



Original article

Peer Passenger Influences on Male Adolescent Drivers' Visual Scanning Behavior During Simulated Driving

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A B S T R A C T

Purpose: There is a higher likelihood of crashes and fatalities when an adolescent drives with peer passengers, especially for male drivers and male passengers. Simulated driving of male adolescent drivers with male peer passengers was studied to examine passenger influences on distraction and inattention.

Methods: Male adolescents drove in a high-fidelity driving simulator with a male confederate who posed either as a risk-accepting passenger or as a risk-averse passenger. Drivers' eye movements were recorded. The visual scanning behavior of the drivers was compared when driving alone with when driving with a passenger and when driving with a risk-accepting passenger with a risk-averse passenger.

Results: The visual scanning of a driver significantly narrowed horizontally and vertically when driving with a peer passenger. There were no significant differences in the times the drivers' eyes were off the forward roadway when driving with a passenger versus when driving alone. Some significant correlations were found between personality characteristics and the outcome measures.

Conclusions: The presence of a male peer passenger was associated with a reduction in the visual scanning range of male adolescent drivers. This reduction could be a result of potential cognitive load imposed on the driver due to the presence of a passenger and the real or perceived normative influences or expectations from the passenger.

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IMPLICATIONS AND CONTRIBUTION

The presence of male peer passengers was associated with deficient visual scanning in male adolescent drivers. Such reduced scanning behavior is evident in drivers with high cognitive load. Further investigation of passenger influences on adolescent drivers should include examination of distraction and inattention aspects of passenger influence.

Motor vehicle crashes (MVCs) are the leading cause of death and a major cause of injury among adolescents in the United States [1], with teenaged drivers having inordinately higher crash rates than other drivers [2]. These high crash rates have been attributed to a variety of factors including inexperience,

immaturity, risk taking, and distraction [3,4]. Studies also identify the presence of peer passengers as an important risk factor for adolescent drivers' MVC, especially for male drivers with male peer passengers [5,6]; however, it is unclear what the mechanisms for these associations could be. Peer passengers could influence adolescent drivers by introducing visual distractions or by causing inattention to the driver due to other sources of influence such as social norms. The normative influence on adolescents from peers is well studied with peer pressure and influence on adolescents being stronger from risk-taking friends [7–10]. Thus the magnitude or direction of the passenger's influence could depend on the risk-taking propensity of the passenger or the driver's perception thereof.

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A few experimental studies have looked at the effects of peers on risky driving behaviors including a pilot study [11] that shows mixed results for risky driving with peer passengers. However, there is evidence that overt peer pressure results in risky behaviors as measured by other driving-related outcomes [12]. A separate article based on this current study [13] examining the effects of peer influence in the form of injunctive norms on risk-taking behaviors has found that adolescents are more likely to engage in risky behaviors in the presence of a passenger and in the presence of a risk-accepting passenger versus a risk-averse one.

However, there is limited research on passengers' influences on drivers' visual scanning. Drivers have different visual search patterns depending on factors such as age, experience, and cognitive load. Young and inexperienced drivers have different general scanning strategies and also look at different areas when driving. Young novice drivers scan less widely, look closer to the vehicle's front and right, look less often at mirrors, and tend to look at traffic-related objects for longer times than older and more experienced drivers [14]. As novices, young drivers have an underdeveloped scanning pattern while driving [14] and a tendency toward longer off-road glances [15]. In addition, less cognitively loaded drivers have wider search patterns compared with more cognitively loaded drivers [16–19]. Wide visual scanning is an important component of safe driving [20], and narrow scanning patterns increase probabilities of missing signs, lessen abilities to anticipate risky driving situations, and increase likelihood of failing to detect hazards. Other aspects of teen driving, including driving with passengers, may further adversely affect adolescents' scanning behavior, especially if the driver's visual attention is shifted away from the forward roadway and toward vehicle occupants. In this study, we are interested in understanding the influence of peer passengers on adolescent drivers by studying the visual behavior of the drivers under various passenger presence and passenger type conditions. The following research hypotheses were formulated for the driver's visual behavior: (1) the presence of a peer passenger increases the duration of looks away from the forward roadway and (2) the presence of a peer passenger narrows the driver's visual scanning range.

Method

Participants

Sixty-six participants were recruited from the Ann Arbor, MI, United States, area. Eligible participants were 16- to 19-year-old male high school students ($M = 16.97$; $SD = .57$) who had held a Level 2 Michigan driver license (allows independent driving with restrictions) for 4–9 months, drove at least twice a week on average, and had normal vision or corrected-to-normal vision. Participant assent and parental consent were required. Participants received compensation of \$50.00 for a study visit lasting 150–180 minutes. The University of Michigan Behavioral Sciences/Health Sciences Institutional Review Board approved the study protocol.

Fifty-eight participants were included in the final analyses, seven being excluded due to simulator sickness or technical issues, and one participant being excluded due to parental report of a previous autism spectrum diagnosis that was not reported during screening. Sample demographics are listed in Table 1.

Apparatus

Driving simulator. A fixed-base, high-fidelity Drive Safety driving simulator consisting of the front three quarters of the body and

Table 1
Sample demographic characteristics (N = 58)

| | Total N | Study condition | | | |
|-----------------|------------|--------------------------------------|-------|---|------|
| | | Risk-averse passenger (n = 31) | | Risk-accepting passenger (n = 27) | |
| | | n | % | n | % |
| Race | | | | | |
| Black | 4 | 4 | 100.0 | 0 | .0 |
| White | 46 | 21 | 44.7 | 25 | 54.4 |
| Asian | 3 | 2 | 66.7 | 1 | 33.3 |
| Other | 2 | 2 | 100.0 | 0 | .0 |
| Hispanic/Latino | | | | | |
| Yes | 4 | 3 | 75.0 | 1 | 25.0 |
| No | 53 | 27 | 50.0 | 26 | 49.1 |
| Age (years) | | | | | |
| 16 | 37 | 21 | 60.0 | 16 | 40.0 |
| 17 | 15 | 7 | 46.7 | 8 | 53.3 |
| 18 | 4 | 3 | 75.0 | 1 | 25.0 |

The numbers may not add to the total due to missing values. Chi-square tests revealed no significant differences, but the results should be used with caution because many cell sizes are <5.

the front interior of a sedan was used. Three screens were located in front of the car and one screen behind the car onto which were projected the simulated road scenes at 60 Hz and at 1024×768 pixels resolution and provided 120° of forward field of view and 40° of rear field-of-view visible through the side and rearview mirrors (Figure 1A).

Simulated drives. The protocol required participants to drive three simulated worlds. The first was a 5- to 10-minute practice drive to acclimatize the participants to the simulator. The second and the third worlds were experimental drives about 15–20 minutes each. These worlds represented an urban setting including a series of signalized intersections with ambient traffic and relevant cultural elements (e.g., buildings, trees, signs and pedestrians). The intersections were placed along a straight path to preclude left or right turns during the drive, and the drives were programed to minimize any chance of crashes or other events that could interrupt a drive.

Eye tracker. A remotely mounted eye tracking system (Smart Eye AB) was integrated into the driving simulator (Figure 1B). Three infrared cameras mounted inside the vehicle monitored the driver's face. The eye tracking software calculated and recorded the driver's gaze location at a frequency of 60 Hz.

Study design

Participants were randomly assigned to one of the two passenger type conditions: risk accepting and risk averse. There were also two within-subject conditions: passenger drive, in which a confederate passenger was in the car with the participant, and solo drive, in which the participant was in the car alone. Participants were randomly assigned and counterbalanced to two drive orders: passenger drive first followed by solo drive and solo drive first followed by passenger drive.

Procedure

One young-looking male confederate (appearing 16–18 years old) was trained to portray the passenger in both conditions, that



Figure 1. (A) Driving simulator and (B) eye tracker.

is, risk accepting and risk averse, and to interact identically with each participant based on the appropriate condition.

Participants completed an online preappointment survey 7–10 days before the study appointment and a predrive and a postdrive survey the day of the appointment. The surveys measured individual characteristics and measures to test the effectiveness of the experimental manipulation. The pre-appointment survey included measures that could influence either the drive or the driver if administered immediately before or after the drives and hence were administered in advance.

Following the predrive survey, the participants were exposed to a predrive experimental manipulation. This procedure

manipulated the participant's perception of the confederate as being another study participant who was either risk accepting or risk averse and had three components. First, the confederate arrived late to the appointment and explained his tardiness saying "Sorry I was a little late getting here. Normally I drive way faster but I hit like every red light" or "Sorry I was late getting here. I tend to drive slowly, plus I hit every yellow light." for the risk-accepting and the risk-averse conditions, respectively. Second, together the participant and confederate watched two videos showing footage of highway driving (without audio) taken from the viewpoint of a passenger—one video portraying a riskier driver (e.g., higher speed, close following, abrupt lane

changes) than the other. The video presentation order was counterbalanced. After each video, the participant responded verbally, on a scale of 1–10, to “How similar is your driving to the driver in the video?” and “How likely would you be to ride with the person in the video?” The confederate replied second after each question and responded in a manner that was congruent with the study condition (i.e., risk accepting or risk averse). Third, the participant was informed that he had been randomly chosen to be the driver for the experiment. The confederate was told that he would, however, be allowed to drive the simulator for a few minutes. The confederate then drove the simulator briefly in a manner consistent with the study condition (i.e., aggressively and unbelted in the risk-accepting condition and conservatively and belted in the risk-averse condition) while the participant sat in the passenger seat.

Following these procedures, the participants completed the experimental drives. They were instructed to drive as they normally would, to follow traffic laws and posted speed limits, and to refrain from conversation. The confederate maintained his character during the experimental drives through body language but without interacting or conversing with the participant.

In addition to the confederate ruse, as experimental cover the participants were told that the study was being conducted to measure physiological characteristics such as heart rate during driving. These steps were implemented to minimize the risk of the participants being suspicious of the confederate. Following the experimental drives, the participants completed a postdrive survey and debriefing. The debriefing showed that participants did not suspect that the passenger was a confederate. The participant perceptions of the passenger risk were as manipulated. Further details and analyses of risk perception and driver risky behavior can be seen in a separate article [13].

Measures

Eye glance measures. Three dependent variables were calculated to estimate visual scanning range and time eyes-off-road (TEOR): (1) horizontal gaze: SD of horizontal gaze (radians); (2) vertical gaze: SD of vertical gaze (radians); and (3) TEOR: total duration (seconds) of driver’s gaze away from the forward roadway.

Individual characteristics measured preappointment. *Susceptibility to peer pressure* [21] was measured by 11 items asking how the participant would respond to peer pressure. An example item was “If a friend offered you a drink at a party, would you ‘want’ to take it?” Possible responses were 1 = no, 2 = probably not, 3 = probably, and 4 = yes. Mean of the 11 items was calculated after two items were reversely coded.

Resistance to peer influence [22] was measured by 10 paired items (laid out in left and right columns), for example, left-column item in pair 1 “Some people think it’s more important to be an individual than to fit in with the crowd” and right-column item in pair 1 “But, other people think it’s more important to fit in with the crowd than to be an individual.” Participants were asked to choose the statement that best described them and then asked to rate how true that statement was of them (left-column options in order: “really true of me,” then “sort of true of me”; right-column options in order: “sort of true of me,” then “really true of me”). Each item was scored from 1 to 4 (reading left to right on the instrument), three were reversely coded, and valid items (≥ 7) were averaged.

Friends’ risk behavior [23] was measured by four items that asked about the substance use behavior of the participant’s friends. An example item was “How many of your closest friends use marijuana?” The response options were 1 = none, 2 = a few, 3 = some, 4 = most, and 5 = all. Mean of the four items was calculated.

Social expectations of driving scale—this 16-item scale was adapted from *Akers Social Learning Theory* [24] and asked participants to rate their agreement (1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neither agree nor disagree, 5 = somewhat agree, 6 = agree, and 7 = strongly agree) with statements such as “I don’t care if I get caught by the police for doing something I think is fun.” Five items were reversely coded, and mean of the 16 items was calculated.

High scores of the scales above indicate greater susceptibility to peer pressure, greater resistance to peer pressure, higher friends’ risky behaviors, and greater social expectations of driving.

Individual characteristics measured predrive. *Tolerance of deviance* was measured by items asking participants how wrong (1 = very wrong to 4 = not wrong) it was to engage in eight behaviors (e.g., smoking even though your parents don’t want you to) [25,26]. Five items were reversely coded, and mean of the 13 items was calculated. High score indicates greater tolerance of deviance.

Individual characteristics measured postdrive. *Sensation seeking*—an adaptation of the *brief sensation seeking scale* [27,28] was administered. The brief sensation seeking scale has eight items and a five-point response scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree and 5 = strongly agree). Example items included “I would like to explore strange places.” Mean of the eight items was calculated. High score indicates greater sensation seeking.

Analyses

t Tests were conducted to test for possible carryover effects of passenger presence. Group comparisons were conducted using repeated measures analysis of variance with one between-group independent variable with two levels (risk-averse vs. risk-accepting passenger conditions) and one within-group independent variable with two levels (solo drive vs. passenger drive). Correlation analyses between outcome measures and survey variables were also conducted. All analyses were performed in SAS (version 9.2; SAS Institute Inc., Cary, NC).

Results

Carryover effects

Analyses of possible carryover effects of passenger presence on subsequent solo drives did not reveal significant differences in any of the eye glance measures, suggesting that in those drive orders with the passenger-present condition first, there was no carryover effect of passenger presence from the first drive to the solo drive (Table 2).

Passenger presence and passenger type effects

Table 3 lists the results of repeated measures analysis of variance testing effects of passenger type and presence. There

Table 2
Results of *t* test for carryover effects

| | Risk-averse passenger group | | | | | | Risk-accepting passenger group | | | | | | | | | |
|-----------------|-----------------------------|-------|-------|---------------------|-------|----|--------------------------------|----------|---------------------|-------|-------|---------------------|-------|-------|------|----------|
| | Solo then passenger | | | Passenger then solo | | | T | <i>p</i> | Solo then passenger | | | Passenger then solo | | | T | <i>p</i> |
| | N | M | SD | N | M | SD | | | N | M | SD | N | M | SD | | |
| Vertical gaze | 15 | .07 | .02 | 15 | .07 | 15 | .23 | .82 | 13 | .06 | .01 | 14 | .07 | .02 | -.67 | .52 |
| Horizontal gaze | 15 | .16 | .03 | 15 | .15 | 15 | 1.34 | .19 | 13 | .15 | .02 | 14 | .15 | .03 | .50 | .62 |
| TEOR (s) | 15 | 36.47 | 20.95 | 15 | 39.32 | 15 | -.39 | .70 | 13 | 50.54 | 22.77 | 14 | 41.76 | 14.85 | 1.21 | .24 |

TEOR = time eyes-off-road.

was a significant main effect for passenger presence for vertical gaze ($F(1,52) = 8.09, p < .01$) and horizontal gaze ($F(1,52) = 23.37, p < .001$). There was no effect of passenger presence on TEOR. There were no significant main effects of passenger type on any of the eye glance measures or passenger type by passenger presence interactions.

Individual correlates

Pearson's correlation coefficients between individual characteristics and eye glance measures were examined to identify individual correlates associated with visual scanning driving. Correlation analyses were conducted for participants (overall) and for each passenger type (Table 4).

Overall, greater deviance acceptance was associated with higher horizontal gaze ($r = .34, < .05$). In addition, greater resistance to peer pressure was associated with lower TEOR ($r = -.32, p < .05$), whereas greater friends' risky behavior was associated with higher TEOR ($r = .26, p < .05$).

In the risk-averse group, greater deviance acceptance was associated with higher horizontal gaze ($r = .38, p < .05$), and greater friends' risky behavior was associated with higher TEOR ($r = .37, p < .05$). In the risk-accepting group, greater social

expectations of driving was associated with higher TEOR ($r = .44, p < .05$), and greater sensation seeking was associated with higher TEOR ($r = .41, p < .05$). No significant correlations were found for vertical gaze and individual characteristics overall or by passenger type.

Discussion

Distraction is a growing factor in MVC and of special concern to the young driver population. Much of the research focus on distraction has been on in-vehicle technological distractions [29]. A few studies have looked particularly at the effects of secondary tasks on adolescent distraction [30,31]. This study examines peer passengers as potential sources of distraction in adolescent drivers to understand peer influences on distraction-related driving behaviors.

The outcome measures for this study, vertical/horizontal gaze variability and TEOR, represent separate approaches to measuring inattention or distraction. The former is a measure of the scanning range or attentional window while driving. This is a critical measure of situational awareness, since the driving task requires frequent scanning [20] in front of the vehicle and in lateral areas on either side of the forward roadway, such as traffic signs, oncoming traffic, and pedestrians to detect and predict safety-relevant cues including latent risks and developing hazards [20]. TEOR is a more direct measure of distraction

Table 3
Analysis of variance for vertical gaze, horizontal gaze, and TEOR

| Source | df | F | η^2 | <i>p</i> |
|-----------------|----|----------|----------|----------|
| Vertical gaze | | | | |
| Between groups | | | | |
| PC | 1 | .37 | .01 | .55 |
| Error (between) | 52 | (.0004) | | |
| Within groups | | | | |
| PP | 1 | 8.09 | .13 | .006 |
| PC × PP | 1 | .45 | .01 | .51 |
| Error (within) | 52 | (.0001) | | |
| Horizontal gaze | | | | |
| Between groups | | | | |
| PC | 1 | .60 | .01 | .44 |
| Error (between) | 52 | (.07) | | |
| Within groups | | | | |
| PP | 1 | 23.37 | .31 | <.001 |
| PC × PP | 1 | .34 | .01 | .56 |
| Error (within) | 52 | (.0004) | | |
| TEOR | | | | |
| Between groups | | | | |
| PC | 1 | 3.09 | .06 | .08 |
| Error (between) | 52 | (790.11) | | |
| Within groups | | | | |
| PP | 1 | .87 | .03 | .36 |
| PC × PP | 1 | 1.84 | .02 | .18 |
| Error (within) | 52 | (208.29) | | |

Values enclosed in parentheses represent mean square errors.
PC = passenger condition; PP = passenger presence; TEOR = time eyes-off-road.

Table 4
Correlations between outcome variables and survey variables

| | Vertical gaze | Horizontal gaze | TEOR |
|----------------------------------|---------------|-----------------|-------|
| Overall | | | |
| Resistance to peer pressure | .02 | -.01 | -.32* |
| Friends risky behavior-substance | .10 | .10 | .26* |
| Deviance acceptance | .15 | .34* | .17 |
| Social expectations of driving | .15 | .03 | .19 |
| Sensation seeking | .08 | -.03 | .17 |
| Risk averse | | | |
| Resistance to peer pressure | -.10 | -.02 | -.27 |
| Friends risky behavior substance | -.02 | .01 | .37* |
| Deviance acceptance | .13 | .38* | .19 |
| Social expectations of driving | .23 | -.14 | .00 |
| Sensation seeking | .06 | -.23 | .09 |
| Risk accepting | | | |
| Resistance to peer pressure | .16 | .00 | -.33 |
| Friends risky behavior substance | .25 | .18 | .30 |
| Deviance acceptance | .18 | .28 | .17 |
| Social expectations of driving | .02 | .34 | .44* |
| Sensation seeking | .08 | .33 | .41* |

Higher scores of survey variables represent greater resistance, risky behavior, deviance, social expectations, and sensation seeking.

TEOR = time eyes-off-road.

* $p < .05$.

particularly related to tasks that reallocate visual as well as cognitive and manual resources away from the driving task. It is an important measure of visual attention allocated to the roadway and to the driving task, with longer TEOR resulting in poor driving performance [32] and greater crash risk [33,34].

Of the two postulated hypotheses, the study confirmed the second one: the adolescent driver's visual scan narrowed in the presence of a peer passenger. Specifically, a reduction in variance of the driver's horizontal gaze and vertical gaze was observed in the presence of a peer passenger, indicating a narrowing of the driver's focus, a situation similar to tunnel vision associated with cognitive load [16–19,35–38]. However, there was no difference in the time spent looking away from the forward roadway when with a passenger (Figure 2), disconfirming the first hypothesis. These two results offer an insight into peer influence on teen drivers. Of note is the fact that the driver and the passenger did not interact or speak with each other during the drives. This can potentially explain the lack of differences in TEOR between the passenger and solo drives, suggesting that the passenger's presence had limited impact on the driver's glances away from the forward roadway perhaps due to lack of interaction. However, the observed narrowing of drivers' attentional focus in the presence of a passenger suggests some other modes of passenger influence. Since measures of visual distraction as measured by TEOR were unchanged in both passenger presence conditions, one explanation could be that the passenger imposed some demand on the attentional capacity of the driver. Despite the lack of a physiological or subjective assessment of cognitive load or arousal in this study, the findings from this analysis, that is, the tunneling of vision, lend credence to the cognitive load explanation, suggesting that the presence of a passenger in the vehicle cab potentially added to the cognitive load of the driver. Indeed the narrowing of attentional focus is consistent with that seen in other experimental and natural driving and aviation studies [16–19,35–38], where additional cognitive load was imposed on the driver via nonvisual or nonmanual secondary tasks. This focus narrowing is also observed in drivers who are involved in cell phone conversations [39].

The correlational analyses show that some personality characteristics were significantly associated with horizontal gaze and

TEOR although the associations were not consistent between the driving conditions. An association of note was the negative correlation between TEOR and the resistance to peer pressure for the overall analysis. The participants with a higher resistance to peer pressure had lower TEOR during the drives. The other associations are mixed, and the limited sample size in this study precludes a closer interpretation of the associations between the personality characteristics and visual scanning behavior, warranting a more detailed future look at the mediating effects of personality characteristics on visual behavior while driving in the presence of passengers. Previous studies have found that risk-taking personality characteristics are linked to risky driving. For instance, higher sensation seeking [40], excitement seeking [41], deviance acceptance [42,43], and desirability [44] were associated with risky driving behaviors such as speeding, aggressive driving, or at-fault vehicle crashes. In combination with these, the present study confirms that adolescent risky driving is a complex phenomenon with driving-related behaviors being influenced by multiple factors including passenger presence, driving condition, and individual personality characteristics.

A separate analysis of risky driving behaviors from this study [13] showed that there was an effect of the type of passenger on risky driving, concluding that perceived social norms imposed by the passenger played a role in influencing the risky driving behavior of male teenagers. However, the analyses showed no significant main effects of the passenger type condition on visual scanning. This suggests that, at least with a silent passenger who did not impart overt peer pressure, the level of risk-taking propensity of the passenger or perceived social norms or expectations of a passenger did not have any differential effect on the driver's visual behavior. However, regardless of his risk-taking personality, the peer passenger still influenced the male driver's attentional focus.

Limitations

The generalizability of these results is restricted by the sample being only male adolescents with a silent passenger, not quite the case for adolescent drivers in the real world. An important related limitation is the use of a confederate as the peer

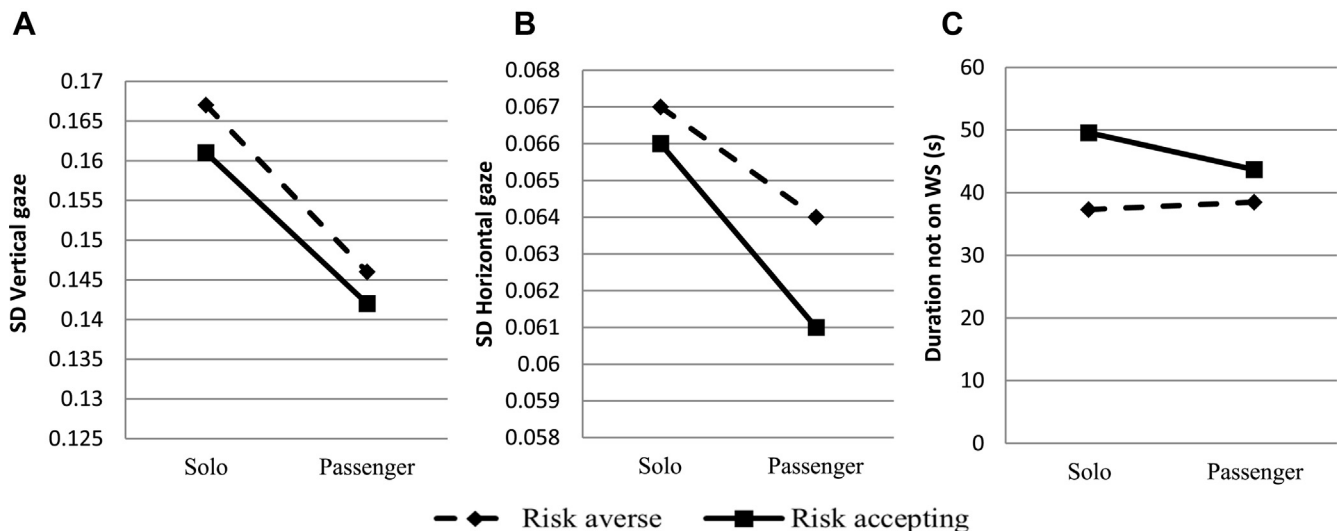


Figure 2. (A) SD of horizontal gaze, (B) SD of vertical gaze, and (C) TEOR (s).

passenger versus using a friend. Although the experimental manipulation was designed to create a perception of risk taking (or lack of) in the passenger and although the debrief and post-experimental surveys validated the manipulation, it is a weak substitute for a real friend, one with known risks and personalities and concomitant influences on the driver. The overall measures of horizontal gaze and TEOR offer insights into the driver's general attention; however, outcome measures were not recorded for specific locations or behaviors such as those related to hazard anticipation or during secondary task engagement. The limitation imposed by the relatively small sample size prevented much interpretation of associations of personality characteristics with visual scanning behaviors, and future studies should be designed and conducted to clarify the interactive impact of those factors on teen risky driving.

Male adolescents drove alone and in the presence of a male peer passenger. They were not pressured by the passenger, did not speak with the passenger during the drive, were not subjected to any overt distractions, and were not asked to perform any tasks secondary to driving. Nevertheless, the drivers reduced their horizontal and vertical scanning eye in the presence of a peer passenger. Decreased scanning implies reduced attentional focus and has been observed in conditions where the driver was cognitively loaded with verbal or spatial tasks or when the driver was involved in a cell phone conversation. This passenger effect was similar regardless of passengers' risk acceptance or aversion. The results provide evidence that a potential mechanism for the influence of adolescent passengers on adolescent drivers could be increased cognitive load on the driver. Additional research is needed to explore the effects of peer influence in cases of overt peer pressure and in cases of distracting secondary task engagement more in line with common distracting behaviors.

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