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Quasi-Experimental Trial Examining the Effectiveness of Driver Training Modules on Simulated Driving Performance in Young Drivers

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Abstract

Young and novice drivers have the highest representation of driver injuries and fatalities. While driver education provides in-class and in-car exposure to the driving environment, the use of driving simulators can further expose challenging driving environments that are not typically provided as part of current driver education programs. The aim of this study was to examine and compare the delivery of a driver training program on simulated driving performance and confidence in young drivers. Sixty participants (aged 15–20; 66% male) completed cognitive and visual assessments, a driving comfort scale, and a pre-test simulated drive. Subsequently, participants were assigned to: (1) an intervention with feedback group (n = 20), (2) an intervention without feedback group (n = 20), or (3) control group (n = 20). Intervention group participants completed fifteen training scenarios, and all participants completed a post-test simulated drive and driving confidence scale. Outcome measures assessed on the simulator were driving errors (e.g., speed, vehicle position, braking distance) and the number of collisions. Across all groups, simulated crashes significantly decreased and driving confidence significantly increased post-test. Training with feedback produced the most consistent improvements, including improved speed regulation and safer following distances. All participants reported greater confidence in challenging conditions such as heavy rain, snow, icy roads, and night driving. Findings indicate that high-fidelity simulation, particularly when paired with structured feedback, can improve novice drivers' skills and confidence, supporting simulation as a valuable complement to traditional driver education.

Keywords: young drivers; driving simulation; intervention; feedback; crash risk

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1. Introduction

In many developed and developing countries, motor vehicle crashes (MVCs) represent the leading cause of injury and death, especially among novice and young drivers [1]. For example, in Canada, novice and young drivers aged 15–24 represent 11.9% of the driving population, yet they account for 11.1–14.6% of fatal and 6.3–8.6% of injurious crashes [2], consistent with rates in other countries [3]. However, some Canadian provinces such as Saskatchewan (SK) have much higher crash rates than the national average. Novice and young drivers account for 6.5% of the driving population in SK, but are involved in 10% of all fatal and 14.7% of all injurious crashes [4–6]. Smaller urban environments with surrounding rural areas, as seen in provinces such as SK, provide different contextual factors related to crashes.

While prior studies show that crashes in novice and young drivers occur from a variety of factors including distracted driving [7–9], driving under the influence [9–11], poor weather (e.g., snow; rain) and visibility (e.g., fog; nighttime) [9,12,13], speeding [9,13–15], and driving on rural roads [12,16], our prior work that examined driving habits in novice drivers living in small cities with surrounding rural areas found that crashes also occurred due to driver inexperience, tailgating, poor road conditions (e.g., potholes) and evading wildlife [9]. These findings were corroborated by police officers and driving instructors who reported the most challenging situations for novice and young drivers were related to speed control, lane positioning, blind-spot monitoring, hazard identification, pedestrian and wildlife avoidance, and driving in poor weather conditions [9].

These challenging driving situations that novice and young drivers face can be potentially addressed using driving simulators [17]. Prior studies consistently show that driver training can significantly reduce speed regulation, adjustment to stimuli, and lane maintenance errors compared to those who do not undergo training [18–22]. However, most of these driver training programs have used personal computers and computer-based training with interactive pictures and videos, requiring participants to identify the hazards on the computer screen [18–20]. There is a paucity whether driver training using a driving simulator as the intervention (as opposed to the outcome measure) can similarly produce improvements in driving performance in novice and young drivers. Simulator training can serve as an adjunct to conventional driver education by providing exposure to high-risk driving scenarios without the risk associated with being in a real-world environment. Driving simulators allow learners to experience hazardous, infrequent, or weather-dependent scenarios in a safe, controlled, and repeatable environment, conditions that cannot be reliably provided through conventional training alone [9,18,23,24]. A recent systematic review found that driver training on a simulator, compared to video-based or classroom training, resulted in fewer speed regulation, adjustment to stimuli, and lane maintenance errors, as well as overall driving performance when immediately evaluated on a driving simulator [23–25]. Moreover, data shows that driver training on a simulator can increase the driving confidence of novice and young drivers to navigate difficult driving situations [26,27]. For example, novice and young drivers reported feeling more confident in their abilities when performing evasive maneuvers, such as emergency lane changes when avoiding objects on the road [5,26,27].

Beyond standard driver training delivered on a computer, some studies have incorporated structured feedback as part of the training process [18,28–31]. For example, providing written feedback on the screen alongside simulator training enhanced learners' speed management [18,28–30], gap acceptance [30], and hazard detection skills [18,29], compared with learners who received no written feedback. Similarly, the inclusion of auditory feedback given by the researcher or computer during training improved learners' speed management [32], lane positioning [31], and reduced real-world crash rates [31], compared to those who received no feedback. Notably, across these studies, both written and auditory feedback were delivered using standardized scripts by the researcher or computer, such that participants received identical feedback contingent on whether they made the predefined errors [18,28–31]. However, it remains unclear whether simulator-based (as opposed to computer-based) training modules, coupled with individualized feedback, yield additional benefits.

Given the high crash rate of novice and young drivers in SK, we developed and pilot-tested driver training modules to reflect the local conditions that novice and young drivers are typically exposed to. The modules created were developed with input from young drivers themselves to supplement existing training in SK that consists of high school driver training (education and some exposure to computer-based examples) [9,33]. The

objectives of this study are to: (1) examine and compare differences in driving performance and confidence between novice and young drivers who received driver training on the simulator; and (2) examine and compare differences in driving performance and confidence between, and before and after, by intervention type (i.e., simulator training with verbal feedback; simulator training; and controls).

2. Methods

2.1. Study Protocol

This study was approved by the Behavioral Research Ethics Board at the University of Saskatchewan [REB #2511], and involved novice drivers attending two to four in-person sessions that lasted 60 to 90 min each. Data collection took place from January to March 2023 at the Driving Research and Simulation Laboratory at the University of Saskatchewan. Prior to attending the first in-person session, drivers were screened over the phone or via email to verify they were eligible to participate. Drivers were eligible to participate if they: (1) were 15–20 years old, (2) possessed a valid Class 7 learner's permit, (3) were currently enrolled in the Saskatchewan Government Insurance (SGI) Class 5 driver training program, (4) had completed at least 2 in-vehicle lessons with a Saskatchewan Government Insurance (SGI) instructor, (5) lived in Saskatchewan, (6) were proficient in English, and (7) were a low risk for simulator adaptation syndrome (SAS). In total, 60 young and novice drivers participated in and completed all aspects of the study.

Participants were provided transportation to/from the University via taxi (paid for by the research team) or, if the participant preferred, their parent/guardian transported them to/from the University. Once eligible participants arrived for their session, informed consent was obtained from either themselves (if the participant was 18 years or older) or their parent/guardian (if the participant was less than 18 years old). Groups of 20 participants were recruited at a time and participants were placed in one of the following intervention groups: (1) intervention with feedback (n = 20), (2) intervention without feedback (n = 20), and (3) control (n = 20). All participants, regardless of their intervention group, underwent the same protocol for the first session, completing a demographic questionnaire, a battery of cognitive and visual assessments, a driving confidence scale, two acclimation drives (approximately 20 min), followed by the pre-test driving scenario (approximately 25 min).

For both intervention groups (regardless of feedback type), their second and third sessions involved fifteen training scenarios on the simulator, which took approximately 2.5 h. For the intervention group that received feedback, the researcher was free to offer advice and went through the results screen at the end of each drive with the participant to show empirical evidence for how the participants drove. For the intervention group that did not receive feedback, the researcher said nothing about how the participant drove and did not explain the results screens at the end of each scenario, even if the participant asked for feedback.

For the control group participants, their second (and final) session involved watching an 8-min video about defensive driving tips, completing a post-test simulated drive which was similar, but not identical to the pre-test driving scenario, followed by a driving confidence scale. Similarly, for the intervention group participants (regardless of feedback type), their fourth (and final) session involved watching the same 8-min video about defensive driving tips, completing the post-test simulated drive, followed by the driving confidence scale. While participants in the control group completed their first and last sessions a maximum of 7 days apart, participants in the intervention groups (regardless of feedback type) completed their first and last sessions a maximum of 14 days apart. Throughout the study, the simulator room was kept at 20 °C to minimize the risk of SAS [34], and

refreshments were available. At the end of the study, participants received a 50-dollar cash honorarium (taxi fees were also covered, if applicable) in appreciation for their time.

2.2. Participant Recruitment

Participants were conveniently recruited to take part in the study through advertisements posted in eleven high schools throughout Saskatoon, Saskatchewan, on social media (e.g., Facebook; Reddit), through the University of Saskatchewan's announcement page, and through announcements made by SGI driving instructors during Class 5 High School Driver Training programs in Saskatoon. Interested participants contacted the research team via email or office phone to undergo screening and enrollment. Participants from the same high school were placed into the same intervention group to avoid the possibility of them discussing the study and discovering there were different intervention groups.

2.3. Instruments

2.3.1. Questionnaire

The questionnaire gathered information on participant demographics such as age, gender, completed education, and their city/town of residence. Additionally, the questionnaire collected driving history, including the number of years the participant has been driving, whether they have been in a crash, and if they have, whether they were found at fault, how many days per week they drive, as well as whether they have received a ticket, and if they have, what it was for.

2.3.2. Cognitive Tests

The Montreal Cognitive Assessment (MoCA) consists of eleven subtests that assess attention, executive function, memory, language, visuospatial skills, and concentration [35,36]. The MoCA is scored out of 30, with higher scores indicating better cognitive functioning [36,37], and a cut-point of 26 was used to differentiate between normal (26 or more) and impaired (less than 26) cognitive function [37]. If a participant had a low education level (a grade 12 education or less), an additional point was added to their total MoCA score. In total, 39 participants had an additional point added to their MoCA score.

The Trail Making Test A (TMTA) measures visual processing and attention, whereas the Trail Making Test B (TMTB) assesses divided attention and executive skills [38,39]. Both the TMTA and TMTB are completed using paper and pen; TMTA requires the participant to connect numbers in sequential order (e.g., 1 to 2, 2 to 3, etc.) as fast as they can without lifting their pen off the paper, whereas the TMTB requires participants to connect both numbers and letters in sequential order (e.g., 1-A-2-B-3-C) as fast as they can [38,39]. A cut-point of 90 s and 180 s was used for the TMTA and TMTB, respectively, to distinguish between normal and impaired cognitive function [37,38,40].

The Beery Buktenica Developmental Test of Visual-Motor Integration (Beery-VMI) (sixth edition; Full Form test) measures basic gross motor, fine motor, visual, and visual-fine motor skills and produces a standard score that assesses the extent to which individuals can integrate their visual and motor abilities [41]. The Beery VMI requires participants to copy 30 geometric shapes, which are arranged in a developmental sequence, using pencil and paper [41]. The test continues until the participant fails to correctly copy three consecutive items [41]. Upon completion of the test, or three consecutive failures, one point is awarded for each correctly copied item and the raw score is calculated, up to a total raw score of 30 points [41]. Raw scores are then converted to standard scores, which are adjusted for age [40]. Standard score categories and their associated performance descriptions (specific to the sample age group) are as follows: 90–109 (Average); 80–89 (Below Average); 70–79 (Low); <70 (Very Low) [41].

The Symbol Digit Modalities Test (SDMT) is a substitution task that assesses processing speed and sustained attention [42]. The SDMT is administered using paper and pencil and requires participants to use a reference key (contains 9 numbers, each paired to a unique geometric figure) to pair as many numbers with their associated geometric figure as fast as they can in 90 s [42]. The SDMT is scored based on how many correct substitutions are made in 90 s, with higher scores indicating better cognitive functioning [41].

The Useful Field of View (UFOV) measures visual search/processing speed, divided, and selective attention consecutively through three distinct subtests which increase in difficulty [43–45]. The UFOV test is administered and scored using a computer [44]. The first subtest, UFOV-1, requires the participant to detect a target located centrally on the screen that is momentarily shown and determine whether it was a car or truck [44]. During the second subtest, UFOV-2, the participant must identify the centrally located target while also locating a separate target within the periphery [43]. The final subtest, UFOV-3, is a reiteration of UFOV-2; however, the peripherally located target is surrounded by various distractions [44]. UFOV-1 evaluates visual search and processing speed and has four score groupings: (1) 0–30 milliseconds (ms); (2) 31–60 ms; (3) 61–349 ms; and (4) 350–500 ms. A score of 0–30 ms represents normal central vision and processing speed; every score after the first grouping indicates slower search and visual processing speed [44]. UFOV-2 evaluates divided attention and has three score groupings: (1) 0–99 ms; (2) 100–349 ms; and (3) 350–500 ms. A score of 0–99 ms constitutes normal divided attention ability, with every score after indicating difficulties with divided attention [44]. UFOV-3 assesses selective attention and is scored in 3 groupings: (1) 0–349 ms; (2) 350–499 ms; and (3) 500 ms. A score that falls within 0–349 ms represents normal selective attention ability, with every score after indicating difficulties with selective attention [43]. When all three subtests are completed, a UFOV Risk Index (RI) is calculated by the program. This RI assesses the likelihood that a person is unsafe to drive, and is classified into five categories: (1) very low; (2) low; (3) low to moderate; (4) moderate to high; and (5) high [44].

2.3.3. Visual Assessments

Static far point binocular visual acuity (VA) was assessed using the Early Treatment Diabetic Retinopathy Study (ETDRS) Scale [46]. To assess binocular VA, the participant was instructed to stand 10 feet away (indicated by tape on the floor) from the ETDRS chart, which was hung on the wall at eye level and viewed in normal lighting conditions. Participants were instructed to start at the beginning and read the chart out loud moving downwards. Participants continued to read the chart until they could no longer identify at least three letters on a line. Participants were scored by how many letters they correctly identified. Scores ranged from 0.3 to −0.2 LogMAR units, which were converted to feet (e.g., 20/20 vision). No participants had a binocular VA poorer than 20/40.

Binocular contrast sensitivity (CS) was assessed using the Pelli-Robson chart, which was placed on the wall at eye level and viewed under normal lighting conditions, with the participant standing 1 m away (indicated by tape on the ground). The participant was instructed to read the letters out loud beginning at the top of the chart, moving from left to right and down until they could no longer determine the individual letters. CS was scored as log sensitivity using the triplet letter method, where each letter triplet correctly identified, except for the first triplet, received a score of 0.15 log units, for a total of 2.25 log units [47]. A minimum of 2 out of 3 letters must be correctly identified in order to receive a score for the triplet.

The Optec vision screener was used to assess participants' vision in the following areas: near point binocular VA, far point color perception, far and near point lateral phoria, far point vertical phoria, far point depth perception, far point fusion, and sign

recognition. Near point binocular VA was scored in seconds of arc and then converted into feet (e.g., 20/20 vision). Far point color perception was assessed for color deficiency in participants and was scored as pass (i.e., not color deficient) or fail (i.e., color deficient). Far and near point lateral phoria scores are categorized as esophoria (i.e., tendency for one or both eyes to drift inward towards the nose), orthophoria (i.e., ideal ocular alignment), or exophoria (i.e., tendency for one or both eyes to drift outward). Far point vertical phoria scores are categorized as left hyperphoria (i.e., tendency for the left eye to drift upward), orthophoria (i.e., ideal ocular alignment), and right hyperphoria (i.e., tendency for the right eye to drift upward). Far point depth perception is scored as normal (i.e., participants' VA is 20 s of arc), acceptable (i.e., participants' VA is between 50–25 s of arc), or poor (i.e., participants' VA is worse than 50 s of arc). Far point fusion score is categorized as pass (i.e., both eyes are able to fuse and work together to maintain a single clear image) or fail (i.e., both eyes do not fuse or work together to maintain a single clear image). Lastly, sign recognition was scored out of a total of 12, with each correctly identified sign receiving one point.

2.3.4. Driving Confidence Scale

The 8-item Driving Confidence Scale requires participants to rate their driving ability in a variety of driving situations (e.g., heavy rain; heavy snow; icy roads; at night; merging). The scale is pen-and-paper based, where participants rate their level of confidence (on a 5-point scale ranging from 0 to 100%) from not at all confident (0%) to completely confident (100%), with higher scores indicating greater driving ability. Participant score for the Driving Confidence Scale was computed by summing the responses and then dividing by the number of items answered. In the present study, all participants completed all items on the scale (i.e., 100% completion rate).

2.3.5. Simulated Driving Performance

The Virage car simulator (see Figure 1) was used to assess participant driving performance and evaluated several key driving metrics such as speed, vehicle position, braking distance, and the number of collisions. All driving errors were assessed and captured by the simulator and were displayed to the research team after the pre- and post-test.



Figure 1. Virage car simulator.

Acclimation Drive

Participants first completed two acclimation drives of approximately 20 min in total to allow them to practice the basic controls of the driving simulator. The first acclimation drive involved learning how to brake and change lanes on a straight roadway. The second

acclimation drive involved driving in an urban center while following a lead vehicle that made a series of right- and left-hand turns at controlled intersections with a speed limiter in place that did not allow participants to take the turns faster than 20 km/hr. Following the acclimation drives, all participants had their driving performance tested on a pre- and post-test driving scenario.

Pre- and Post-Test Driving Scenarios

The pre- and post-test driving scenarios were selected for participants as they represent realistic driving scenarios that mimic the events and conditions experienced by Saskatchewan drivers. For example, Saskatchewan drivers have very monotonous driving routes in both rural and urban environments; therefore, selecting simulated driving scenarios that are similar to what Saskatchewan drivers experience in the real world allows us to assess their driving performance in a more controlled environment. Both the pre-test and post-test included traffic on rural highways, expressways, urban roadways, and multiple hazards in both clear and snowy weather during dusk and at night. Participants were not provided with any assistance or feedback during these drives. Both of these scenarios present many obstacles for the driver, including: hazard perception (e.g., unpredictable pedestrians, bicyclists, and vehicles; wildlife), making left- and right-hand turns, headway/space management (e.g., leaving sufficient space when driving in front and behind vehicles), merging, and speed regulation.

Simulated Driver Training Scenarios

Only participants in the intervention groups (regardless of feedback type) completed 15 driver training scenarios on the simulator, which were selected in the prior phase of this project [9,48]. The scenarios included training on basic vehicle control (e.g., speed regulation; lane keeping; steering), hazard perception (e.g., pedestrian; cyclist; vehicle; animal), hard braking at different speeds (e.g., 50 km per hour (km/hr); 70 km/hr; 90 km/hr; 110 km/hr) and in different weather conditions (e.g., clear; rain; snow), merging on different roadways (e.g., highways; expressways; cloverleaf), passing vehicles on highways and gravel roads, giving right of way (e.g., ambulance; firetruck), following road laws (e.g., slowing down to 60 km/hr when passing a stopped police or emergency vehicle with its lights flashing), as well as driving in different weather conditions (e.g., clear; rain; snow) in different environments (e.g., city; rural; highway; gravel), and at different times of day (e.g., day; night; dawn/dusk).

2.4. Data Analysis

Data were analyzed using SPSS (Version 28) [49]. Continuous variables were presented using mean and standard deviation (mean ± SD) and range. Categorical variables were presented using frequencies and percentages. Associations were explored using Chi-Square tests (if parametric assumptions were met) or Fisher's Exact tests (if parametric assumptions were not met). Within-group differences between driving metrics in pre-test vs. post-test drives were investigated through either One-Way ANOVA for dependent samples (provided parametric assumptions were met) or Friedman's ANOVA (if parametric assumptions were not met). Post hoc analyses for within-group differences were investigated through either *t*-Test for repeated measures (provided parametric assumptions were met) or Wilcoxon signed-rank tests (if parametric assumptions were not met). Between-group differences (control, intervention with feedback, and intervention with no feedback) in driving metrics in both the pre-test and post-test drives were investigated through either One-Way ANOVA for independent samples (provided parametric assumptions were met) or Kruskal–Wallis One-Way ANOVA (if parametric assumptions were not met). Post hoc analyses for between-group differences were investigated through either *t*-Test for

two independent samples (provided parametric assumptions were met) or Mann-Whitney U tests (if parametric assumptions were not met). All results were presented with 95% CIs and p-values of ≤ 0.05 to indicate statistical significance.

3. Results

3.1. Sample Description

The mean age of participants in the control group, intervention group with no feedback, and intervention group with feedback was 15.7 ± 1.1 years (range 15–20), 15.6 ± 1.2 years (range 15–20), and 16.5 ± 1.3 years (range 15–20), respectively (see Table 1). Post hoc analyses revealed that participants in the intervention group with feedback were significantly older than both participants in the intervention group with no feedback (p = 0.006) and participants in the control group (p = 0.033). The majority of participants, regardless of intervention group, were currently in high school (88.3%), resided in Saskatoon (78.3%), and had driven less than one year (81.7%). No participants had received a ticket, but one participant (in the control group) was in a collision and was found at-fault.

Table 1. Sample description (n = 60).

Variable	Control (n = 20)	Intervention with No Feedback (n = 20)	Intervention with Feedback (n = 20)	Sig
Age (years)	15.7 ± 1.1 (15–18)	15.6 ± 1.2 (15–20)	16.5 ± 1.3 (15–20)	**0.009**
Gender				
Female	10 (50.0%)	5 (25.0%)	9 (45.0%)	0.436
Male	10 (50.0%)	14 (70.0%)	9 (45.0%)	
Gender diverse	0 (0.0%)	1 (5.0%)	2 (10.0%)	
Current education				
In high school	18 (90.0%)	18 (90.0%)	17 (85.0%)	0.396
High school diploma	0 (0.0%)	0 (0.0%)	1 (5.0%)	
In university or college, but no degree	2 (10.0%)	2 (10.0%)	2 (10.0%)	
City/town of residence				
Urban				
Saskatoon	16 (80.0%)	12 (60.0%)	19 (95.0%)	
Rural				
Moose Jaw	1 (5.0%)	0 (0.0%)	0 (0.0%)	0.117
Martensville	2 (10.0%)	4 (20.0%)	0 (0.0%)	
Osler	1 (5.0%)	0 (0.0%)	0 (0.0%)	
Melfort	0 (0.0%)	1 (5.0%)	0 (0.0%)	
Wynyard	0 (0.0%)	1 (5.0%)	0 (0.0%)	
Fiske	0 (0.0%)	1 (5.0%)	0 (0.0%)	
Delisle	0 (0.0%)	1 (5.0%)	0 (0.0%)	
Asquith	0 (0.0%)	0 (0.0%)	1 (5.0%)	
Employment status				
Part-time	3 (15.0%)	3 (15.0%)	2 (10.0%)	0.693
Not employed	17 (85.0%)	17 (85.0%)	18 (90.0%)	
Years driving				
Less than 1 year	16 (80.0%)	18 (90.0%)	15 (75.0%)	0.266
1–2 years	4 (20.0%)	0 (0.0%)	4 (20.0%)	
3–4 years	0 (0.0%)	1 (5.0%)	0 (0.0%)	
5+ years	0 (0.0%)	1 (5.0%)	1 (5.0%)	
Days driving per week				
0 days	5 (25.0%)	2 (10.0%)	4 (20.0%)	0.304
1–2 days	11 (55.0%)	12 (60.0%)	12 (60.0%)	
3–4 days	4 (20.0)	2 (10.0%)	3 (15.0%)	
5+ days	0 (0.0%)	4 (20.0%)	1 (5.0%)	
Owns vehicle				
Yes	1 (5.0%)	3 (15.0%)	3 (15.0%)	0.504
No	19 (95.0%)	17 (85.0%)	17 (85.0%)	

Table 1. *Cont.*

Variable	Control (n = 20)	Intervention with No Feedback (n = 20)	Intervention with Feedback (n = 20)	Sig
Involved in a collision (in the past 6 months)				
Yes	1 (5.0%)	0 (0.0%)	0 (0.0%)	0.371
No	19 (95.0%)	20 (100.0%)	20 (100.0%)	
Was found at-fault for the collision				
Yes	1 (100.0%)	-	-	-
No	0 (0.0%)	-	-	

Note: Continuous variables are shown as mean ± SD (range) and analyzed using One-Way ANOVA. Categorical variables are shown as frequencies (%) and analyzed using Chi-square test.

3.2. Clinical Test Scores

All participants had adequate visual search/processing speed, divided, and selective attention, as shown by their UFOV-1, UFOV-2, and UFOV-3 scores, respectively (see Table 2). Additionally, all participants were categorized as having a very low UFOV RI. Scores on the MoCA ranged from 17 to 30 (mean 26.6 ± 3.0); 31.7% were considered to have mild cognitive impairment. On the TMTA, all participants received a score below the cut-point (90 s), indicating their visual processing and attention were intact. Similarly, all drivers received a score below the cut-point (180 s) for the TMTB, indicating their divided attention and executive skills were within normal limits. On the Beery-VMI, the majority of participants' scores were average for their age group (80.0%). Participants who received a below-average (or poorer) score on the Beery-VMI were significantly more likely to score below 26 on the MoCA (58.3% vs. 41.7%; p = 0.039).

Table 2. Cognitive test scores (n = 60).

Variable	Control (n = 20)	Intervention with No Feedback (n = 20)	Intervention with Feedback (n = 20)	Sig
MoCA (score out of 30)	26.5 ± 3.6 (17–30)	26.9 ± 2.3 (23–30)	26.6 ± 3.1 (19–30)	0.988
Non-impaired	12 (60.0%)	13 (65.0%)	16 (80.0%)	0.367
Mild cognitive impairment	8 (40.0%)	7 (35.0%)	4 (20.0%)	
TMTA (seconds; s)	23.3 ± 6.4 (11–42)	23.8 ± 6.9 (13–35)	25.4 ± 9.8 (15–53)	0.967
TMTB (s)	49.3 ± 15.3 (19–70)	54.1 ± 23.3 (27–130)	52.8 ± 18.9 (23–90)	0.961
Beery-VMI				
Average	17 (85.0%)	17 (85.0%)	14 (70.0%)	0.596
Below average	3 (15.0%)	2 (10.0%)	5 (25.0%)	
Low	0 (0.0%)	1 (5.0%)	1 (5.0%)	
SDMT	53.3 ± 11.9 (35–75)	53.2 ± 10.3 (31–70)	54.2 ± 13.8 (36–81)	0.763
UFOV (milliseconds; ms)				
Subtest 1 (ms)	17.0 ± 0.0 (17–17)	17.0 ± 0.0 (17–17)	17.0 ± 0.0 (17–17)	-
Subtest 2 (ms)	38.7 ± 14.9 (17–77)	31.5 ± 12.1 (17–57)	38.7 ± 21.6 (17–90)	0.300
Subtest 3 (ms)	84.8 ± 46.9 (30–213)	83.6 ± 27.4 (37–133)	101.5 ± 61.1 (44–240)	0.672
Risk Index				-
Very low	20 (100.0%)	20 (100.0%)	20 (100.0%)	

Note: Continuous variables are shown as mean ± SD (range) and analyzed using One-Way ANOVA. Categorical variables are shown as frequencies (%) and analyzed using Chi-square test.

The majority of participants had 20/20 binocular VA or better based on their ETDRS (76.7%) and Optec (81.7%) scores, as seen in Table 3. Depth perception scores between groups were significantly different; post hoc analyses revealed that participants in the intervention group with feedback had significantly poorer depth perception compared to participants in the control group ($p = 0.015$). Additionally, the majority of participants had adequate far (85.0%) and near (70.0%) lateral phoria, vertical phoria (81.7%), fusion (96.7%), and color perception (96.7%).

Table 3. Visual assessment scores ($n = 60$).

Variable	Control ($n = 20$)	Intervention with No Feedback ($n = 20$)	Intervention with Feedback ($n = 20$)	Sig
Static binocular VA (in ft)				
Far point				
20/12.5	2 (10.0%)	1 (5.0%)	1 (5.0%)	
20/16	5 (25.0%)	7 (35.0%)	6 (30.0%)	
20/20	10 (50.0%)	7 (35.0%)	7 (35.0%)	0.957
20/25	3 (15.0%)	3 (15.0%)	4 (20.0%)	
20/32	0 (0.0%)	1 (5.0%)	1 (5.0%)	
20/40	0 (0.0%)	1 (5.0%)	1 (5.0%)	
Near point				
20/20	17 (85.0%)	16 (80.0%)	16 (80.0%)	0.895
20/30	3 (15.0%)	4 (20.0%)	4 (20.0%)	
Binocular CS (in log units)	1.9 ± 0.1 (1.7–2.0)	1.9 ± 0.1 (1.8–2.0)	1.8 ± 0.1 (1.7–2.1)	0.391
Depth perception				
Normal	6 (30.0%)	7 (35.0%)	3 (15.0%)	**0.025**
Acceptable	11 (55.0%)	4 (20.0%)	5 (25.0%)	
Poor	3 (15.0%)	9 (45.0%)	12 (60.0%)	
Lateral phoria				
Far point				
Esophoria	0 (0.0%)	2 (10.0%)	0 (0.0%)	0.260
Orthophoria	17 (85.0%)	16 (80.0%)	18 (90.0%)	
Exophoria	3 (15.0%)	2 (10.0%)	2 (10.0%)	
Near point				
Esophoria	0 (0.0%)	1 (5.0%)	1 (5.0%)	0.304
Orthophoria	13 (65.0%)	12 (60.0%)	17 (85.0%)	
Exophoria	7 (35.0%)	7 (35.0%)	2 (10.0%)	
Vertical phoria				
Left hyperphoria	3 (15.0%)	3 (15.0%)	2 (10.0%)	0.153
Orthophoria	17 (85.0%)	16 (80.0%)	16 (80.0%)	
Right hyperphoria	0 (0.0%)	1 (5.0%)	2 (10.0%)	
Color perception				
Not color deficient	19 (95.0%)	19 (95.0%)	20 (100.0%)	0.596
Color deficient	1 (5.0%)	1 (5.0%)	0 (0.0%)	
Fusion				
Pass	20 (100.0%)	19 (95.0%)	19 (95.0%)	0.596
Fail	0 (0.0%)	1 (5.0%)	1 (5.0%)	
Sign recognition (out of 12)	8.8 ± 1.0 (1–10)	8.9 ± 0.7 (8–10)	8.7 ± 1.0 (6–10)	0.963

Note: Continuous variables are shown as mean ± SD (range) and analyzed using One-Way ANOVA. Categorical variables are shown as frequencies (%) and analyzed using Chi-square test.

3.3. Driving Confidence

All groups had significantly higher driving confidence scores post-test when driving in heavy rain, heavy snow, on icy roads, at night, and when merging on expressways, as seen in Table 4. Additionally, participants in the control group (p = 0.002), intervention group with no feedback (p = 0.001), and intervention group with feedback (p = 0.002) all felt significantly more confident in their driving ability post-test compared to their driving ability pre-test.

Table 4. Driving confidence differences pre-post intervention within groups (n = 60).

Driving Confidence	Control (n = 20)			Intervention with No Feedback (n = 20)			Intervention with Feedback (n = 20)		
	Pre	**Post**	**Sig**	**Pre**	**Post**	**Sig**	**Pre**	**Post**	**Sig**
Heavy rain	45.0 ± 22.4 (0–75)	60.0 ± 20.5 (25–100)	**0.010**	55.0 ± 19.2 (25–100)	65.0 ± 17.0 (25–75)	**0.021**	40.0 ± 23.5 (0–100)	58.8 ± 18.6 (25–100)	**0.001**
Heavy snow	32.5 ± 18.3 (0–50)	52.5 ± 24.2 (0–100)	**0.012**	36.3 ± 22.2 (0–75)	53.8 ± 18.6 (25–75)	**0.001**	26.3 ± 25.0 (0–75)	45.0 ± 23.8 (0–75)	**0.021**
Icy roads	27.5 ± 19.7 (0–50)	41.3 ± 24.7 (0–75)	**0.017**	36.3 ± 19.0 (0–50)	50.0 ± 22.9 (0–75)	**0.012**	33.8 ± 20.3 (0–75)	46.3 ± 21.9 (0–75)	**0.047**
At night	57.5 ± 25.8 (0–100)	71.3 ± 20.3 (25–100)	**0.024**	70.0 ± 15.4 (50–100)	82.5 ± 11.8 (75–100)	**0.008**	53.8 ± 26.0 (0–100)	68.8 ± 25.5 (0–100)	**0.008**
Merging	50.0 ± 26.9 (0–100)	70.0 ± 20.8 (25–100)	**0.001**	62.5 ± 22.2 (0–100)	76.3 ± 19.0 (50–100)	**0.005**	55.0 ± 27.6 (0–100)	72.5 ± 21.3 (25–100)	**0.005**
Headway	76.3 ± 17.2 (0–100)	78.8 ± 16.8 (50–100)	0.606	78.8 ± 16.8 (50–100)	80.0 ± 17.4 (50–100)	0.666	72.5 ± 25.5 (0–100)	75.0 ± 19.9 (25–100)	0.589
Left turns	56.3 ± 24.2 (0–100)	63.8 ± 25.0 (0–100)	0.267	61.3 ± 22.2 (25–100)	73.8 ± 25.0 (25–100)	**0.047**	52.5 ± 26.8 (0–100)	68.8 ± 25.5 (25–100)	**0.005**
Scanning	68.8 ± 21.3 (0–100)	75.0 ± 18.1 (50–100)	0.204	75.0 ± 18.1 (50–100)	78.8 ± 18.6 (50–100)	0.366	66.3 ± 27.2 (0–100)	71.3 ± 16.8 (50–100)	0.507
Mean score (out of 100)	51.7 ± 15.7 (15.6–78.1)	64.1 ± 14.9 (37.5–93.8)	**0.002**	59.4 ± 14.4 (28.1–81.3)	70.0 ± 14.1 (46.9–90.6)	**0.001**	50.0 ± 19.1 (0.0–81.3)	63.3 ± 15.5 (37.5–90.6)	**0.002**

Note: Continuous variables are shown as mean ± SD (range) and analyzed using One-Way ANOVA.

3.4. Differences in Driving Performance Between Pre- and Post-Test Scenarios

When examining driving performance differences between pre- and post-intervention, participants in the control group had a significantly slower average speed when merging on the expressway post-test (p = 0.035), but a significantly faster average speed when driving in traffic on the expressway post-test (p = 0.011), compared to pre-test (see Table 5). Moreover, when driving in expressway traffic, the control group participants had a significantly greater average time headway (p = 0.002) post-test, compared to pre-test. Comparatively, participants in the intervention group with no feedback had a significantly faster average speed when driving during dusk (p = 0.010) post-test, compared to pre-test, but no other differences were observed. Lastly, participants in the intervention group with feedback had a significantly faster average speed when merging on the highway (p = 0.001), a significantly smaller minimum time headway (p = 0.038) when merging on the highway, and a significantly smaller average time headway when merging both on the highway (p = 0.017) and expressway (p = 0.001) post-test, compared to pre-test. Regarding collisions, all participants, irrespective of intervention group, were involved in significantly fewer collisions post-test (p = 0.001), compared to pre-test.

Table 5. Simulated driving performance differences pre-post intervention within groups (n = 60).

Driving Variable	Control (n = 20)			Intervention with No Feedback (n = 20)			Intervention with Feedback (n = 20)		
	Pre	Post	Sig	Pre	Post	Sig	Pre	Post	Sig
Highway merge									
Avg speed	52.4 ± 6.4 (36.5–62.3)	53.2 ± 6.4 (40.0–69.8)	0.483	50.6 ± 7.1 (34.6–67.2)	54.4 ± 8.2 (36.8–69.0)	0.091	48.6 ± 8.5 (28.0–65.5)	55.6 ± 7.3 (38.6–65.3)	**0.001**
Avg headway	40.0 ± 9.0 (29.5–61.6)	37.8 ± 8.0 (26.9–64.1)	0.279	41.7 ± 8.7 (30.6–66.6)	38.0 ± 11.4 (27.6–75.8)	0.084	44.1 ± 12.6 (28.6–71.4)	38.2 ± 10.2 (26.8–62.0)	**0.017**
Min headway	6.7 ± 2.2 (2.0–11.1)	6.4 ± 1.7 (3.6–9.7)	0.482	7.1 ± 2.0 (4.0–12.9)	6.6 ± 2.1 (4.0–12.7)	0.153	7.6 ± 2.3 (3.3–11.8)	6.4 ± 1.6 (3.7–9.3)	**0.038**
Expressway merge									
Avg speed	61.8 ± 9.0 (47.0–86.6)	56.0 ± 12.4 (29.1–74.0)	**0.035**	59.4 ± 7.3 (40.7–70.1)	57.7 ± 6.0 (46.3–67.0)	0.282	56.2 ± 13.9 (22.2–72.8)	58.5 ± 8.8 (41.7–74.5)	0.852
Avg headway	34.9 ± 6.0 (26.4–50.2)	33.7 ± 7.0 (23.7–46.7)	0.167	32.9 ± 5.6 (24.1–46.1)	31.9 ± 6.5 (25.6–52.1)	0.421	36.5 ± 6.3 (27.5–48.2)	31.0 ± 4.7 (23.9–43.9)	**0.001**
Expressway traffic									
Avg speed	54.7 ± 5.1 (44.0–66.0)	59.7 ± 8.2 (49.5–85.7)	**0.011**	56.9 ± 6.6 (42.9–73.6)	58.1 ± 4.7 (45.7–64.5)	0.136	57.5 ± 9.0 (44.9–86.7)	57.1 ± 6.3 (44.8–68.3)	0.911
Avg headway	12.5 ± 5.0 (3.4–19.6)	24.2 ± 14.8 (4.8–52.0)	**0.002**	18.4 ± 13.3 (4.3–54.9)	19.1 ± 7.9 (3.0–35.2)	0.687	21.2 ± 15.8 (6.6–79.2)	21.5 ± 14.9 (5.7–55.2)	0.370
Min headway	1.2 ± 0.7 (0.1–3.1)	1.8 ± 1.7 (0.5–8.2)	0.147	1.1 ± 0.6 (0.4–2.6)	1.2 ± 0.9 (0.2–3.9)	0.663	2.8 ± 4.3 (0.2–18.9)	1.6 ± 1.2 (0.4–6.0)	0.573
Lighting									
Dusk—Avg speed	25.6 ± 5.0 (14.6–33.5)	26.9 ± 4.4 (18.3–37.1)	0.339	26.7 ± 3.5 (22.0–33.4)	29.3 ± 4.0 (22.4–36.5)	**0.010**	27.6 ± 4.3 (18.1–35.4)	29.4 ± 3.8 (24.5–40.2)	0.212
Night—Avg speed	21.3 ± 3.7 (9.7–26.1)	22.1 ± 3.0 (13.7–26.6)	0.279	22.4 ± 3.1 (16.8–28.8)	21.6 ± 3.0 (16.2–27.3)	0.344	21.6 ± 4.2 (13.1–27.8)	22.0 ± 2.6 (16.4–25.3)	0.741
Weather									
Normal—Avg speed	25.4 ± 4.2 (16.9–32.3)	26.6 ± 3.6 (17.9–35.2)	0.276	26.5 ± 3.0 (22.0–31.6)	28.4 ± 3.4 (22.6–36.2)	0.103	26.1 ± 4.4 (15.0–32.3)	28.3 ± 3.7 (24.8–40.6)	0.100
Snow—Avg speed	21.3 ± 4.1 (8.7–27.5)	22.2 ± 2.8 (15.3–26.4)	0.391	22.4 ± 3.6 (16.5–28.8)	22.4 ± 3.8 (17.0–29.6)	0.982	21.4 ± 4.4 (11.6–27.6)	22.7 ± 3.0 (17.2–27.2)	0.258
Collisions	0.9 ± 0.7 (0.0–2.0)	0.0 ± 0.0 (0.0–0.0)	**0.001**	1.2 ± 0.7 (0.0–2.0)	0.0 ± 0.0 (0.0–0.0)	**0.001**	1.0 ± 0.5 (0.0–2.0)	0.0 ± 0.0 (0.0–0.0)	**0.001**

Note: Continuous variables are shown as mean ± SD (range) and analyzed One-Way Anova. Avg = average; Min = minimum; Speed = km/hr; Headway = number of seconds between participants' vehicle and the vehicle immediately in front.

3.5. Differences in Driving Performance Between Intervention Groups

When examining driving performance differences between intervention groups, participant's average speed during the highway merge was significantly different (p = 0.023) between groups, as seen in Table 6. Post hoc analyses revealed that participants in the intervention with feedback group drove significantly faster post-test compared to participants in the control group (p = 0.006). No other driving performance differences were observed between intervention groups.

Table 6. Simulated driving performance differences post-pre intervention between groups (n = 60).

Driving Variable	Control (n = 20)	Intervention with No Feedback (n = 20)	Intervention with Feedback (n = 20)	Sig
Highway merge				
Average speed	0.8 ± 5.0 (−5.8–14.1)	3.8 ± 9.4 (−20.5–17.8)	6.9 ± 8.2 (−8.9–25.0)	**0.023**
Average headway	−2.2 ± 7.7 (−17.8–9.5)	−3.5 ± 9.0 (−15.2–19.5)	−5.9 ± 11.3 (−36.5–20.0)	0.341
Minimum headway	−0.3 ± 1.9 (−3.5–3.2)	−0.6 ± 1.9 (−3.5–2.8)	−1.1 ± 2.2 (−4.6–3.5)	0.501

Table 6. *Cont.*

Driving Variable	Control (n = 20)	Intervention with No Feedback (n = 20)	Intervention with Feedback (n = 20)	Sig
Expressway merge				
Average speed	−5.9 ± 11.6 (−29.9–7.3)	−1.8 ± 7.1 (−16.1–9.8)	2.3 ± 12.1 (−12.1–43.7)	0.332
Average headway	−6.3 ± 8.5 (−20.5–13.8)	−9.7 ± 7.8 (−22.3–8.1)	−13.1 ± 12.9 (−44.0–8.5)	0.162
Expressway traffic				
Average speed	5.0 ± 7.9 (−5.5–26.3)	1.4 ± 4.9 (−9.1–9.1)	−0.5 ± 10.9 (−31.8–22.9)	0.225
Average headway	11.6 ± 14.4 (−6.0–46.6)	0.7 ± 10.9 (−25.1–16.7)	0.4 ± 19.7 (−68.3–23.2)	0.081
Minimum headway	0.6 ± 2.0 (−1.3–8.2)	0.1 ± 0.7 (−1.1–1.8)	−1.2 ± 4.2 (−17.6–1.4)	0.468
Lighting				
Average speed at dusk	1.3 ± 5.7 (−9.4–17.4)	3.0 ± 4.5 (−6.7–10.9)	2.0 ± 6.5 (−8.3–16.5)	0.391
Average speed at night	0.8 ± 3.7 (−7.7–9.3)	−0.7 ± 3.0 (−6.9–5.0)	0.4 ± 4.8 (−6.6–10.8)	0.460
Weather				
Average speed in normal weather	1.2 ± 4.8 (−9.7–12.6)	1.9 ± 3.6 (−3.9–9.4)	2.2 ± 5.7 (−7.5–16.6)	0.911
Average speed in snowstorm	0.8 ± 3.6 (−5.1–9.4)	0.1 ± 3.8 (−6.6–7.2)	1.3 ± 5.1 (−6.1–13.1)	0.818
Collisions	−0.9 ± 0.7 (−2.0–0.0)	−1.2 ± 0.7 (−2.0–0.0)	−0.9 ± 0.5 (−2.0–0.0)	0.422

Note: Continuous variables are shown as mean ± SD (range) and analyzed using One-Way ANOVA. Speed = km/hr; Headway = number of seconds between participants' vehicle and the vehicle immediately in front.

4. Discussion

Our findings show that the driver training intervention with structured feedback enhanced the simulated driving performance of novice drivers. Pre-post driving performance differences show that participants had significantly faster average speed when merging on the highway and significantly smaller average time headway when merging on the highway and expressway. The increase in average speed suggests improved vehicle-handling skills [50,51], as drivers selected speeds more closely aligned with posted speed limits (e.g., 60 km per hour) after receiving structured feedback. Additionally, prior to completing the training program, this group had a large time headway (i.e., nearly 15 times the recommended time headway) [52]; however, with structured feedback, drivers learned to maintain a more appropriate following distance, while also adhering to the posted speed limit. These findings are consistent with prior driving simulator studies demonstrating that simulator training with feedback can effectively modify young drivers' behavior by reducing average driving speed [30,32], reducing time spent exceeding the speed limit [31], and increasing average time headway [30], compared to young drivers who do not receive structured feedback.

The driver training modules that participants completed focused on dangerous driving conditions such as driving in heavy snow and on icy roads, in heavy rain, merging, and left-hand turns in controlled and uncontrolled intersections in both rural and urban environments. We found that participants, irrespective of whether structured feedback was provided, had better simulated driving performance and were more confident, consistent with prior studies [19,22,25,50,53,54]. Participants in both intervention groups were

involved in significantly fewer crashes and were significantly more confident driving in heavy rain, heavy snow, on icy roads, at night, making left-hand turns, and merging.

In the intervention group without feedback, participants had a significantly faster average speed when driving at dusk after training. The increase in average speed and driver confidence observed after training in this group likely reflects improvements in vehicle-handling skills, enabling drivers to select a more appropriate driving speed and feel confident doing so [50,51]. Together, these improvements show that the developed driver training modules alone can enhance driving performance in novice drivers, including reduced crashes, safe following distances, adherence to speed limits, and increased confidence, similar to prior study findings [18,24,25,55,56].

We also found that driving performance and confidence improved in the control group that did not receive any training or feedback. Control participants were involved in significantly fewer crashes and were significantly more confident driving in heavy rain, heavy snow, on icy roads, at night, and merging post-assessment. When comparing pre- and post-test driving performance, control participants had a significantly faster average speed and a significantly larger average time headway when driving in expressway traffic post-test. Upon comparing groups, post hoc analyses revealed that control participants drove significantly slower post-test than participants who received feedback, although no other driving performance differences were observed between groups. The significant improvements in driving performance (i.e., speed regulation, gap acceptance, fewer crashes) and confidence may be attributable to the one-week interval between pre- and post-test drives, during which participants likely had an in-car driving lesson as part of the High School Driver Education program. However, the actual number of in-car lessons completed with an SGI instructor during this period is unknown for all groups; consequently, some drivers in the control group may have received more instructional hours than those in the other intervention groups, which helps to explain the improvements observed in simulated driving performance.

It is important to note that we observed fewer improvements in the driving performance of participants in the intervention group without feedback compared to both participants in the control group and in the intervention group with feedback, consistent with prior studies [32,50,57,58]. Without feedback during the driver training intervention, novice drivers may not recognize their errors or understand how to adjust their driving practices [28,50]. Feedback provides corrective guidance that supports more efficient skill development, whereas unguided practice can reinforce existing habits (good or bad) [28]. Additionally, a greater proportion of drivers in the intervention without feedback group resided in rural regions compared to those in the control group (40% vs. 20%). It is therefore possible that rural novice drivers were less confident navigating the urban environment due to lack of experience [9], which was a large portion of both the pre- and post-test drives. This lack of confidence and/or experience may have limited their ability to modify their driving behavior [28], resulting in similar performance across both tests. This is in line with the Risk Homeostasis Theory that states that people accept a certain level of risk [59]. For example, if people perceive a driving situation as low-risk, they may modify their behavior, which subsequently increases their exposure to that risk (e.g., driving faster at night). Driver training programs must balance the improvements in confidence versus actual risk, as prior studies have shown that over-confident drivers may drive more dangerously in challenging driving conditions (e.g., over-speeding in winter conditions). Therefore, this theory provides a possible explanation as to why drivers do not always respond to road safety initiatives as they drive according to their own perceived level of risk [60].

While most participants in the control and intervention without feedback groups demonstrated adequate depth perception, those in the intervention with feedback group

predominantly demonstrated poor depth perception. However, no significant associations were found between depth perception and driving performance, indicating that depth perception did not meaningfully influence simulated driving performance. All participants performed within normal limits on measures of visual processing (TMTA; SDMT; UFOV-1), divided attention (TMTB; UFOV-2), selective attention (UFOV-3), and executive function skills (TMTB). However, 31.7% failed the MoCA and 20% scored below average on the Beery-VMI. Participants who received a below-average (or poorer) score on the Beery-VMI were significantly more likely to fail the MoCA (58.3% vs. 41.7%; $p = 0.039$). As deficits in visual-motor integration commonly co-occur with broader cognitive impairments [22,60] and attention deficit hyperactivity disorder (ADHD) [31,61], these findings suggest that we likely had participants with diagnosed/undiagnosed autism spectrum disorder (ASD) and/or ADHD, particularly given the significant association between Beery-VMI and MoCA scores. However, these deficits did not translate into poorer simulated driving performance in the present study. This is unsurprising as the MoCA is generally used to screen for mild cognitive impairment, dementia, and stroke in older drivers [35] with there being weak evidence linking MoCA scores to poorer driving performance in older drivers compared to other clinical tests (e.g., Trails B; UFOV) [62]. It is possible that poorer MoCA scores reflect similar deficits in executive function and attention observed between ASD/ADHD and those with cognitive impairment [63].

Limitations

Participants in the present study reflected the typical demographics of novice young drivers in prior studies [19,61,64], with a mean age of 15.9 ± 1.3 years (range 15–20), with the majority currently enrolled in high school (88.3%), having less than one year of driving experience (81.7%), and having never been involved in a crash (98.3%). However, participants were not randomly assigned to the intervention and control groups; instead, participants from the same high school were grouped together to minimize cross-group communication/contamination. Therefore, this non-random allocation may limit the internal validity of the study findings, as it increases the likelihood that pre-existing differences between groups, such as prior driving experience, or school-specific driver training programs, rather than the intervention itself, accounted for the observed outcomes (e.g., selection bias). This is evident in that the intervention with feedback group was significantly older than the other groups (e.g., 16.5 years vs. 15.7 years and 15.6 years). Prior studies show that spatial awareness and risk perception are more developed in those aged 16 versus 15 years of age [65], and this age difference may have contributed to the significant improvements observed in the intervention with feedback group. Additionally, we are unaware of the number of in-car lessons participants completed during their study involvement, which may have influenced our findings. While the pre-post tests were completed within a week for the control group participants, it is possible they received instructional hours from the SGI driver education program (outside of our study), contributing to the positive driving performance findings overall compared to both the intervention groups. Given the improvements in the control group, this may weaken the causal inference that the intervention itself improved driving performance. However, there were no differences in pre-post simulated driving performance observed among drivers whose sessions occurred one, two, or three weeks apart, suggesting that the length between sessions did not significantly affect driving performance. Finally, it remains to be determined whether the observed improvements in novice drivers' performance are maintained over the long term. Current evidence is mixed, with some studies reporting long-term reductions in driving infractions [66,67] and risky driving behaviors [29] among novice and young drivers following simulated training, while other studies report unclear

effects [20,25,26,28]. For example, studies show that improved driving skills on the simulator immediately following an intervention may not translate to a long-term reduction in crashes (especially given the infrequency of crashes) [25]. Additionally, there is a lack of longitudinal studies that follow participants over time after study completion to determine whether crash risk is indeed reduced following driver training in young drivers [24]. Lastly, given the exploratory nature of this study, we did not correct for multiple comparisons, as using a Bonferroni correction using a *p*-value of 0.0167 (i.e., 0.05 divided by 3 groups) would not have changed the results substantially.

5. Conclusions

The study findings show that simulated driver training can improve the driving skills and confidence of young novice drivers. Simulator practice paired with structured feedback significantly enhanced key aspects of novice drivers' performance (e.g., speed regulation; following distance; left-hand turns; hazard awareness) and confidence across a range of driving conditions. Although all participants benefitted from simulator exposure, training with feedback yielded the most robust and consistent improvements, highlighting the importance of guided skill development over unguided practice.

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