safety

MDPI

Article

Exploring the Benefits of a Simulator-Based Emergency Braking Exercise with Novice Teen Drivers

Rakesh Gangadharaiah [1], Johnell O. Brooks [1,*], Lauren Mims [2], Patrick J. Rosopa [3], Mark Dempsey [4], Robert Cooper [4] and Donnie Isley [5]

1 Department of Automotive Engineering, Clemson University, Greenville, SC 29607, USA; rakeshg@g.clemson.edu
2 Westat, Rockville, MD 20850, USA; lmims@g.clemson.edu
3 Department of Psychology, Clemson University, Clemson, SC 29634, USA; prosopa@clemson.edu
4 Dorman High School, Spartanburg, SC 29376, USA; cooperrw@spart6.org (R.C.)
5 BMW Performance Center, Greer, SC 29651, USA
* Correspondence: jobrook@clemson.edu; Tel.: +1-864-283-7272

Abstract: This exploratory study investigated whether using the Pedals Emergency Stop© interactive driving simulator exercise improved the understanding and performance of emergency braking among novice teen drivers. Seventy-one high school driver education students (aged 15–19) participated. All of the teens completed the Pedals Emergency Stop© interactive exercise driving simulator task and then an on-road ABS exercise in a driver's education vehicle; there was no control group. Students' ability to complete the simulator-based emergency braking task increased from an initial passing rate of only 18.3% to a maximum of 81.7% by the end of the simulation exercise. A positive trend was observed over successive simulator trials, with the linear effect explaining 51.1% of the variance in emergency stopping "pass" rates using the simulator task. In addition, participants who passed more trials during the Pedals Emergency Stop© simulator exercise were 12.3% more likely to fully activate the ABS during the on-road emergency stop activity using the driver's education vehicle. Post-study surveys revealed that 95% of the participants improved their understanding of ABS as a result of the simulation-based training, and 98% felt there was a positive impact from the driving simulation exercise on their real-world emergency braking capabilities. Participants highly endorsed the Pedals Emergency Stop© exercise for ABS education and refresher training, with a rating of 4.7 out of 5. This study emphasizes the potential benefits of incorporating simulator-based exercises into driver education and training, with the long-term goal of promoting safe driving behaviors and outcomes.

Keywords: teenage drivers; emergency braking; anti-lock braking system training; logistic regression; simulator-based training; driver education; driving performance evaluation

Citation: Gangadharaiah, R.; Brooks, J.O.; Mims, L.; Rosopa, P.J.; Dempsey, M.; Cooper, R.; Isley, D. Exploring the Benefits of a Simulator-Based Emergency Braking Exercise with Novice Teen Drivers. *Safety* **2024**, *10*, 14. https://doi.org/10.3390/safety10010014

Academic Editor: Raphael Grzebieta

Received: 9 October 2023
Revised: 11 January 2024
Accepted: 22 January 2024
Published: 24 January 2024

1. Introduction

1.1. Teenage Drivers

For many teenagers, acquiring a driver's license signifies an important passage into adulthood and represents a step towards achieving personal independence [1,2]. The capacity to drive offers personal mobility and freedom, an essential aspect of a teenager's personal, social, and economic development [2,3]. From a social perspective, driving enables teenagers to strengthen social connections by meeting friends easier, participating in communal activities, and encouraging a sense of belonging within their group [2]. This increased socialization can enhance teenagers' social skills and emotional health, both essential components of adolescent development. From an economic standpoint, driving expands access to job opportunities, allowing teenagers to gain work experience, develop professional skills, and contribute to financial independence [3]. In communities where public transportation is limited or absent, driving can enable teenagers to access resources and opportunities that would otherwise be unreachable. Moreover, a teenager's ability to drive can also provide significant relief to families, particularly those with demanding schedules or limited transportation options. In such scenarios, teenage drivers can contribute to family duties by assisting with running errands, dropping off younger siblings at school, or driving themselves to family obligations. This can reduce stress on parents and encourage a sense of responsibility and maturity among teenagers [2]. Given the importance of driving to a teenager's personal, social, and economic life, comprehensive and effective driver's education and training programs are important.

1.2. Risks Associated with Novice Teenage Drivers

Despite the benefits that driving brings to teenagers, driving introduces safety risks. As per the National Highway Traffic Safety Administration (NHTSA), teenagers, who represent a relatively small portion of the total driving population, are disproportionately involved in fatal traffic crashes [4]. The most common causes for fatal teen crashes include recognition errors (including visual scanning errors and distractions), decision errors (like misjudging following distances and speeding), and performance errors (such as losing control of the vehicle) as primary types of driver errors [5–9]. These errors are often attributed to a lack of driving experience, inadequate situational awareness, and an immature decision-making process, common among novice teenage drivers [6]. Moreover, teenagers' tendency towards risk-taking and overconfidence can increase the probability of dangerous driving behaviors such as driving under the influence, tailgating, or speeding [5,10–12]. Furthermore, teenage drivers are often less likely than older drivers to use safety measures such as seat belts, increasing their risk of injury or death in a crash [13].

Given these factors, current driver's education and training programs can be enhanced and tailored specifically towards addressing the shortcomings and vulnerabilities of teenage drivers [14–16]. This includes integrating comprehensive training on identifying and avoiding recognition errors, making safe driving decisions, and improving vehicle control under various conditions. By focusing on these areas, driver training interventions can potentially enhance the safety of teenage drivers [14,17]. This is consistent with Europe's "TRAINER" initiative, which sought to develop cost-effective driver training through the incorporation of modular driving simulators and multimedia [18]. The integration of "TRAINER" into driver training in Sweden, Spain, Greece, and Belgium marked a significant step towards influencing young and novice drivers positively.

1.3. The Importance of Anti-Lock Braking System (ABS)

ABS is a safety feature in vehicles engineered to prevent wheel lock-up and skidding during braking, especially in sudden or emergency braking situations [19–22]. By preventing wheel lock-up, ABS allows drivers to maintain steering control while braking, a feature that can be instrumental in avoiding collisions. ABS operates through sensors attached to each wheel that monitor rotational speed. When the system detects a wheel is about to lock up during braking, it modulates brake force to that wheel. This modulation can occur multiple times per second, enhancing the vehicle's braking effectiveness and stability [23,24]. ABS does require some level of understanding and correct utilization by drivers. For instance, in an emergency braking scenario, the ABS engages and triggers a pulsating sensation on the brake pedal that is unfamiliar to many drivers, particularly new drivers, and can be interpreted incorrectly as a system failure [19,25]. As a result, some drivers may instinctively release the brake pedal, negating the benefits of ABS and potentially leading to crashes. Given the importance of ABS and the misconceptions surrounding its operation, effective driver's education and training programs should incorporate ABS-related instruction. By familiarizing novice drivers with the operation and feel of ABS, such education can ensure drivers effectively utilize ABS in critical situations.

1.4. Driving Simulators in Novice Driver Training

In recent decades, driving simulators have evolved from tools used in professional contexts such as commercial driver testing to playing a role in driver training, education, and rehabilitation [26–32]. Simulators' capability to provide a virtual driving environment without exposing drivers to actual risks increases the value of training novice drivers. Simulators can create driving scenarios and conditions from basic to complex situations. This flexibility provides a comprehensive training platform, preparing drivers for a diverse range of situations they might encounter on the road [33–35]. The technological advancements of driving simulators encompass visual graphics, vehicle dynamics, and feedback systems that simulate real-world driving. This augments the learning experience, helping novice drivers in their transition to on-road driving [36,37]. The secure, controlled environment of a simulator allows novice drivers to obtain driving experience without the risks of on-road training. An advantage of driving simulators lies in their ability to reproduce critical or hazardous driving conditions, which pose significant challenges to safety during real-world driver training. These conditions can include emergency braking, adverse weather driving, or responding to sudden obstacles. Through repeated exposure to these scenarios in the simulator, novice drivers can improve their response skills, equipping them for actual on-road emergencies [36,38].

Simulators deliver consistent, unbiased feedback on drivers' performance, enabling novice drivers to identify, understand, and rectify their mistakes. This feedback is an integral part of the learning process, enhancing self-awareness and enabling targeted improvement. The opportunity for repetitive practice using simulators can be beneficial when learning complex maneuvers or emergency responses, where repetition is important to mastering the necessary skills and reactions.

The following section summarizes recent research from our lab to provide context and a foundational backdrop for the present study. A comprehensive review of work from other research groups is summarized in these manuscripts.

1.5. Previous Emergency Braking Research

Several previous studies have been conducted on driver training related to ABS and emergency braking, including explorations of driving programs and driving simulators [14,19,36]. Research on training for emergency braking with ABS in driving simulators is scarce. A notable study in this area is Task 5.1 of the NHTSA's Light Vehicle ABS Program, which involved the National Advanced Driving Simulator (NADS) [39]. This task explored crash avoidance behavior using the NADS simulator, which featured a 190-degree forward and 60-degree rear field-of-view, 6 degrees-of-freedom movement, and a 1993 Saturn LS2 vehicle. Notably, the NADS was adapted to include ABS, which was based off a Ford Taurus vehicle dynamics model. The study explored drivers' collision avoidance behaviors rather than ABS training.

Mims et al. [14] focused on the impact of a post-license defensive driving program designed for teenagers. The program emphasized hands-on training in emergency braking with ABS, skid recovery, and the risks of distracted driving. In the phone interviews conducted three months post-program, numerous teenage participants described applying the skills acquired during the program. They attributed these skills, particularly emergency braking with ABS, as instrumental in helping them avert crashes. In another study, Mims et al. [19] examined how prior knowledge and experience with ABS influenced a driver's ability to activate this system effectively. Participants who had prior experience with ABS or had undergone training to activate ABS performed better in activating the system than those with limited ABS knowledge or experience. This study highlights the importance of hands-on training and familiarization with ABS for more effective usage during real-life driving scenarios.

A recent study by Mims et al. [36] consisted of two research components using an emergency braking task on a simulator, specifically the interactive exercise, Pedals Emergency Stop©. In this exercise, participants were required to quickly and fully press the brake pedal and hold it at maximum pedal depression, similar to real-life ABS activation, experiencing haptic feedback. Across 15 trials, 85% of the participants successfully "passed" within the first four trials. Interestingly, there were no significant performance differences between those with prior ABS knowledge and those without.

In response to participants' usability feedback, improvements were proposed and incorporated, including a practice session followed by three tests, each with four trials, and a passing criterion of successful completion of at least three out of the four trials [36]. The proposed "pass" criterion was tested, and the results showed that 95% of participants were able to pass on Test 1, confirming that the criteria were reasonable and achievable. However, further research was needed to establish how well these simulator exercises generalize to on-road driving.

Mims' team [40] conducted a study to evaluate the impact of the novel Pedals Emergency Stop© driving simulator interactive exercise, designed for emergency braking training, specifically to provide novice drivers with the ability to fully activate the ABS on a driving simulator prior to a closed-road course. The study included 38 participants who used the Pedals Emergency Stop© exercise and another group of 31 who did not. All participants attempted to activate the ABS on the on-road course, with their braking performance assessed by a professional driving instructor who used a 5-point behaviorally anchored rating scale. This scale ranged from 1, indicating no ABS activation, to 5, indicating full ABS activation throughout the stop (see Mims et al., [19]). The study found no significant differences in the on-road braking performance between those who had undergone the Pedals Emergency Stop© exercise and those who had not. The participants were all licensed adult drivers with an average age of 30.9 years (*SD* = 12.6, Min = 18, Max = 60); differences may be more salient with novice teen drivers.

1.6. Purpose of the Study

This study explored the potential benefits of the Pedals Emergency Stop© interactive exercise on a driving simulator for novice teenage drivers. Simulator-based emergency braking practice may help mitigate performance-related or decision-related braking errors. This study explored whether the Pedals Emergency Stop© interactive exercise can improve in-vehicle braking performance and examined the potential benefits of incorporating this simulator-based emergency braking practice into driver's education. The goal of this exploratory study was to assess if such integration can enhance novice teen drivers' (high school students) understanding of emergency braking, familiarize them with the haptic feedback from ABS activation, improve their braking performance, improve their understanding of ABS, and determine if teens endorse this type of training.

Furthermore, to fully assess the impact of the Pedals Emergency Stop© interactive exercise, this study not only focused on the simulator but also incorporated a real-world on-road portion in the vehicle. Participants' ABS performance was rated by a trained driving instructor, with the goal of examining how effectively the simulator practice translated to real-world emergency braking. This bridged the gap between the simulated practice and actual driving.

2. Methods

The participant recruitment, driving simulator, study procedures, surveys, and on-road exercises are described in this section.

2.1. Participant Recruitment and Demographics

This study was completed during the Spring of 2023. Participants included 74 high school driver's education students from a public school in the southeastern U.S. Three individuals withdrew or were dropped from this study: two due to the presence of a floor mat, which interfered with the simulator (which was removed for subsequent participants) and one due to a non-study related injury. The final sample of 71 participants included 38 males (53.5%) and 33 females (46.5%) with an age distribution of 33 participants (46.5%)

who were 15 years old, 29 (40.8%) who were 16 years old, 7 (9.9%) who were 17 years old, 1 (1.4%) who was 18 years old, and 1 (1.4%) who was 19 years old.

2.2. Materials

2.2.1. Driving Simulator for Emergency Braking Practice with ABS Brake Pedal Feedback

During this study's training phase, participants engaged in emergency braking exercises using a simulator equipped with haptic ABS brake pedal feedback (see Figure 1). The simulation setup used Fanatec ClubSport V3 Inverted Pedals [41] and a ButtKicker Gamer2 [42] for haptic feedback, affixed to the pedal structure. The assembly was supported by aluminum extrusions to offer stability for both the pedal set and the seat, ensuring the stability needed for emergency braking practice. DriveSafety software and related hardware were used for the simulator [43].

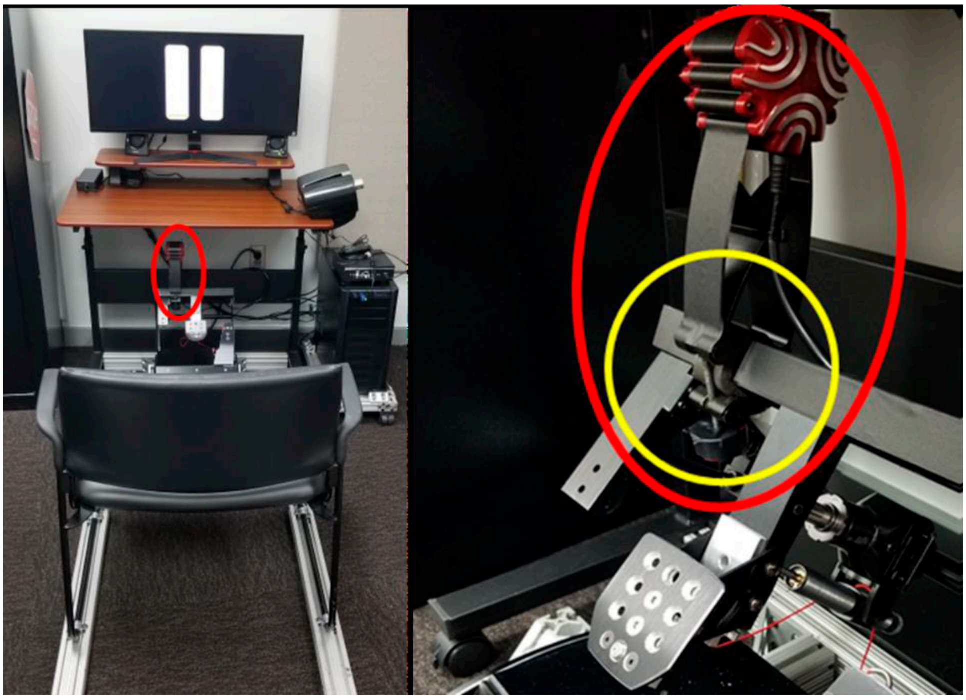


Figure 1. The study simulator with the haptic feedback device is in red. The yellow circle indicates how the haptic feedback was mounted to the pedal assembly.

The haptic ABS feedback, produced by the ButtKicker Gamer2, mimicked the sensation of activating ABS in an actual vehicle. The input signal for the ButtKicker was taken from the execution of ABS activation by a certified driving instructor within a real-world vehicle setting. The simulator's ABS sensation was validated by a subject matter expert who is also a professional driving instructor. See Mims et al. [36,40] for a comprehensive explanation of the simulator's development.

2.2.2. Interactive Exercises

The simulator used three different DriveSafety interactive exercises that focused exclusively on the gas and brake pedal. None of the interactive exercises used a driving scene; as a result, simulator sickness was not possible.

Pedals Static©

DriveSafety's Pedals Static© interactive exercise required participants to press the pedal and maintain the indicator within a static target zone. This task was used to help the participants become familiar with the simulator and to ensure the participants could effectively move their foot from the gas pedal to the brake pedal. This task presented two pedal visualizations, each with its own target zones. Participants were instructed to press the pedal until the indicator remained within the static target zone for a period of three seconds. The Tutorial, Level 1, Level 2, and Level 3 were completed for training purposes only. The Tutorial provided instructions for the interactive exercise. As participants advanced through the levels, the size of the target zone reduced, creating a more challenging task. Specifically, for Level 1, the target zone encompassed 37.5% of the pedal, whereas, for Level 2, the target zone was reduced to 25% of the pedal. Finally, at Level 3, the target zone was the smallest, accounting for just 12.5% of the pedal [26], see Figure 2.

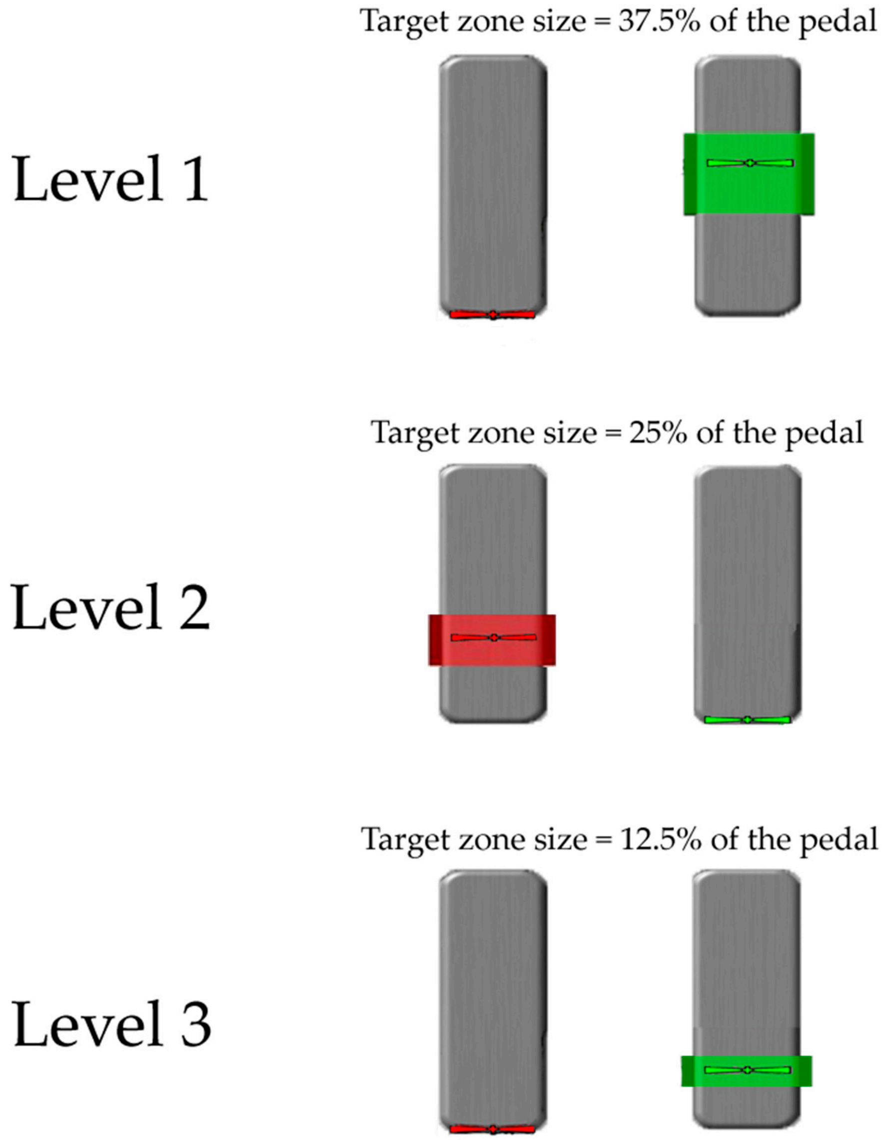


Figure 2. Pedals Static© Level 1, Level 2, and Level 3 target zone sizes, reproduced from Brooks et al. [26]. The right, gas pedal uses a green target zone and indicator, while the left, brake pedal uses red.

Pedals Chase©

Next, DriveSafety's Pedals Chase© interactive exercise was completed, which served as a platform for participants to familiarize themselves with the modulation of the gas and brake pedals. This exercise involved moving targets displayed on a visual representation of the gas and brake pedals (as shown in Figure 3). In order to align the indicator line (which represents the pedal position) with the dynamic target zone, the participant was required to manipulate the gas or brake pedal accordingly. This dynamic target zone moved vertically along the pedal, initially starting on the gas pedal before transitioning to the brake pedal. The exercises implemented were Level 1 and Level 2. In Level 1, the target zone encompassed 31% of the total pedal size, and in Level 2, the target zone encompassed 31% of the total pedal size but the speed was 67% faster than in Level 1 [26].

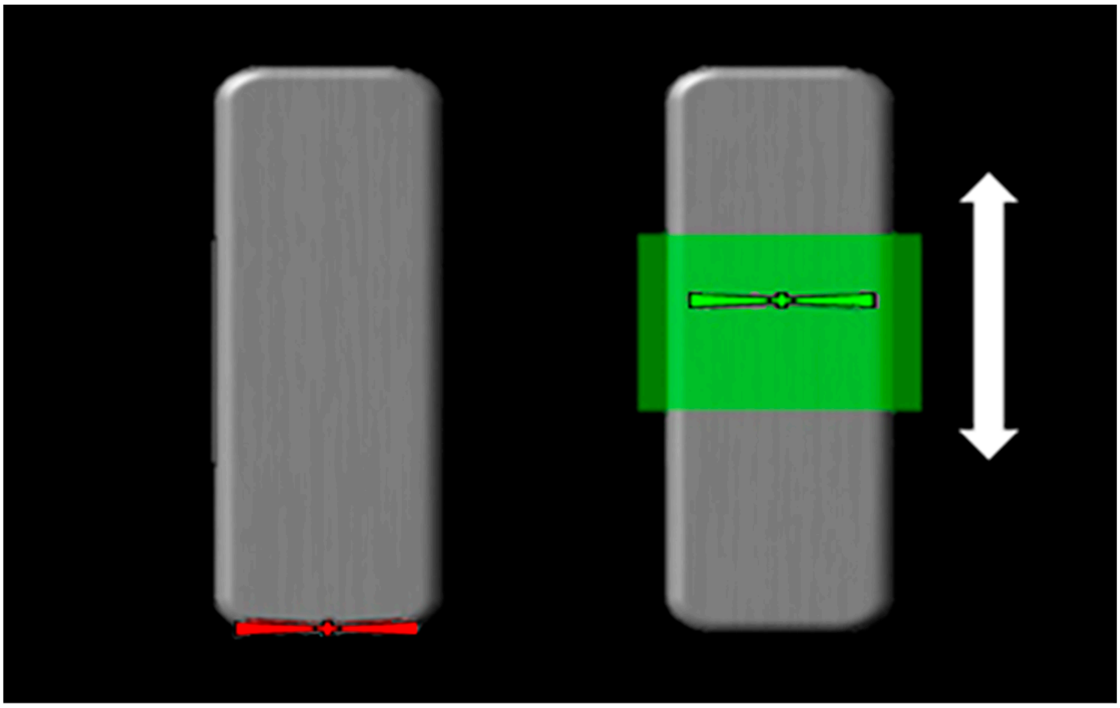


Figure 3. Pedals Chase© Level 2. The up and down arrow shows the target zone moves vertically on the pedal.

Pedals Emergency Stop©

The DriveSafety Pedals Emergency Stop© interactive exercise was developed to provide practice with emergency braking and to familiarize the participant with the haptic feedback associated with ABS, typically encountered during emergency braking. It begins with a dynamic target zone displayed on the gas pedal, similar to the method of the Pedals Chase© Level 2 (refer to Figure 4, left). The gas pedal target moves up and down on the pedal until the target zone appears on the brake pedal. The number of times the target moves up and down on the pedal is randomized (ranging from a minimum of two to a maximum of six times the gas pedal target crossed the middle of the gas pedal) to prevent anticipatory reactions from the driver. Subsequently, a brake target appears at the top of the brake pedal (Figure 4, right), and an audio cue of “Stop” plays, prompting the participant to apply maximum force on the brake pedal. Upon reaching the brake indicator within the target zone, the participant was required to hold the indicator within this zone for three auditory tones while experiencing haptic brake pedal feedback [36]. This act of maintaining the indicator in the target zone mimics the real-world duration required for a vehicle to stop completely once the brake is fully engaged.

After each brake response, an evaluation of the participant’s performance was displayed on the simulator screen (Figure 5). The exercise comprised four practice trials, followed by three individual tests, each containing four trials. The feedback for the practice and tests was divided into two columns; the left column labeled “Pass?” conveyed the performance outcome of each emergency braking attempt. A display of “Yes” implied that the participant pressed the brake pedal with adequate speed and force, holding the indicator in the target zone for three tones. A “No” meant that the participant either did not press the brake pedal hard/fast enough or did not maintain the indicator’s position within the target zone for the necessary three tones. The right column, titled “Advice”, delivered constructive suggestions for performance enhancement in cases where the participant failed to pass. If the failure was due to insufficient speed and/or force on the brake pedal, "Press harder/faster" was advised. If the participant did not hold the indicator within the brake target zone for three tones, "Hold longer" was displayed. In cases where both mistakes were made, the advice provided was "Press harder/faster". The four initial practice trials served to familiarize participants with the interactive exercise, which was subsequently followed by three tests. Because the primary objective of this study was to determine if new drivers can become familiar with emergency braking using a driving simulator task, to ensure sufficient exposure, participants completed the task twice where each task encompassed the Practice, Test 1, Test 2, and Test 3. Therefore, the participants completed a total of 32 trials, with 16 trials repeated twice to provide enough opportunity for learning and skill development.

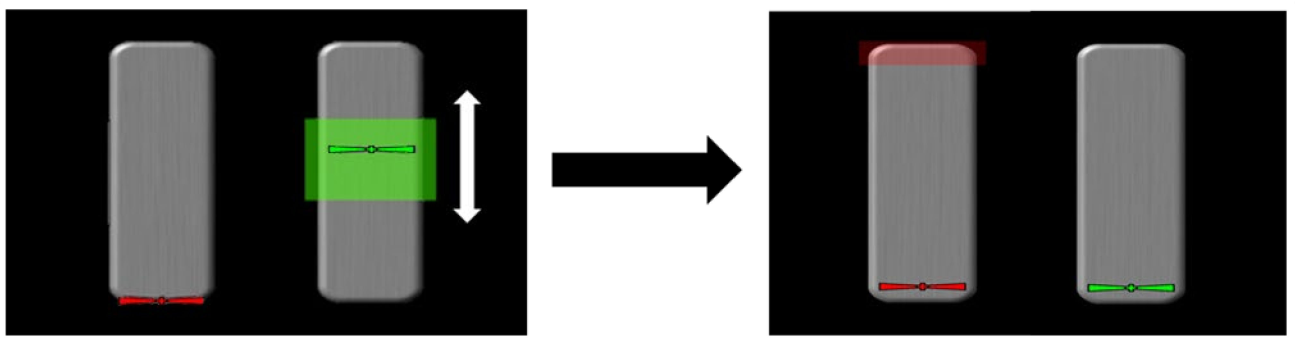


Figure 4. Pedals Emergency Stop© dynamic gas target (**left**) and static brake target (**right**).

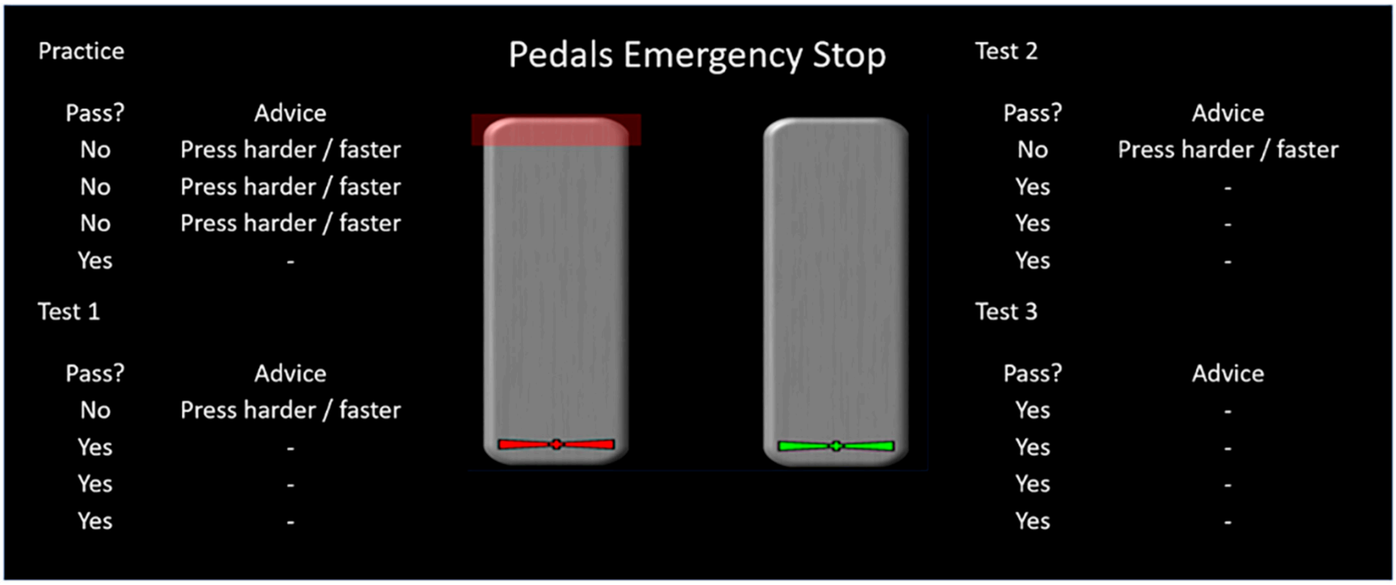


Figure 5. Example illustrates the results obtained after the Pedals Emergency Stop© interactive exercise. In trials where participants did not achieve a pass, advice was provided.

2.3. Procedure

2.3.1. Consent and Background Survey

Prior to the beginning of this study, two researchers went to the high school and spoke to the driver's education students about this study. After hearing about this study, interested participants were given a packet that contained a student consent form, a parent consent form, and a background survey to complete at home. The background survey aimed to understand their existing understanding and knowledge of ABS and included a range of questions from demographic details, familiarity with ABS, and their physical ability to drive. The survey assessed their understanding of ABS, whether they had previously used ABS or practiced activating it, and their experiences during such instances. The findings from this survey provided an initial reference to the participants' understanding and perception of ABS. Participants who wanted to participate in this study returned the packet with a completed student consent form, a completed parent consent form, and a completed background survey before being scheduled to participate. All participants completed all aspects of this study; there was no control group.

2.3.2. Driving Simulator Session Setup and Initial Interactive Exercises

The driving simulator sessions were scheduled during the students' study hall while their classmates were practicing driving with their instructor, with individual sessions lasting between 19 to 54 min, averaging 31 min (*SD* = 7.7 min). The simulator exercises were initiated by adjusting each participant's position in relation to the simulator to ensure comfortable access to the pedals. This was verified by having the participants fully depress the gas and brake pedals three times each. This familiarization was followed by a series of interactive exercises, starting with the Pedals Static© exercise. Participants were given a tutorial explaining each task. For the Pedals Static© and Pedals Chase© tasks, participants practiced until they achieved a minimum performance threshold where they could make up to 1 error in Level 1, 2 errors in Level 2, and 3 errors in Level 3. Next, they progressed to the Pedals Chase© task, where up to 2 errors were permitted for both Level 1 and Level 2. These exercises were designed to ensure that participants had the required motor control to effectively modulate the gas pedal during the subsequent Pedals Emergency Stop© task.

2.3.3. Instructions and Implementation of the Pedals Emergency Stop© Interactive Exercise

Participants were given the instructions for Pedals Emergency Stop©, specifically, "For this task, you will be practicing emergency braking. During emergency braking, the driver presses the brake pedal as fast and as hard as possible to get the vehicle to slow down quickly. It is common for the anti-lock braking system (ABS) to activate during emergency braking. ABS activates to prevent the wheels from locking up. Locked wheels can cause skidding and loss of steering control. ABS quickly holds and releases brake pressure to prevent the wheels from locking up. As a result, the driver feels vibration and hears noise from ABS activating. To practice emergency braking, you must release pressure from the gas pedal, lift your right foot up from the gas pedal and the floor, move it above the brake pedal, press the pedal as quickly as possible all the way down and keep full pressure on the brake pedal. You will experience vibration and noise to simulate ABS in the simulator, continue to hold down the brake pedal when you feel the vibration". For the Pedals Emergency Stop© task, each participant completed two runs, with each run consisting of 16 trials, scored as either pass or fail. All participants completed the full set of 32 total trials.

2.4. ABS Activation Rating Scale: Instructor Training

To quantitatively assess participants' performance during attempts to activate the ABS, Mims et al. [19] collaborated with professional driving instructors to develop a behaviorally anchored rating scale. This scale comprised five distinct ratings, each suggesting a different degree of ABS activation: 1 for "No ABS activation", 2 for "Brief ABS activation", 3 for "Some ABS activation", 4 for "Most ABS activation", and 5 for "Full ABS activation" throughout the entire stop. In addition to providing ratings, instructors provided the reason for the rating whenever a rating fell between 1 and 4. The justifications for the 1 to 4 ratings were also standardized, including "Eased onto the brake pedal", "Let off the brake pedal", "Need to press brake harder", or a combination of "Need to press brake harder, Eased onto the brake pedal".

For this study, the high school driver's education teachers received hands-on training and knowledge from the professional driving instructor who was the rater in the

Mims et al. [19,40] study. This direct knowledge transfer ensured the high school teachers had the expertise needed for this study.

The rating scale from the previous studies involved the instructors rating the drivers from outside of the vehicle on a test track. In contrast, in the current study, the teachers were inside the vehicle, sitting beside the participant as the front passenger. Therefore, the teachers were not able to visually inspect the wheels, which was a part of the original rating system. An adapted approach was used in the current study where during the teacher's rating training, they sat in the front passenger seat, enabling them to become familiar with the rating system from inside the vehicle. Importantly, the vehicle used for this study was equipped with an extended brake pedal on the front passenger side, which allowed the teachers to feel the pedal vibrations during ABS activation. This provided a tactile feedback mechanism, instrumental in rating the degree of ABS activation based on the established scale. This training process ensured that the teachers had a comprehensive understanding of the rating scale and could accurately assess the participants' performance in activating the ABS from inside the vehicle.

2.5. On-Road ABS Emergency Braking Exercise in the Vehicle

Following the completion of the simulator exercises, a final real-world emergency braking exercise was conducted for all participants during the last week of the academic semester. Because participants completed the simulator exercises on different dates throughout the semester, the duration between the simulator exercises and the on-road exercise in the vehicle varied between participants. The variation ranged between 1 and 3 weeks between the participants. All participants completed the on-road portion on a single day and performed the exercise on a road closed to the public, on a day free from rain. Participants completed the driving exercises in a Chevrolet Impala sedan. Prior to the exercises, the vehicle was serviced to confirm the proper functioning of the ABS, and new tires were installed. Since the vehicle is used for driver's education, the instructor had an additional brake pedal extension installed on the passenger side, ensuring the instructor's ability to intervene if needed.

The on-road ABS exercise was conducted on a straight road. Before beginning the exercise, participants were instructed to adjust their seat to a comfortable position and buckle their seatbelt. The driving instructor then explained the task where the driver accelerated up to 35 mph, maintaining this speed until reaching a designated set of cones, at which point they performed an emergency stop where they attempted to activate the ABS. Following each run, the driving instructor rated the participant's performance on an iPad using a 1 ("No ABS activation") to 5 ("Full ABS activation") scale and reasons for the rating, as described in Section 2.5. Each participant completed two runs at 35 mph. A single driving instructor rated the performance of all participants.

2.6. Final Survey

After finishing the vehicle exercise, participants completed a final survey. This survey was designed to gain insight into the participants' experiences and gain feedback on this study. The survey included several open-ended questions related to the participant's demographics (age and gender), experiences with the ABS exercise in the vehicle, understanding of ABS, benefits they received from the emergency braking practice on the simulator, and their views on the amount of practice provided. In addition, the survey contained a section where participants were asked to rate their agreement with various statements on a scale of 1 to 5, with 1 representing "strongly disagree" and 5 denoting "strongly agree". These statements focused on the perceived practicality of the simulator, how the simulator practice improved their understanding of ABS, their preparedness for the ABS exercise in the vehicle, the improvement in their performance during the ABS exercise in the vehicle, and whether they would recommend the emergency braking practice in the simulator to new drivers in driver's education classes or for refresher training. Overall, the final survey served as a comprehensive tool to gather participant feedback and measure the efficacy of this study. After the completion of the final survey, participants were given a $50 gift card as a token of appreciation for their participation in this study.

2.7. Data Analysis Process

Data analyses were conducted in two stages: descriptive analysis and statistical analysis for the simulator exercises and then for the on-road driving exercise. In the first stage, the descriptive analysis provided a summary of participants' demographics, their performance on the simulator exercises, and their responses to the surveys. After the descriptive analysis of the Pedals Emergency Stop© interactive exercise, further statistical analyses such as a trend analysis were performed to evaluate the pattern of ABS activation success rates across trials. A repeated measures analysis of variance (ANOVA) and time-series autocorrelation for trend analysis were conducted to determine whether there was a significant improvement in ABS activation over the course of the trials. Furthermore, for the two forms of advice, "Press harder/faster" and "Hold longer," provided to participants when they did not pass a trial, the chi-square test for independence was conducted to examine if there was a significant association between trial and type of advice. The Type I error rate was set at 0.05.

The second stage of data analysis, a binomial logistic regression, analyzed the Pedals Emergency Stop© simulator data and the on-road exercise data with three independent variables to determine an outcome. Of the two runs in the on-road exercise, the first run data were used for the regression analysis. The binary outcome was the successful or unsuccessful activation of the ABS during the on-road driving exercise. The dichotomous (binary) dependent variable was defined as successful when the rating was 5 (full ABS activation), which is ABS activated throughout the entire stop. Otherwise, the dependent variable was defined as unsuccessful for the rest of the ratings, 1 to 4. The reason for this conversion was to simplify the interpretation of results and to focus on distinguishing between successful and unsuccessful ABS activations. The three independent variables (predictors) were age, prior ABS knowledge, and performance on the Pedals Emergency Stop© simulator exercise. Age was categorized as 15 years old (46.5%), 16 years old (40.8%), and 17 years old and above (12.7%). This age classification was created to assess if significant differences existed in the learning outcomes between the 15 years old, 16 years old, and 17 years old and older groups. These analyses were conducted using IBM SPSS statistical software version 27. Due to the exploratory nature of this study, statistical significance for the logistic regression was assessed at the 0.10 level [44–47].

3. Results

The results section provides insights into the participants' existing knowledge of the anti-lock braking system (ABS), and their experiences with the simulator and on-road exercises. Results from the final survey were provided, which revealed participants' positive perceptions of the exercises.

3.1. Anti-Lock Braking System (ABS) Knowledge and Experience

Regarding participants' knowledge and experience with the anti-lock braking system (ABS) prior to this study, only 1 participant (1.4%) reported having practiced activating ABS in a vehicle, while the vast majority, 70 participants (98.6%), had not. Only 4 participants (5.6%) had ever used ABS, while the rest, 67 (94.4%), had not. When asked what happens when the ABS is activated, 20 participants (28.2%) responded with a response indicating that they knew the answer, 25 participants (35.2%) responded with "No" or an incorrect response indicating they did not know what happens when the ABS is activated, and 26 participants (36.6%) responded with "I don't know".

3.2. Simulator Exercises

3.2.1. Pedals Static© and Pedals Chase© Results

For the Pedals Static© interactive exercise, participants needed an average of 1.3 attempts to pass both the first and second levels, while the third level averaged 1.5 attempts to pass, see Table 1. For the Pedals Chase© interactive exercise, participants required an average of 1.7 attempts to pass the first level, and an average of 1.2 attempts for the second level, see Table 1. All participants were able to complete all training tasks within five attempts.

Table 1. Number of attempts needed to pass Pedals Static© and Pedals Chase© interactive exercises.

Interactive Exercise	Level	Criteria to Pass	Number of Attempts to Pass			
			Average	Standard Deviation	Minimum	Maximum
Pedals Static©	Tutorial	-	-	-	-	-
Pedals Static©	Level 1	up to 1 error	1.3	0.7	1	5
Pedals Static©	Level 2	up to 2 errors	1.3	0.6	1	5
Pedals Static©	Level 3	up to 3 errors	1.5	0.8	1	5
Pedals Chase©	Level 1	up to 2 errors	1.7	1.0	1	5
Pedals Chase©	Level 2	up to 2 errors	1.2	0.6	1	5

3.2.2. Pedals Emergency Stop© Results

For the Pedals Emergency Stop© interactive exercise, participants completed a total of 32 trials. Over these trials, there was an increase in the number of participants who passed, successfully activating the ABS, see Figure 6. During Practice 1, only 18.3% of participants passed and fully activated the ABS. A surge in passed trials was observed between the fourth and eighth trials, where the rate of passed trials jumped from 52.1% to 67.6%. From that point on, there was a plateau with success rates maintaining around 70.4% to 74.6% between trials 9 and 16. By trial 21, a further increase was observed, where the pass rate was 80.3%, and by trial 27, the pass rate peaked at 81.7%. Subsequently, the pass rate fluctuated but remained above 70% for the remaining trials, and by the end of the trials, 77.5% of participants passed, fully activating the ABS.

To better understand these improvements, further statistical analyses were performed to evaluate the pattern of ABS activation success rates across trials. A repeated measures ANOVA on the successful ABS activation rates across the 32 trials showed a statistically significant difference between trials (F (19.747, 1382.257) = 7.662, $p < 0.001$), with a significant linear trend ($p < 0.001$), indicating that the participant's ability to pass progressively improved over time. Additionally, the partial eta squared (η^2) was 0.511 (a large effect size), suggesting that more than half of the variance in passing rates is accounted for by the linear effect. The analysis also revealed significant quadratic ($p < 0.001$, $\eta^2 = 0.367$) and cubic ($p < 0.001$, $\eta^2 = 0.237$) trends, suggesting the fluctuations in the progress of passing over the trials. However, the smaller effect sizes for these trends indicate that the linear component is the dominant trend in the data.

A time-series autocorrelation analysis was conducted on the passing rates across 32 trials, which demonstrated a strong positive trend, suggesting a significant improvement in passing rates over time. Specifically, a high positive autocorrelation coefficient of 0.618 was observed at lag 1, signifying a strong positive relationship between successive trials. A lag represents the interval between two trials. For instance, a lag of 1 refers to the comparison between the passing rate of a given trial and the one immediately preceding it. This analysis helps to evaluate the correlation or the degree of relationship between the outcomes of two trials separated by a trial interval. The autocorrelation coefficient gradually declined with increasing lag, from 0.487 at lag 2, to 0.365 at lag 3, and 0.315 at lag 4. The Box–Ljung statistics for lags 1 through 4 were all significant ($p < 0.001$), implying that the passing rates across trials were not independently distributed. When controlling for other lags, the partial autocorrelation remained strong at 0.618 for lag 1, although the contribution of lags 2 through 4 was notably smaller. These findings highlight that over the course of the 32 trials, participants enhanced their ability to pass, with the passing rates in each trial significantly influenced by those in preceding trials.

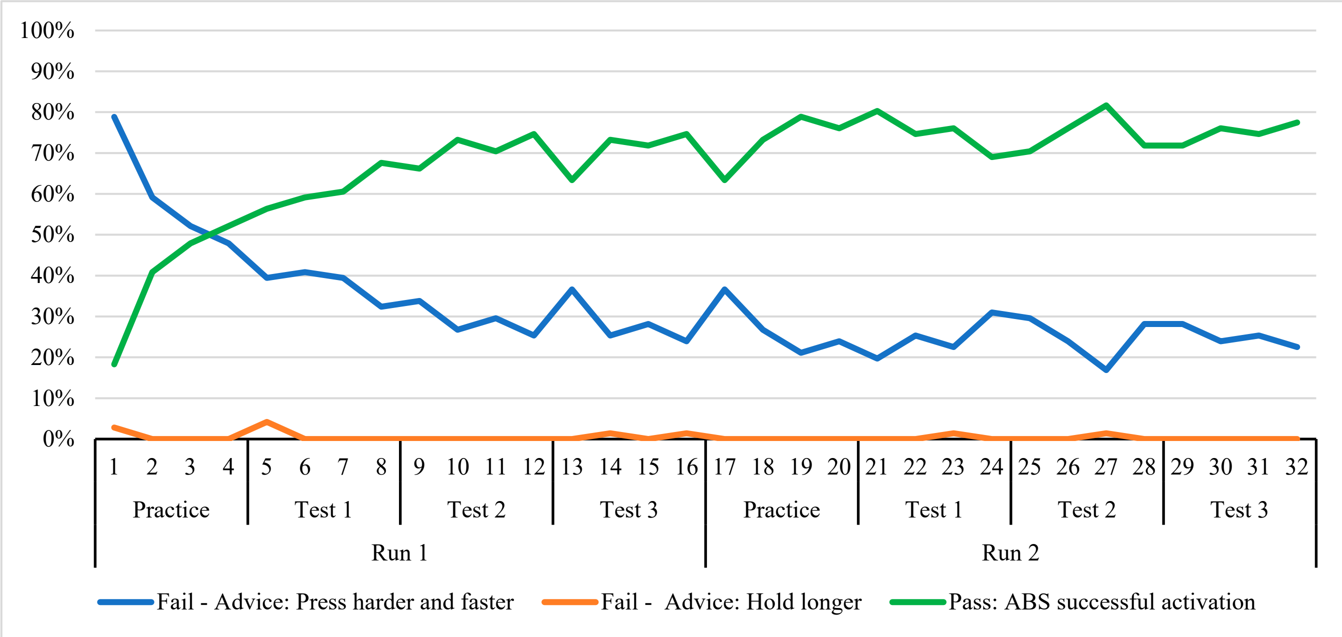


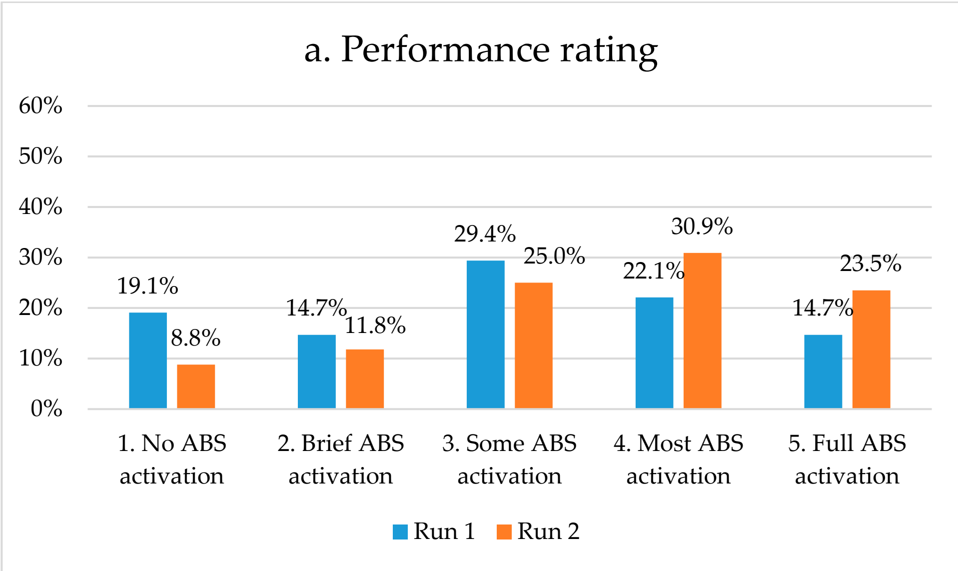
Figure 6. Participants' performance in percentage to pass Pedals Emergency Stop© exercise.

In terms of the feedback/advice received when participants failed a trial, the majority of participants were advised to "Press harder/faster", with 78.9% of participants receiving this advice on the first practice. This proportion decreased to 22.5% by the final trial. Only a very small number of participants received the feedback to "Hold longer", with the greatest percentage of participants receiving this advice during Trial 5 with 4.2% of the participants who did not pass.

Based on the descriptive data, the advice to "Press harder/faster" was given more frequently than "Hold longer". However, a chi-square test for independence was conducted to statistically compare the frequencies of these two types of advice. The chi-square test on 54 degrees of freedom was 60.923 ($p = 0.241$) and was not statistically significant. Therefore, based on the statistical analysis, the type of advice and trial were not associated.

3.3. ABS On-Road Emergency Braking Exercise

Participants completed two runs during the on-road exercise and their performance was rated using a 1 to 5 scale. During the first run, a rating of "1" was earned for 19.1% of the participants, which represents no ABS activation throughout the stop. ABS was briefly activated (rating "2") for 14.7% of the participants, while some ABS activation (rating "3") was observed for 29.4% of the participants. The rating "4" was achieved by 22.1% of participants, which represents ABS activation throughout most of the stop and 14.7% of the participants had full ABS activation (rating "5"), see Figure 7a. For participants who did not fully activate the ABS, the reason for the rating was 51.5% of the participants eased onto the brake pedal, while 26.5% of the participants needed to press the brake harder. A minor proportion (2.9%) of the participants let off the brake pedal, see Figure 7b.



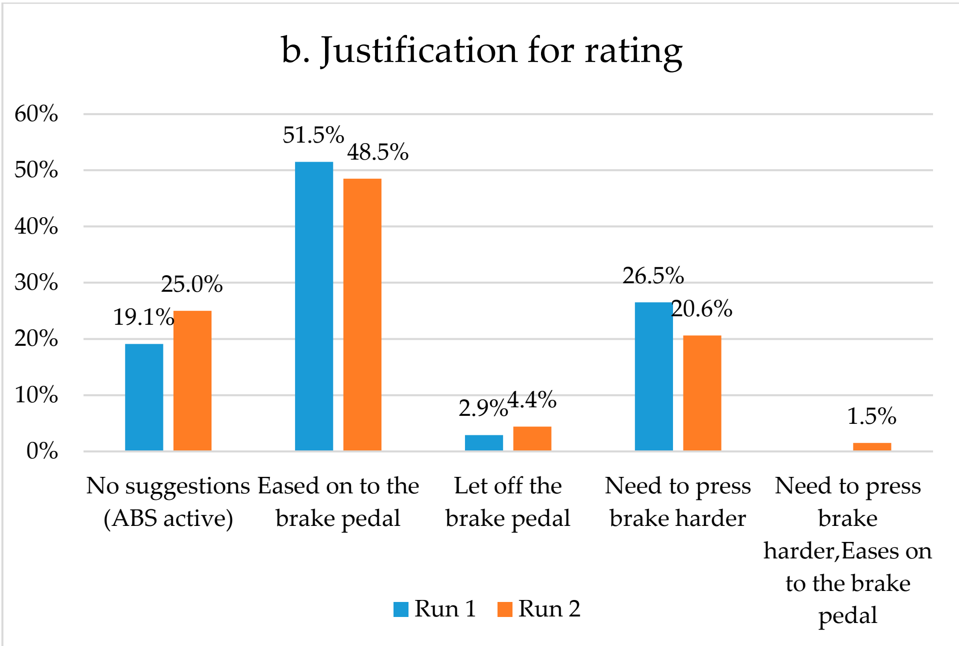


Figure 7. ABS on-road exercise performance. (**a**) The top figure shows the participants' performance ratings of the ABS exercise. (**b**) The instructor's justifications for rating the participants who did not pass ABS activation for both Run 1 and Run 2.

In the second run, the percentage of participants with no ABS activation (rating "1") reduced to 8.8% of the participants, while those with brief ABS activation (rating "2") comprised 11.8% of the participants. Some (rating "3"), most (rating "4"), and full (rating "5") ABS activation ratings were achieved by 25%, 30.9%, and 23.5% of the participants, respectively. Regarding the justification for the rating, 48.5% of participants eased onto the brake pedal, and 20.6% needed to press the brake harder. A small number of participants (4.4%) let off the brake pedal and 1.5% needed to press the brake harder and eased onto the brake pedal.

3.4. The Influence of the Simulator Interactive Exercises on the On-Road Emergency Braking Exercise

An exploratory binomial logistic regression was conducted for the first run outcome of successful activation of the ABS (i.e., rating 5) during the on-road driving exercise considering the age, prior ABS knowledge, and performance on the Pedals Emergency Stop© interactive exercises as predictors. The regression model was statistically significant (χ^2 (4) = 10.372, $p < 0.05$), with a correct classification rate of 85.3% cases. Based on Wald tests, the Pedals Emergency Stop© performance was a statistically significant predictor, see Table 2. The positive regression coefficient for Pedals Emergency Stop© performance indicated that for every additional trial passed during the simulator exercise (out of 32 attempts), the odds of achieving full ABS activation (rating = 5) during the on-road exercise increased. For each additional passed trial during the simulator exercise, the odds of achieving full ABS activation in the on-road exercise increased by approximately 12.3%, while holding all other variables constant. This suggests that participants with more passed trials during the simulator exercise were more likely to achieve full ABS activation in the on-road exercise. The other predictors in the model (age and prior ABS knowledge) were not statistically significant in predicting full ABS activation during the on-road exercise at the 0.10 level.

Table 2. Binomial logistic regression result of the ABS on-road exercise.

Predictor	*B*	Standard Error	Wald χ^2 (1)	Odds Ratio	Odds Ratio 95% CI (Lower, Upper)	
Age—15 years old [a]	−1.361 [ns]	1.41	0.93	0.26	0.02	4.06
Age—16 years old [a]	0.819 [ns]	1.19	0.47	2.27	0.22	23.43
ABS activation knowledge	−1.461 [ns]	0.90	2.62	0.23	0.04	1.36
Pedals Emergency Stop© performance	0.116 *	0.07	2.78	1.12	0.98	1.29

[a] Reference is 17 years old and above; [ns] not significant; * $p < 0.10$.

3.5. Final Survey Results

After the completion of this study, participants were asked to complete a survey. Descriptive analyses were performed on these items.

3.5.1. Hardest Part of the On-Road Emergency Braking Exercise

For this open-ended survey question, participants indicated a variety of challenges experienced during the on-road emergency braking exercise. Approximately 35% of the participants found it hard to press the brake rapidly and forcefully enough. Additionally, 25% of the participants reported struggling to accelerate quickly enough. Some participants (10%) found the abruptness of the stop and the feel of the brakes as a challenge. Another 25% of the participants reported no difficulties with the exercise.

3.5.2. Participants' Understanding of ABS after the On-Road Emergency Braking Exercise

Participants were asked if they thought their understanding of ABS was improved because of this study. About 95% of the participants reported an improved understanding of ABS due to their involvement in the study. The primary reasons given included gaining firsthand experience in performing emergency braking (30% of respondents), understanding the functionality and the importance of ABS in preventing collisions (20%), and realizing the need for hard and quick braking to activate the ABS (15%). Another 10% of the participants mentioned that this study made them realize the ability to maintain control over the vehicle, particularly steering, even during hard braking. Around 5% of the participants expressed that this study did not change their understanding of ABS.

3.5.3. Benefited and/or Performed Better in the Vehicle as the Result of the Emergency Braking Practice on the Simulator

The participants overwhelmingly agreed that the simulator-based emergency braking practice influenced their performance in the vehicle during the on-road exercise. Around 98% of the participants reported that the emergency braking exercise in the simulator positively influenced their ability to handle emergency braking in an actual vehicle. The reasons varied, with 35% of the participants attributing the improvement to the realistic experience the simulation provided. Another 25% of the participants emphasized that the practice allowed them to understand the degree of force required to activate the ABS. About 15% of the participants mentioned that the simulation helped them overcome initial hesitations and nervousness associated with hard braking. Another 5% of the participants indicated that they were able to transition more smoothly from the gas to the brake pedal after the simulation exercise.

3.5.4. Amount of Emergency Braking Practice on the Simulator

Most participants (93%) reported they received sufficient emergency braking practice on the simulator. However, the remaining participants (7%) felt the need for more practice sessions. Suggestions varied from an additional week or two of practice to one or two extra practice sessions per week, to just two or three more sessions overall.

3.5.5. Learning from the Study

Around 30% of the participants reported they learned how to effectively use the ABS and the associated hard braking required for its activation. They also learned about ABS' usefulness in emergency situations. Another 10% of the participants emphasized how this study helped them understand the significance of fast and hard braking in response to emergencies. Around 15% highlighted that ABS allows them to maintain steering control of the vehicle even while braking hard, emphasizing the enhanced safety it provides. Another 10% of the participants mentioned how the ABS functions and the level of control it provides during high-speed braking. However, about 5% of the participants expressed uncertainty regarding what they learned from this study.

3.5.6. Participant Feedback on the Use of Pedals Emergency Stop© for ABS Education and Training

As shown in Table 3, participants provided their feedback on the Pedal Emergency Stop© exercise using statements about the exercise using a 5-point scale (1—"strongly disagree" to 5—"strongly agree"). Questions were identical to the items used in Mims' research [40].

Table 3. Participant feedback on the use of Pedals Emergency Stop©. Questions identical to those used by Mims [40].

Participant Feedback	*M*	*SD*
I found the emergency braking practice on the simulator to be a practical tool	4.4	0.8
I think my understanding of ABS was improved from the emergency braking practice on the simulator	4.5	0.8
I think the emergency braking practice on the simulator prepared me for the ABS exercise in the vehicle	4.5	0.8
I feel as though my performance during the ABS exercise in the vehicle was improved from the emergency braking practice on the simulator	4.5	0.7
I would recommend the emergency braking practice on the simulator for new drivers in drivers education classes	4.7	0.7
I would recommend the emergency braking practice on the simulator for refresher training	4.6	0.7

Note: 5-point scale rating range is 1 to 5.

4. Discussion

This study aimed to explore the potential benefits of an interactive simulator exercise on the understanding and performance of emergency braking with ABS activation for novice teenage high school participants. The results highlight that the Pedals Emergency Stop© exercise significantly improved the participants' ability to activate the ABS in the on-road emergency braking exercise. Prior to the Pedals Emergency Stop© exercise, for the Pedals Static© and Pedals Chase© exercises, participants were able to pass the levels within a small number of trials (between 1.2 and 1.7 trials on average), indicating the simulator exercises were comprehensible and well understood. Participants showed a learning curve, with most individuals successfully completing the Pedals Static© and Pedals Chase© exercises within five attempts.

The results from the Pedals Emergency Stop© exercise showed that the participant's ability to pass or successfully complete an emergency braking stop where ABS was activated improved progressively over time. Initial passing rates were low, with only 18.3% of participants managing to pass during the first trial. However, by trial 27, the passing rate peaked at 81.7%, and by the end of the trials (32 trials), 77.5% of participants successfully passed a trial. This increase in passes over the trials was significant ($p < 0.001$), and the large effect size (partial $\eta^2 = 0.511$) in the repeated measures ANOVA suggested that more than half of the variance in passing rates was due to the linear effect of progressive training and familiarity with the system. A time-series autocorrelation analysis supported this, showing a strong positive relationship between successive and passed trials. A high positive autocorrelation coefficient of 0.618 at lag 1 indicated a significant improvement in passed trials over time. Interestingly, the two pieces of advice provided to participants who did not pass a trial were not statistically significant between them. Although the advice to "Press harder/faster" was given more frequently, the chi-square test indicated that there was no strong evidence to suggest that this type of advice was given significantly more often than "Hold longer".

The on-road exercise findings corroborated the Pedals Emergency Stop© simulator exercise results. Participants who passed more trials during the Pedals Emergency Stop© exercise were more likely to activate the ABS fully during the on-road exercise. For each additional trial passed during the Pedals Emergency Stop© exercise, the odds of achieving full ABS activation during the on-road exercise increased by approximately 12.3%. This highlights the potential benefits of the Pedals Emergency Stop© simulator exercise in preparing participants for real-world ABS activation. In terms of age and prior ABS knowledge, neither were significant predictors of successful emergency braking with full ABS activation. This suggests that the Pedals Emergency Stop© simulator training appears to have the potential to enhance emergency braking with full ABS activation on the road.

The results from the final survey showed that 95% of participants reported an improved understanding of ABS as a result of the study, with 98% stating that the Pedals Emergency Stop© exercise positively influenced their ability to handle emergency braking in an actual vehicle. Furthermore, 93% of the participants mentioned they received sufficient emergency braking practice on the simulator. Participants positively rated the Pedals Emergency Stop© exercise for ABS education and training. The exercise was considered a practical tool for understanding ABS ($M = 4.5$) and preparing for the ABS exercise in the vehicle ($M = 4.5$). Participants strongly recommended the emergency braking practice on the simulator for both new drivers in driver education classes ($M = 4.7$) and for refresher training ($M = 4.6$).

Overall, the results suggest that the Pedals Emergency Stop© interactive simulator exercise significantly enhances the participants' understanding and performance with emergency braking with ABS activation. These findings emphasize the potential usefulness of such simulator exercises in driver's education and training programs, potentially leading to safer road behaviors and outcomes.

5. Conclusions

Considering the results, this study highlights the potential value and importance of the Pedals Emergency Stop© interactive simulator exercise in enhancing the proficiency and comprehension of emergency braking among novice teenage drivers. With their ability to provide iterative, real-time feedback, such simulator-based approaches may play a pivotal role in fostering essential driving skills before the actual on-road experience. While the simulator training demonstrated a progressive improvement in participants' capabilities, the real-world implications and the overwhelmingly positive feedback from participants were even more compelling. Including these simulator exercises in the driver's education program represents an innovative step, in line with the worldwide focus on proactive road safety initiatives. While the results of this study are encouraging, future studies with control groups are needed to determine the true value of this training.

To further enhance the effectiveness of driver education programs, incorporating simulator-based exercises into a standard curriculum may be beneficial to provide novice drivers with a safe and controlled environment to practice and understand the nuances of emergency braking with ABS. Moreover, future research should aim to include more comprehensive training modules of dynamic driving situations, utilize control groups for comparison, and employ objective measures for evaluating skill transfer to real-world driving.

6. Future Research and Study Limitations

The results of our study indicate that novice teen drivers felt they benefited from a simulator-based ABS task incorporated into their driver's education course. Future research is needed to conduct an identical study with a control group to evaluate the effectiveness of the training for teens with and without the training. A larger sample size will be needed with this follow-up study as well as a more stringent significance level of $p < 0.05$.

The participants were students from a single high school and the age distribution included teens learning to drive in this geographic location. Future studies should include novice drivers from a wide range of states to study the impact of license age on the understanding and performance of ABS braking as well as to increase the generalizability of the results to all novice drivers.

While there is a predominance of automatic transmissions in the US, some drivers use manual transmissions [48]. Emergency braking, especially in coordination with the clutch in manual vehicles, has a unique set of challenges that require dedicated research. Future studies can explore the development and efficacy of simulators that specifically address the simultaneous actuation of the clutch and brake pedals during emergencies, ensuring that drivers are well trained to handle such situations in manual transmission vehicles.

The Brake Assist System (BAS) or Emergency Brake Assist (EBA) in many modern vehicles is designed to detect emergency braking situations and optimize the brake pressure, ensuring maximum braking force and potentially reducing stopping distances. This study focused on the fundamentals of emergency braking using ABS and did not focus on the additional features of advanced systems like BAS. The vehicle used for this study was not equipped with BAS. Recognizing its significance, especially with its increasing prevalence in newer vehicles, future studies can benefit from examining how BAS interacts with drivers' behaviors and how training methodologies could be adapted to account for this advanced technology.

Author Contributions: Conceptualization, R.G., J.O.B. and L.M.; methodology, R.G., J.O.B., M.D., R.C. and D.I.; software, R.G.; validation, R.G., M.D. and R.C.; formal analysis, R.G., J.O.B. and L.M.; investigation, J.O.B., P.J.R. and L.M.; resources, R.G., J.O.B., M.D. and R.C.; data curation, R.G.; writing—original draft preparation, R.G.; writing—review and editing, R.G. and J.O.B.; visualization, R.G. and J.O.B.; supervision, J.O.B.; project administration, J.O.B.; funding acquisition, J.O.B. All authors have read and agreed to the published version of the manuscript.

Funding: This study was made possible by a gift from the American Honda Motor Co., Inc. Foundation.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Clemson University (protocol code IRB2022-0333).

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: Data available on request due to restrictions, e.g., privacy or ethical.

Acknowledgments: The authors are grateful to Dorman High School, Spartanburg, for their willingness to participate in this research study. The authors would like to acknowledge the contributions of Casey Jenkins, Chad Eisele, Rebecca Pool, Braden Hudgins, Drew Girshovich, and Trevor Hobbs for their assistance in the data collection process and Conner Miller for his assistance in the data validation process. Furthermore, the authors are grateful to Ken Melnrick for his helpful comments on the manuscript.

Conflicts of Interest: Mark Dempsey and Robert Cooper are employed at Dorman High School, Lauren Mims is employed at Westat, and Donnie Isley is employed at the BMW Performance Center. Through Clemson University, Johnell Brooks has multiple invention disclosures and Lauren Mims has an invention disclosure. Clemson University has joint intellectual property with DriveSafety, Inc., the driving simulator company that manufactures, sells, and distributes the DriveSafety driving simulators.

References

1. Hashmi, S. Adolescence: An age of storm and stress. *Rev. Arts Humanit.* **2013**, *2*, 19–33.
2. Alderman, E.M.; Johnston, B.D.; Breuner, C.; Grubb, L.K.; Powers, M.; Upadhya, K.; Wallace, S.; Hoffman, B.D.; Quinlan, K.; Agran, P.; et al. The Teen Driver. *Pediatrics* **2018**, *142*, e20182163. [CrossRef] [PubMed]
3. Kesselring, S. Corporate Mobilities Regimes. Mobility, Power and the Socio-geographical Structurations of Mobile Work. *Mobilities* **2015**, *10*, 571–591. [CrossRef]
4. NHTSA. *Traffic Safety Facts 2023 a Compilation of Motor Vehicle Crash Data*; Report No. DOT HS 813 473; NHTSA: Washington, DC, USA, 2023.
5. O'Neal, E.E.; Wendt, L.; Hamann, C.; Reyes, M.; Yang, J.; Peek-Asa, C. Rates and predictors of teen driver crash culpability. *J. Safety Res.* **2023**, *86*, 185–190. [CrossRef] [PubMed]
6. Hossain, M.M.; Zhou, H.; Sun, X. A Clustering Regression Approach to Explore the Heterogeneous Effects of Risk Factors Associated with Teen Driver Crash Severity. *Transp. Res. Rec. J. Transp. Res. Board* **2023**, *2677*, 1–21. [CrossRef]
7. Khattak, A.J.; Ahmad, N.; Wali, B.; Dumbaugh, E. A taxonomy of driving errors and violations: Evidence from the naturalistic driving study. *Accid. Anal. Prev.* **2021**, *151*, 105873. [CrossRef]
8. Stanton, N.A.; Salmon, P.M. Human error taxonomies applied to driving: A generic driver error taxonomy and its implications for intelligent transport systems. *Saf. Sci.* **2009**, *47*, 227–237. [CrossRef]
9. Hulme, A.; Stanton, N.A.; Walker, G.H.; Waterson, P.; Salmon, P.M. Accident analysis in practice: A review of Human Factors Analysis and Classification System (HFACS) applications in the peer reviewed academic literature. *Proc. Hum. Factors Ergon. Soc. Annu. Meet.* **2019**, *63*, 1849–1853. [CrossRef]
10. Williams, A.F. Teenage drivers: Patterns of risk. *J. Saf. Res.* **2003**, *34*, 5–15. [CrossRef]
11. Job, R.F.S. The application of learning theory to driving confidence: The effect of age and the impact of random breath testing. *Accid. Anal. Prev.* **1990**, *22*, 97–107. [CrossRef]
12. Deery, H.A. Hazard and Risk Perception among Young Novice Drivers. *J. Saf. Res.* **1999**, *30*, 225–236. [CrossRef]
13. Shope, J.T. Influences on youthful driving behavior and their potential for guiding interventions to reduce crashes. *Inj. Prev.* **2006**, *12* (Suppl. S1), i9–i14. [CrossRef] [PubMed]
14. Mims, L.; Brooks, J.O.; Jenkins, C.; Schwambach, B.; Gubitosa, D. Teenage Drivers' Views of a Classroom and Closed-Road Post-License Advanced Driving Program, Guard Your Life. *Safety* **2020**, *6*, 44. [CrossRef]
15. Mayhew, D.R.; Simpson, H.M. The safety value of driver education an training. *Inj. Prev.* **2002**, *8* (Suppl. S2), ii3–ii8. [CrossRef] [PubMed]
16. Beanland, V.; Goode, N.; Salmon, P.M.; Lenné, M.G. Is there a case for driver training? A review of the efficacy of pre- and post-licence driver training. *Saf. Sci.* **2013**, *51*, 127–137. [CrossRef]
17. Akbari, M.; Lankarani, K.; Heydari, S.T.; Motevalian, S.A.; Tabrizi, R.; Sullman, M. Is driver education contributing towards road safety? A systematic review of systematic reviews. *J. Inj. Violence Res.* **2021**, *13*, 69–80. [CrossRef] [PubMed]
18. Nalmpantis, D.; Naniopoulos, A.; Bekiaris, E.; Panou, M.; Gregersen, N.; Falkmer, T.; Naten, G.; Dols, J. 'Trainer' Project: Pilot applications for the evaluation of new driver training technologies. In *Traffic and Transport Psychology: Theory and Application*; Elsevier: Amsterdam, The Netherlands, 2005; pp. 141–156. ISBN 0-08-044379-6.
19. Mims, L.; Brooks, J.O.; Jenkins, T.M.; Jenkins, C.; Neczek, J.; Isley, D.; Bormann, A.; Hayes, L.; Gubitosa, D. Instructor's Rating of Driver's Performance during an Anti-Lock Braking Exercise on a Closed-Road Course. *Safety* **2021**, *7*, 62. [CrossRef]
20. Forkenbrock, G.; Flick, M.; Garrott, W.R. *A Comprehensive Light Vehicle Antilock Brake System Test Track Performance Evaluation*; SAE Technical Paper 1999-01-1287; SAE International: Warrendale, PA, USA, 1999. [CrossRef]
21. Arehart, C.; Radlinski, R.W.; Hiltner, E. *Light Vehicle ABS Performance Evaluation—Phase II*; Final Report; National Highway Traffic Safety Administration: Washington, DC, USA, 1992.
22. Rompe, K.; Schindler, A.; Wallrich, M. Advantages of an anti-wheel lock system (ABS) for the average driver in difficult driving situations. In Proceedings of the 11th Experimental Safety Vehicles Conference, Washington, DC, USA, 12–15 May 1987.
23. Webb, C.N. *Estimating Lives Saved by Electronic Stability Control, 2011–2015*; Traffic Safety Facts Research Note, Report No. DOT HS 812 391; NHTSA: Washington, DC, USA, 2017.

24. Broughton, J.; Baughan, C. The effectiveness of antilock braking systems in reducing accidents in Great Britain. *Accid. Anal. Prev.* **2002**, *34*, 347–355. [CrossRef]
25. Mollenhauer, M.A.; Dingus, T.A.; Carney, C.; Hankey, J.M.; Jahns, S. Anti-lock brake systems: An assessment of training on driver effectiveness. *Accid. Anal. Prev.* **1997**, *29*, 97–108. [CrossRef]
26. Brooks, J.; Kellett, J.; Seeanner, J.; Jenkins, C.; Buchanan, C.; Kinsman, A.; Kelly, D.; Pierce, S. Training the Motor Aspects of Pre-driving Skills of Young Adults With and Without Autism Spectrum Disorder. *J. Autism Dev. Disord.* **2016**, *46*, 2408–2426. [CrossRef]
27. Randall, K.N.; Ryan, J.B.; Stierle, J.N.; Walters, S.M.; Bridges, W. Evaluating and Enhancing Driving Skills for Individuals With Intellectual Disabilities Through Simulator Training. *Focus. Autism Other Dev. Disabl.* **2021**, *36*, 191–200. [CrossRef]
28. Classen, S.; Brooks, J. Driving Simulators for Occupational Therapy Screening, Assessment, and Intervention. *Occup. Ther. Health Care* **2014**, *28*, 154–162. [CrossRef] [PubMed]
29. Cox, D.J.; Davis, M.; Singh, H.; Barbour, B.; Don Nidiffer, F.; Trudel, T.; Mourant, R.; Moncrief, R. Driving Rehabilitation for Military Personnel Recovering From Traumatic Brain Injury Using Virtual Reality Driving Simulation: A Feasibility Study. *Mil. Med.* **2010**, *175*, 411–416. [CrossRef] [PubMed]
30. Akinwuntan, A.E.; Wachtel, J.; Rosen, P.N. Driving Simulation for Evaluation and Rehabilitation of Driving After Stroke. *J. Stroke Cerebrovasc. Dis.* **2012**, *21*, 478–486. [CrossRef] [PubMed]
31. Sætren, G.B.; Pedersen, P.A.; Robertsen, R.; Haukeberg, P.; Rasmussen, M.; Lindheim, C. Simulator training in driver education—Potential gains and challenges. In *Safety and Reliability—Safe Societies in a Changing World*; CRC Press: London, UK, 2018; pp. 2045–2049. [CrossRef]
32. Fisher, D.; Rizzo, M.; Caird, J.; Lee, J. *Handbook of Driving Simulation for Engineering, Medicine, and Psychology*; CRC Press: Boca Raton, FL, USA, 2011.
33. Pradhan, A.K.; Fisher, D.L.; Pollatsek, A. Risk Perception Training for Novice Drivers. *Transp. Res. Rec. J. Transp. Res. Board* **2006**, *1969*, 58–64. [CrossRef]
34. Iqbal, M.; Sari, K.; Ade Sekarwati, K.; Kemala Putri, D. Developing PC-Based Driving Simulator System for Driver Behavior Analysis Research. *J. Phys. Conf. Ser.* **2020**, *1566*, 012075. [CrossRef]
35. Chan, E.; Pradhan, A.K.; Pollatsek, A.; Knodler, M.A.; Fisher, D.L. Are driving simulators effective tools for evaluating novice drivers' hazard anticipation, speed management, and attention maintenance skills? *Transp. Res. Part F Traffic Psychol. Behav.* **2010**, *13*, 343–353. [CrossRef]
36. Mims, L.; Brooks, J.; Gangadharaiah, R.; Jenkins, C.; Isley, D.; Melnrick, K. Evaluation of a Novel Emergency Braking Task on a Driving Simulator with Haptic Anti-Lock Braking System Feedback. *Safety* **2022**, *8*, 57. [CrossRef]
37. Alonso, F.; Faus, M.; Riera, J.V.; Fernandez-Marin, M.; Useche, S.A. Effectiveness of Driving Simulators for Drivers' Training: A Systematic Review. *Appl. Sci.* **2023**, *13*, 5266. [CrossRef]
38. Wynne, R.A.; Beanland, V.; Salmon, P.M. Systematic review of driving simulator validation studies. *Saf. Sci.* **2019**, *117*, 138–151. [CrossRef]
39. McGehee, D.V.; Mazzae, E.N.; Baldwin, G.H.S.; Grant, P.; Simmons, C.J.; Hankey, J.M.; Forkenbrock, G.J. *NTHSA Light Vehicle Antilock Brake Systems Research Program Task 5, Part 1: Examination of Drivers' Collision Avoidance Behavior Using Conventional and Antilock Brake Systems on the Iowa Driving Simulator*; NHTSA: Washington, DC, USA, 2000.
40. Mims, L. Investigating Drivers' Knowledge and Experience with the Anti-lock Braking System (ABS) which Led to the Development and Evaluation of an Emergency Braking Training Exercise Using a Driving Simulator with Haptic Pedal Feedback. All Dissertations, 2022, 3070. Available online: https://tigerprints.clemson.edu/all_dissertations/3070 (accessed on 2 February 2023).
41. Fanatec ClubSport V3 Inverted Pedals. Available online: https://fanatec.com/us-en/pedals/clubsport-pedals-v3-inverted (accessed on 9 April 2023).
42. ButtKicker. Available online: https://thebuttkicker.com/products/buttkicker-gamer-plus/ (accessed on 21 April 2023).
43. DriveSafety. Available online: https://drivesafety.com/research-driving-simulators/ (accessed on 12 March 2023).
44. Stevens, J.P. *Applied Multivariate Statistics for the Social Sciences*; Routledge: New York, NY, USA, 2012.
45. Ma, L.; Cao, J. How perceptions mediate the effects of the built environment on travel behavior? *Transportation* **2019**, *46*, 175–197. [CrossRef]
46. Handy, S.; Cao, X.; Mokhtarian, P. Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transp. Res. D Transp. Environ.* **2005**, *10*, 427–444. [CrossRef]
47. Shi, K.; Yang, Y.; De Vos, J.; Zhang, X.; Witlox, F. Income and commute satisfaction: On the mediating roles of transport poverty and health conditions. *Travel. Behav. Soc.* **2022**, *29*, 297–307. [CrossRef]
48. Hawley, D. What Cars Have a Manual Transmission? Available online: https://www.jdpower.com/cars/shopping-guides/what-cars-have-a-manual-transmission/ (accessed on 22 September 2023).