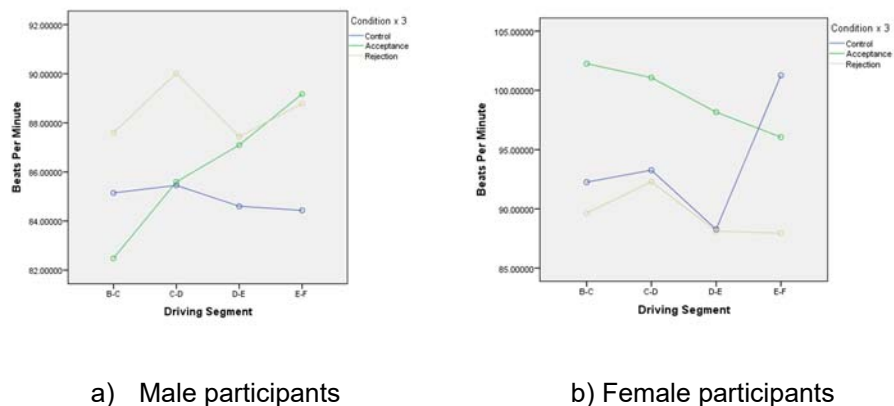


Figure 1: Average beats per minute across conditions and driving segments for male and female participants

## 6 Discussion

This study is a preliminary analysis of the effects of a peer passenger on physiological stress and driving outcomes in young drivers. Our analyses revealed that acceleration and lateral displacement appear sensitive to effects of a peer passenger, and that physiological stress is influenced by interactions between social conditions and gender.

In both social conditions, participants accelerated and reached their top speed across driving segments more slowly than did controls. Though acceleration and speed are considered key risky driving behaviours influenced by peer passengers (Curry et al., 2012; Ouimet et al., 2015), it is also the case that peer passengers can distract drivers from noticing changing road conditions (e.g. the change of a red light to green, speed limit signage) as has been previously found (Pradhan et al., 2014). In this case, participants who drove with a peer passenger may have been slower to accelerate to their top speed due to their passenger serving as a distraction from road conditions.

Further, participants with a peer passenger also had significantly different lateral displacement from the midline of the road in intersections, and this effect appears to be particularly strong for Intersection E which required participants to make a left-hand turn into oncoming traffic. At Intersection E, participants who drove with a passenger were more likely to be closer to the midline (Acc condition) or over it (Rej condition) compared to controls while making a left turn. The ability of a driver to maintain their position in their lane while preparing to turn can influence the likelihood of a head-on collision with oncoming traffic. Thus, a peer passenger may again be serving a distraction, preventing the driver from maintaining a safe position to complete a left-hand turn.

The significant interaction among physiological stress, gender, and experimental condition also reveals that gender and physiological stress may affect driver behaviour. Males consistently had lower heart rates across all experimental and driving segments, regardless of condition, while female participants had significantly higher heart rates during the social stressor and driving segments of the study. Further, female participants also had significantly higher heart rates during both driving segments and intersections. Notably, this trend was unique to female participants in the Acc condition, suggesting that social acceptance increases heart rate, while social rejection does not. This is in contrast to what might be expected, given previous research that suggests social rejection is a significant stressor in adolescence and young adulthood (Jones et al., 2014; Peake et al., 2013).

However, given the gendered nature of this response to social acceptance, it may not be surprising. Previous research suggests that young men are more sensitive to social rewards in competitive environments, while young women tend to seek social rewards via group cohesion (Voroboyev et al., 2015). Thus, elevated heart rates after experiencing social acceptance among the female participants may have been in response to the rewarding nature of getting along with a peer. Under these socially rewarding conditions, it is possible that getting along well with the peer passenger serves as an additional element of distraction once inside the car, consistent with Curry et al.'s (2012) findings that young female drivers are more likely to be distracted by interior stimuli (i.e. passengers). Rejection, however, may remove the socially rewarding nature of interacting with a peer, reducing the peer passenger's power to distract.

## 7 Conclusions

Our preliminary findings indicate that physiological stress and peer passengers, both uniquely and in combination, affect driving behaviour (acceleration and lateral displacement). Though we did not find effects of stress or peer passengers on speeding as a specific outcome, peer passengers particularly affected acceleration and lateral displacement. It is possible that a peer passenger serves a distraction from changing road conditions, subsequently decreasing the driver's ability to modify their behaviour in accordance with road conditions. Gender and social acceptance, in particular, appear to be key variables influencing physiological stress while driving. At the moment, the current sample size is statistically



underpowered to complete more complex modeling of physiological stress, driving outcomes, experimental conditions, and gender. However, our ongoing data collection will allow us to replicate these initial findings and utilize multi-level and structural equation models to predict driving outcomes and driving-related injury risk (i.e. collisions).

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## References

- Bingham, C. R., & Ehsani, J. P. (2012). The relative odds of involvement in seven crash configurations by driver age and sex. *Journal of Adolescent Health, 51*(5), 484. doi:10.1016/j.jadohealth.2012.02.012
- BIOPAC Systems, Inc. [Computer hardware/software]. Goleta, CA.
- Centers for Disease Control and Prevention. (2015). *Teen drivers: get the facts*. Retrieved from [https://www.cdc.gov/motorvehiclesafety/teen\\_drivers/teendriv\\_ers\\_factsheet.html](https://www.cdc.gov/motorvehiclesafety/teen_drivers/teendriv_ers_factsheet.html)
- Centifanti, L. C. M., Modecki, K. L., MacLellan, S., & Gowling, H. (2016). Driving under the influence of risky peers: An experimental study of adolescent risk taking. *Journal of Research on Adolescence, 26*(1), 207-222. doi:10.1111/jora.12187
- Chen, J., Albert, D., O'Brien, L., Uckert, K., & Steinberg, L. (2011). Peers increase adolescent risk taking by enhancing activity in the brain's reward circuitry. *Developmental Science, 14*(2), F1-F10. doi:10.1111/j.1467-7687.2010.01035.x
- Cowell, R. A. (2013). *Do peers alter decision making processes in adolescence? An examination of peer influence on cool and hot executive function* (Unpublished doctoral dissertation). University of Minnesota.
- Curry, A. E., Mirman, J. H., Kallan, M. J., Winston, F. K., & Durbin, D. R. (2012). Peer passengers: How do they affect teen crashes? *The Journal of Adolescent Health, 50*(6), 588-594. doi:10.1016/j.jadohealth.2011.10.016
- Defoe, I. N., Dubas, J. S., Figner, B. C., & Aken, M. A. G. v. (2015). A meta-analysis on age differences in risky decision making: Adolescents versus children and adults. *Psychological Bulletin, 141*(1), 48-84. doi:10.1037/a0038088
- Evans, B. E., Greaves-Lord, K., Euser, A. S., Tulen, J. H. M., Franken, I. H. A., & Huizink, A. C. (2012). Alcohol and tobacco use and heart rate reactivity to a psychosocial stressor in an adolescent population. *Drug and Alcohol Dependence, 126*(3), 296-303. doi:10.1016/j.drugalcdep.2012.05.031
- Falk, E. B., Cascio, C. N., Brook O'Donnell, M., Carp, J., Tinney, F. J., Bingham, C. R., . . . Simons-Morton, B. G. (2014). Neural responses to exclusion predict susceptibility to social influence. *Journal of Adolescent Health, 54*(5), S22-S31. doi:10.1016/j.jadohealth.2013.12.035
- Forbes, E. E., & Dahl, R. E. (2010). Pubertal development and behavior: Hormonal activation of social and motivational tendencies. *Brain and Cognition, 72*(1), 66-72. doi:10.1016/j.bandc.2009.10.007
- Gardner, M., & Steinberg, L. (2005). Peer influence on risk taking, risk preference, and risk decision making in adolescence and adulthood: an experimental study. *Developmental Psychology, 41*(4), 625-635. doi:10.1037/a0026993
- Jones, R. M., Somerville, L. H., Li, J., Ruberry, E. J., Powers, A., Mehta, N., . . . Casey, B. J. (2014). Adolescent-specific patterns of behavior and neural activity during social reinforcement learning. *Cognitive, Affective, & Behavioral Neuroscience, 14*(2), 683-697. doi:10.3758/s13415-014-0257-z
- Ouimet, M. C., Pradhan, A. K., Brooks-Russell, A., Ehsani, J. P., Berbiche, D., & Simons-Morton, B. G. (2015). Young drivers and their passengers: A systematic review of epidemiological studies on crash risk. *Journal of Adolescent Health, 57*(1), S24-S35. doi:10.1016/j.jadohealth.2015.03.010
- Ouimet, M. C., Pradhan, A. K., Simons-Morton, B. G., Divekar, G., Mehranian, H., & Fisher, D. L. (2013). The effect of male teenage passengers on male teenage drivers: Findings from a driving simulator study. *Accident; Analysis and Prevention, 58*, 132-139. doi:10.1016/j.aap.2013.04.024

- O'Brien, L., Albert, D., Chein, J., & Steinberg, L. (2011). Adolescents prefer more immediate rewards when in the presence of their peers: peers and immediate rewards. *Journal of Research on Adolescence*, *21*(4), 747-753. doi:10.1111/j.1532-7795.2011.00738.x
- Park, J., & Baumeister, R. F. (2015). Social exclusion causes a shift toward prevention motivation. *Journal of Experimental Social Psychology*, *56*, 153-159. doi:10.1016/j.jesp.2014.09.011
- Peake, S. J., Dishion, T. J., Stormshak, E. A., Moore, W. E., & Pfeifer, J. H. (2013). Risk-taking and social exclusion in adolescence: Neural mechanisms underlying peer influences on decision-making. *Neuroimage*, *82*, 23-34. doi:10.1016/j.neuroimage.2013.05.061
- Portnoy, J., & Farrington, D. P. (2015). Resting heart rate and antisocial behavior: An updated systematic review and meta-analysis. *Aggression and Violent Behavior*, *22*, 33-45. doi:10.1016/j.avb.2015.02.004
- Pradhan, A. K., Li, K., Bingham, C. R., Simons-Morton, B. G., Ouimet, M. C., & Shope, J. T. (2014). Peer passenger influences on male adolescent drivers' visual scanning behavior during simulated driving. *Journal of Adolescent Health*, *54*(5), S42-S49. doi:10.1016/j.jadohealth.2014.01.004
- Sebastian, C., Viding, E., Williams, K. D., & Blakemore, S. (2011). Social brain development and the affective consequences of ostracism in adolescence. *Brain and Cognition*, *72*(1), 134-145. doi:10.1016/j.bandc.2009.06.008
- Simons-Morton, B.G, Lerner, N., & Singer, J. (2005). The observed effects of teenage passengers on the risky driving behavior of teenage drivers. *Accident Analysis and Prevention*, *37*(6), 973-82. doi: 10.1016/j.aap.2005.04.014
- Simons-Morton, B. G., Ouimet, M. C., Zhang, Z., Klauer, S. E., 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*(6), 587-593. doi:10.1016/j.jadohealth.2011.02.009
- 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. doi:10.1037/a003483
- Somerville, L. H., Jones, R. M., Ruberry, E. J., Dyke, J. P., Glover, G., & Casey, B. J. (2013). The medial prefrontal cortex and the emergence of self-conscious emotion in adolescence. *Psychological Science*, *24*(8), 1554-1562. doi:10.1177/0956797613475633
- Statistics Canada. (2017). *Leading causes of death, total population, by age group and sex, Canada, annual*. (CANSIM database table 102-0561). Retrieved from Statistics Canada website <http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=1020561>
- Stroud, L. R., Foster, E., Papandonatos, G. D., Handwerker, K., Granger, D. A., Kivlighan, K. T., & Niaura, R. (2009). Stress response and the adolescent transition: performance versus peer rejection stressors. *Development and Psychopathology*, *21*(1), 47-68. doi:10.1017/S0954579409000042
- van den Bos, E., Rooij, M., Miers, A. C., Bokhorst, C. L., & Westenberg, P. M. (2014). Adolescents' increasing stress response to social evaluation: Pubertal effects on cortisol and Alpha-Amylase during public speaking. *Child Development*, *85*(1), 220-236. doi:10.1111/cdev.12118
- Vorobyev, V., Kwon, M. S., Moe, D., Parkkola, R., & Hämäläinen, H. (2015). Risk-taking behavior in a computerized driving task: Brain activation correlates of decision-making, outcome, and peer influence in male adolescents. *PLoS One*, *10*(6), 1-20. doi:10.1371/journal.pone.0129516
- Zelazo, P. D., & Carlson, S. M. (2012). Hot and cool executive function in childhood and adolescence: Development and plasticity. *Child Development Perspectives*, *6*(4), 354-360. doi:10.1111/j.1750-8606.2012.00246.x