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RESEARCH FINAL REPORT

Improving Data Validity in a Driving Simulator: Effects of Guided Practice in Older Adults on Simulator Handling Skill and Incidence of Simulator Sickness

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Disclaimer

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Abstract

Driving simulator studies are an important tool for examining safety issues while minimizing risk to participants, and are especially valuable when studying older drivers. However, older drivers often do not have much experience with virtual environments, and the current experiment (N = 115) explored the questions of whether older drivers who have not used a driving simulator previously are able to drive a simulator in a realistic manner, whether skills training in the form of guided practice with feedback can enable them to do so, and whether lack of skill in driving a simulator poses a threat to external validity. Results indicate that practice without feedback provided no benefit relative to a group who had no practice, with over half the data from those groups being invalid. The groups which received guided practice had higher proportions of valid data, with the group receiving interactive, automated feedback performing as well as the reference group of younger drivers. Subject to extending these findings to multiple experimental designs, the results strongly support the need for brief, focused training in simulator handling skills, with feedback provided during practice, for older participants in driving simulator studies.

1. Problem Statement and Objectives

Simulator studies are particularly useful in studying issues related to safety and transportation in an aging population. Environmental variables such as weather, traffic, and onset of events such as pedestrian crossings can be brought under precise experimental control, accurate performance measurements not possible in the field can be made, and scenarios can be designed to test safety issues and potential countermeasures which would not be ethical in the field due to their dangerous nature. The ability to conduct research which would otherwise be unsafe or impractical allows questions to be explored which become even more critical as the baby boomers swell the ranks of older drivers on the roadways. Older drivers are at elevated risk for involvement in crashes (Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998), and are more likely to be killed or suffer severe injury in a crash (e.g. Matthias, De Nicholas, & Thomas, 1996; Li, Braver, & Chen, 2003). These risks underscore the need for sound research. In this project, we address two issues which can have substantial negative impact on the ability to interpret and generalize from simulator studies, as well as on the cost involved in running such studies, and improvement in these areas will provide direct benefits to ASAP Center supported research with simulators and older adults.

The first issue we address is data validity, which can be severely compromised by individual differences in skill in handling a simulator. When participants are unskilled in simulator driving, they may not be experiencing the intended experimental manipulation. As well as undermining the integrity of the collected data, unskilled participants pose a threat to external validity: if they are unable to handle a simulator as if it were a real car, participants' performance in the simulator will be less representative of their driving behaviors in the real world, limiting the generalizability of results.

The second issue we address is high rates of attrition in older participants due to simulator sickness, which in prior studies at FSU, funded by the Florida Department of Transportation and conducted by Drs. Walter Boot and Neil Charness, has been as high as 50%. There is ample evidence that older adults are differentially susceptible to simulator sickness (Stanney et al., 2002; Freund & Green, 2006; Mullen, Weaver, Riendeau, Morrison, & Bédard, 2010). Loss of data in a simulator study is costly, especially when research involves older participants. Such participants are more difficult and expensive to recruit, and it is not only sensible from a cost-management perspective to seek to minimize simulator sickness and participant discomfort, but necessary as well due to the ethical imperative to minimize potential harms (Belmont Report, 1979). Furthermore, it is well established that simulator sickness is itself a threat to data validity, to the degree that any simulator study which fails to account for levels of simulator sickness has compromised the generalizability of its findings (for a thorough review, see Stoner, 2011), making our objectives which relate to this topic additionally relevant to the data validity aspect of the project as well.

Objectives

Specific objectives of this research were to:

1) Further develop our training paradigm, in which participants receive information and feedback as they practice specific simulator handling skills, by extending the training to curving roads and 90-degree turns.

2) Determine whether an automated guided practice scenario structured in the same way is similarly effective for improving data validity, or whether human feedback is an integral component.

3) Examine whether receiving guided practice reduces simulator sickness in older adults.

Background

Data Validity

Under all empirical experimental paradigms, one of the premises underlying any conclusion is that the experimental manipulation had an effect. If a manipulation has no effect on the participants, then despite having been nominally assigned to different conditions they are in fact in the same condition. In such a case, if the effect for which the experiment is intended to produce evidence exists, it will nevertheless fail to be detected – a case of Type II error. In a driving simulator experiment, scenarios must be programmed ahead of time based on assumptions of participants' behavior. These assumptions are reasonable, prima facie, such as that participants who are instructed to maintain a speed of 45 mph will be able to do so, or that participants will drive the simulator much as they drive their own vehicles. When participants' behavior violates these assumptions, the obvious problem is a serious threat to external validity: if a participant is unable to handle a simulator the way they handle a real car, the data they produce cannot support generalizations to behavior in the field.

A less obvious problem is that the intended manipulation may not take place for those participants. The implications are twofold. First, they are essentially performing a different task than others in their assigned condition are performing, so their data cannot contribute to answering the research question. Second, they are essentially performing a different task than the researcher believes they are performing. This is the more insidious of the two, because the researcher is not aware that their data cannot contribute and that any inferences made from such data are compromised. In short, an experimenter may conclude that older adults, on average, tend not to perform as well as younger adults on some task A, when the accurate conclusion would have been that under the circumstances constructed within the experiment, older adults were more likely than younger adults to be doing task B, impairing their apparent performance on task A.

Experimenters conducting driving simulator studies necessarily have a certain degree of technological savvy and familiarity with virtual environments, so that it seems quite natural to sit in a simulated environment and respond to it as if it were real. We speculate that this is also the case for younger and many middle-aged participants, who have grown up in an age where virtual environments abound, whether in the form of video games or actual virtual reality simulations. However, in numerous driving simulator studies focusing on age-related differences over the years, we have frequently observed behavior in older participants which suggests that many of them do not have the particular skillset which allows a person to sit at a driving simulator, automatically map the experience to sitting in a car, and transfer the experience, knowledge, and skills of a lifetime of driving to handling the simulator. These participants had all been screened and demonstrated normal cognitive functioning, and many were highly educated. They also all drove regularly, at least once a week, and had just driven to the experiment location, and yet exhibited unexpected and incongruous behaviors such as pressing the gas pedal and running off the road because they hadn't realized, despite the experimenter having just explained that the simulator is set up exactly like a real car, that they needed to put their hands on the steering wheel and steer the car. Despite the frequency of such observations in our lab, we were unable to find any literature addressing this phenomenon, which we believe to be a cohort effect: a lack of skill in transferring real world knowledge and skills to a virtual environment.

In the current project, we include two intersections modeled after a previous study which tested the effect of varying yellow light durations on red light running (Boot, Charness, Mitchum, Landbeck, & Stothart, 2014), in which we saw a clear example of many participants not experiencing the intended manipulation, and additional recruitment was needed to replace those datasets. The manipulation involved timing a yellow light change to occur at a moment when the participant was in a “dilemma zone,” meaning they should be at a distance from the intersection where it is unclear to them whether the best option is to stop, or to go through the yellow light. We chose to include this condition at two intersections because it offers a straightforward way to compare data validity between groups; if they were in the dilemma zone when the light turned yellow, they experienced the intended manipulation and the trial is considered valid.

Each of the training scenarios was designed for participants to practice specific skills we had observed many participants struggling with during previous studies. They were also provided with information about why the skills needed to be practiced, and given only the information for the current set of skills to be practiced. Subsequent training scenarios built upon earlier ones, so that although the focus was on new skills, they were also integrating one or more of the skills previously practiced.

Simulator Sickness

Given the value of simulators in domains ranging from military flight training to civil engineering to human factors research, together with the challenges posed by simulator sickness, it is hardly surprising that there exists a wealth of research into factors contributing to simulator sickness and ways to minimize it. Stoner (2011) points out, however, that despite all we have learned, even in an optimally configured simulator with ideal scenario design, some sickness will still occur in some proportion of participants. We must also assume that base minimum level of sickness will be aggravated in any given lab by human error in configuration or design. The etiology of simulator sickness is complex and it can manifest in numerous patterns with a wide range of symptoms, hence its more formal classification of "simulator adaptation syndrome." This complex web of contributing factors and presenting phenomena has led some researchers to conclude that there is no reliable way to model, manipulate, or predict simulator sickness (e.g. Jones, Kennedy, & Stanney, 2004).

One of the prevalent theories of the mechanism underlying simulator sickness is cue conflict theory, which involves conflict between and adaptations of perceptual systems such as the optokinetic reflex and vestibulo-ocular reflex (VOR). These two reflexes work in tandem to maintain a stable link between fixated objects, expected visual perception, and actual visual perception (Fisher et al., 2011). For instance, a person wearing a new pair of glasses with a stronger prescription experiences some unpleasantness at first, until their system adapts. Adaptation to a simulator is obviously more complex and problematic than adapting to a fixed set of lenses just in front of the eyes, but speed of VOR adaptation has been linked to simulator sickness (Draper et al., 1997). One source of support for cue conflict theory is that a person without a functional vestibular system cannot experience simulator sickness at all (McCauley & Sharkey, 1992), indicating that symptoms arise from the conflict of other systems with the vestibular system. Therefore, according to cue conflict theory one would expect that when the visual stimuli are suddenly very different from perceptual input, as when an unskilled participant executes a turn with too sharp a motion of the steering wheel and then overcorrects, making the visual display "wobble" horizontally, participants who are susceptible to simulator sickness are more likely to be affected than if they had been able to execute the turn smoothly and with minimal disturbance to the orientation of their visual horizon. It was our frequent observation of precisely such behaviors which led us to speculate that improving participants' skill may reduce rates of simulator sickness

Simulator sickness is of particular concern when working with older adults (Edwards et al., 2004) and when investigating simulated environments where the participant must make turns (Mourant, Rengarajan, Cox, Lin, & Jaeger, 2007). As many research questions of interest which would be likely to be investigated in a driving simulator will necessarily include turns, simulator sickness is clearly a critical issue. For instance, older adults are at elevated risk for crashes involving left turns (Matthias, De Nicholas, & Thomas, 1996; Alexander, Barham, & Black, 2002). Additionally, although reports on attrition due to simulator sickness from institutions performing research with older participants vary widely, ranging from 35% to 75%, the average dropout rate is approximately 40% (Trick & Caird, 2011). It seems reasonable to assume that not all of the studies which yielded that range involved turns, and that the prevalence of simulator sickness severe enough to cause dropout is even higher in studies with turns than the average of 40%. Simulator Sickness Questionnaire (SSQ) data collected in our lab across five simulator studies reflects the association between elevated symptoms and scenarios with turns. The SSQ is a commonly used index of symptoms of simulator sickness (Kennedy, Lane, Berbaum, & Lilienthal, 1993). Of the five studies, two involved turns and three used only straight roadways. The SSQ data were classified according to whether the participant was in a straight-roadway-only study or a turning study, and t-tests showed that every SSQ item was significantly elevated in turning relative to straight studies (all Bonferroni-adjusted *p*s $< .001$). The mean SSQ total scores for turning studies, M = 15.5, SD = 11, $n = 201$, were more than three times the mean total scores for straight studies, M = 4.57, SD = 5.52, $n = 214$, and the difference was significant, Welch-adjusted t (296) = 15.1, $p < .001$, with a Cohen's d of 1.26. To put this effect size into terms of impact on driving simulator experiments, there is an 80% chance that a randomly selected person in a turning study will have a higher total SSQ score than a randomly selected person in a straight study, and for every 2.3 people who participate in a turning study, one of them will have an elevated total SSQ score. Accordingly, to be able to study the effects of our guided practice training on rates of simulator sickness in the current project, we reproduced the main task from the study with the highest rate of simulator sickness among the five, one which contains one right turn and four left turns.

2. Driving Simulator Experiment

Methods

Participants

Participants were a community sample of 100 “older” participants (aged 65 to 94, M=73, SD=6.08) and an undergraduate sample of 15 “younger” participants (aged 20 to 31, M=22.6, SD=2.8), who completed the study in a single, 1-hour session and received $15 compensation for their participation.

Materials and Procedures

Experimental Groups

Participants were randomly assigned to groups as shown in Figure 2.1. Full protocols for all conditions are available in APPENDIX A-E. The first four groups we describe here are composed exclusively of older adults. In all three practice groups, the experimenter read general information about the differences between the experiences of driving a simulator vs. a real car, emphasizing the lack of inertia. In addition, two of the three practice groups received guided practice, in which they received instructions on what skills to practice and active coaching as they did so.

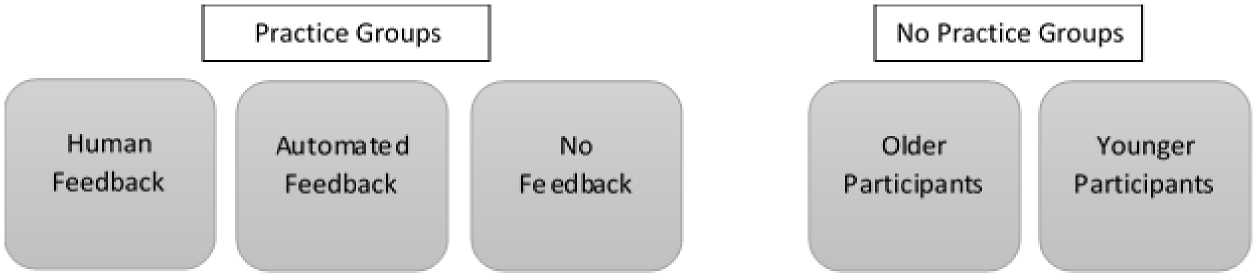

Figure 2.1 Groups for random assignment of participants. All practice groups consist of older participants (n = 25 per older group, n = 15 for the younger group).

In the Human Feedback condition (*n* =25), this entailed an experimenter giving participants precisely scripted instructions throughout the practice segments. Scripts were always read word-for-word to maintain consistency between groups; however, in the human feedback condition the experimenter used judgement to make additional comments, give encouragement, repeat instructions, and emphasize any aspects of the skill being practiced that a particular participant may be having trouble implementing or understanding. As well as more specifically addressing executional errors participants may make while learning different mechanics, this served to foster a more personal experience for participants, and may have helped reduce participants' anxiety over what many of them seem to consider to be poor performance. Participants would receive instructions for what to do during the upcoming training segment, and were told they would get reminders during the task as well. This meant that rather than attempting to remember the detailed instructions, they could focus on the skills they were practicing.

In the Automated Feedback condition (*n* = 25), after the first block of general information and instructions, further instructions and coaching were delivered via the simulator rather than the experimenter. Instructions were recorded in audio files which were triggered at the appropriate times between and during training segments. All instructions were in the same order and used the same wording as in the Human Feedback condition, and additional audio files were programmed to be triggered by problem behaviors or poor execution. For instance, if a participant was easing off the gas pedal to slow to the requested speed during braking practice, they would hear a recording asking them to actively use the brake pedal instead. In this way, the programmed, interactive feedback was designed to mimic the type of individualized feedback given in the Human Feedback condition and make the guided practice for the two groups as similar as possible. In both guided practice conditions, participants completed a certain number of iterations of a task, such as changing lanes six times, and then the training segment concluded and they were moved to the beginning of the next one.

The No Feedback condition (n = 25) serves as a control for the guided practice groups. Participants in this condition received all the same instructions, but massed at the beginning of the study rather than interspersed throughout the training scenarios. Participants then drove all the same training scenarios without further instruction or feedback. Prior to each scenario, they were simply told what the layout of the next scenario was (i.e., "This segment will be a long straight road with a number of stop sign intersections. You will not be making any turns.") To equate across practice groups for driving time, we first collected data from 10 participants in both guided practice groups and calculated the average time spent to complete each training segment. Then the No Feedback version of the scenarios was programmed to so that each segment would end based on average drive time for that segment rather than achieving a target number of performances of a task.

A fourth group of older participants (n = 25) was assigned to the No Practice condition, in which participants only received basic instruction about the simulator prior to driving the same main task which the practice groups drove after their training. This group served as an age-group-matched control for the three practice groups.

Finally, a group of younger participants (*n* = 15) was also run in the No Practice condition, serving as a reference group. This group is expected to show behavior that meets two underlying assumptions of the original experiment: the ability to follow directions in the driving simulator such as maintaining a certain speed; and the ability to handle the simulator as if it were a car. The second of those entails a level of comfort with the virtual driving environment which precludes extremes of cautious behavior that would not be exhibited by the participant in their own vehicle. If these assumptions are met, the resulting data should indicate that these participants consistently experienced a dilemma zone at the critical intersections, and will serve as the basis for comparison of other groups' data.

To recap, all five groups received basic simulator instruction. The two no practice groups then proceeded directly to the main task, whereas the practice groups received additional information regarding adapting to the differences between simulators and real vehicles, then drove six training scenarios before driving the main task. Of those practice groups, one group did not receive feedback during practice.

Simulator Sickness Monitoring

During development and piloting of the training scenarios described below, one of our aims was to gradually expose the participants to potentially sickness-inducing design elements. For instance, the first training segments involve driving only on straight roadways, eliminating any problems curves and turns may provoke while the participant works on gaining control of the more basic skills of braking and accelerating. We needed a way to assess if any segment was eliciting symptoms so that we could consider whether to alter the trajectory of training, but administering the full SSQ after each training segment would not be feasible. We therefore devised the Quick Simulator Sickness Assessment (QSSA), a three-item measure based on the subscales of the SSQ and couched in language aimed to collect information not about individual symptoms a participant might be experiencing, but those symptoms' effects in the form of the subjective level of discomfort experienced in particular regions of the body. The measure proved so minimally disruptive to the experimental flow that rather than drop it after piloting, we retained it for the duration of the study, intending to test whether it might have any predictive utility.

Because the QSSA would be administered at such frequent intervals, we took care to introduce it in a way intended to minimize experimental demand by reducing the likelihood that participants would believe we were expecting them to experience symptoms. Just prior to beginning the first training segment, the experimenter read the following:

> "One more thing – you know how some people tend to get carsick? In the same way, some people can experience discomfort in the simulator. Most people are fine, but all the same, I'm going to check in with you after each segment by asking you three short questions about any discomfort, and we'll do it once right now.
>
> Would you rate any discomfort in your head, including your eyes, as none, slight, moderate, or severe?
>
> How about stomach discomfort – would you rate that as none, slight, moderate, or severe?

And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?"

All participants responded to the QSSA at baseline, after each training segment, and one final time after the main task. Each time after the first, the experimenter would use a pre-scripted phrase such as "Ok, time to check in," and then ask the questions. The phrases varied to keep the language natural, but always included the phrase "check in," to reinforce the idea that this was simply a routine check. The response options were displayed on the center screen of the simulator as the experimenter read them aloud each time. At the end of the experiment, participants also completed the SSQ and a demographics form.

Driving Simulator

An RS-250 series driving simulator, produced by the company DriveSafety and seen in Figure 2.2, was used to collect data for the experiment. The RS-250 series utilizes the cab from a Ford Taurus including the steering wheel, automatic drive gearshift, turn signals, accelerator and brake pedals, as well as a CD/radio, among other peripherals. The simulator comes equipped with three 24" LCD displays giving the driver a 180° horizontal and 50° vertical field of view during simulations. Displays are set to a resolution of 1440x900 pixels and a refresh rate of 60 Hz.

Figure 2.2: RS-250 Research Simulator Created by DriveSafety

Training Scenario Design

For each training segment, we give the general layout of the scenario and a picture from the driver’s viewpoint, a description of the tasks participants in the guided practice groups are given to direct their skill practice, a brief description of the skills participants are to practice, some key details of the text read to the participant in the guided practice conditions, and some key design features. For the full script which was read to participants, see the protocol for the Human Feedback condition in APPENDIX A. All training scenarios were free of any traffic and designed with as few peripheral details (trees, houses etc.) as possible to minimize visual flow.

Segment 1

Layout: a long, straight roadway.

Tasks:

- Accelerate to 50mph, gently brake, come to a complete stop. (Additional instructions precede the next task.)
- Accelerate to 50mph, use the brake to slow to 20mph, repeat twice more, come to a complete stop.

Skills:

- Braking and using visual cues rather than inertia to detect the change in speed.

Key instructions:

- Use the brake while paying attention to the landscape. Even though it doesn't ***feel*** like you are slowing down, if you are looking for it you will be able to ***see*** that you are slowing down.

Figure 2.3 Driver's view of the simulator screens for segment 1.

Segment 2

Layout: a long, straight roadway with multiple, stop sign-controlled intersections..

Tasks:

- At each intersection, come to a stop at the stop bar.

Skills:

- Braking and stopping at a target point; using deliberate practice to make a judgment in the simulated environment reflect a real-world judgment.

Key instructions:

- See if you can stop at the same distance from the stop bar as you would in real life, on the first try.

Figure 2.4 Driver's view of the simulator screens for segment 2.

Segment 3

Layout: gently curving sections of highway.

Tasks:

- Steer along gradual curves.

Skills:

- Begin to acclimate to handling the simulator along curves.

Key instructions:

- Just start getting a feel for how the simulator responds to steering on curves.

Figure 2.5 Driver's view of the simulator screens for segment 3.

Segment 4

Layout: a long, straight stretch of highway.

Tasks:

- Change lanes six times.

Skills:

- Begin to incorporate steering with minor changes of direction and attend to the lack of inertia.
- Use small, gentle motions to steer, to learn steering with control rather than using a lot of overcorrections

Key instructions:

- Steering a simulator can feel weird, because you won’t feel a pull to the left or the right like you would in a real car. It’s good to use the smallest motion of the steering wheel that you can to get the change of direction you want.

Figure 2.6 Driver's view of the simulator screens for segment 4.

Segment 5

Layout: a stretch of road curving a little more sharply than in segment 3.

Tasks:

- Steer along a greater curve.

Skills:

- Extend the skill of steering with control to a more challenging curve.

Key instructions:

- Just focus on steering smoothly and gently around the curve.

Figure 2.7 Driver's view of the simulator screens for segment 5.

Segment 6

Layout: begins in the left turn lane at an intersection with the vehicle in position to make a turn; after the turn, a stretch of two-lane rural road, and then an intersection for a right turn.

Tasks:

- From a full stop, make a left turn, then proceed at 50 mph to the stop sign, changing lanes along the way, and stop at the intersection. Make a right turn.

Skills:

- All of the previously practiced skills, integrated in a single task.
- Extend the skill of steering with control to right angle turns, under minimally challenging conditions.

Key instructions:

- You'll be putting all the skills you've been practicing to work together here.
- You'll be making two turns, focusing on smooth, gentle steering.

Main Task

For the main task, there was no longer any difference between the groups. All participants received the same instructions by the same method of delivery. Participants were told they were driving to meet a friend at a cafe, and that they would hear GPS directions to follow to their destination. They drove in an urban environment with moderate traffic through seven intersections (sequence: left, straight, right, left, straight, left, left). The signals at two intersections remained green, and turned yellow at the others. The two intersections where they did not turn are the ones used for the data validity analysis.

Figure 2.8 Driver's view of the simulator screens during the main task.

Post-Task Measures

After completing the main task and responding to the QSSA a final time, participants left the simulator and immediately filled out the SSQ at a PC, followed by a basic demographics form. These were administered via Qualtrics. They were then debriefed and compensated.

3. Results

Data Validity Results

Dependent Variable

The variable of interest for this analysis was whether a participant had been in a dilemma zone when the signal changed to yellow. Because the structure of the previous study had imposed certain strictures on the way its signal changes were triggered, we implemented the dilemma zone intersections for our study with the same restrictions. In that study, the experimental trials put the participant in a dilemma zone, while in the control trials participants were far enough from the intersection at yellow light onset that the only possible choice was to stop. The yellow light onset was programmed to occur 11 seconds after a participant drove over an invisible trigger area on the road. Participants had been instructed to maintain a given speed, and the trigger was placed so that a participant driving at that speed would, at yellow light onset, be at a distance from the intersection where it would not be obvious whether to stop or continue through the yellow light.

To define the boundaries of this dilemma zone, we calculated where participants would be at yellow light onset, relative to the stop bar, if they had been driving 5mph above or below the prescribed speed. Actual participant distances from the stop bar at both dilemma zone intersections were then coded for the dependent variable dilemma_zone as “Yes” if they fell within the dilemma zone, and “No” if they were outside it. Trials with a “Yes” value constitute valid data, as trials with a “No” value indicate that the manipulation did not take place for that participant. As a trial which should have been in the experimental condition was instead in the control condition, it is an invalid trial because it cannot contribute information to the question under investigation.

Analysis

In our analysis, we tested the following hypotheses. Although these were planned comparisons, we expected that a full set of pairwise comparisons would afford more nuanced information, so a sequential Bonferroni correction was chosen to control for multiple comparisons.

1. Within the no practice condition, a significantly higher proportion of trials will be valid for younger drivers relative to older drivers.
2. Among the three groups who had practice, those who received *human feedback* will not differ from the younger drivers in the no practice condition.
3. Among the three groups who had practice, we predict that those who received *automated feedback* will have a lower proportion of valid trials than the younger drivers in the no practice condition; this is an extension of the fifth prediction.
4. Among the three groups who had practice, those who received *no feedback* will have a significantly lower proportion of valid trials than the younger drivers in the no practice condition.
5. Among the two groups who received feedback during practice, drivers who received human feedback will contribute a significantly higher proportion of valid trials than those who received automated feedback.

A binomial logistic GEE regression was performed in SPSS to test these hypotheses, using robust estimation of the covariance matrix. Each of our participants contributed two trials, and this analytical approach is able to model the dependence of the within-subjects observations and yield valid standard errors, so that valid inferences can be made (Huh, Flaherty, & Simoni, 2012). Parameter estimates are depicted in Table 3.2, and estimated marginal means in Table 3.1. Pairwise comparisons are presented in Table 3.3, with the rows for two conditions removed to reduce the amount of duplicate data in the table.

Pairwise comparisons are based on the estimated marginal means, which due to the binary nature of the dependent variable, are the mean proportion of valid responses for each group. They are calculated from the original scale of the dependent variable rather than the logit transformation, providing more clarity of interpretation than the odds ratios. Therefore, we focus on the results of the pairwise comparisons. Addressing our predictions:

Older drivers who received no practice showed a lower proportion of valid trials (n = 50, M = .44, SE = .091) than did younger drivers (n = 30, M = .97, SE = .032), and the proportional difference of .53 was statistically significant (p < .001, Wald 95% CI = .26, .80).

Drivers who received guided practice with human feedback (n = 49, M = .74, SE = .081) did not statistically differ significantly (difference = .23, p = .052, Wald 95% CI = .00, .46) from younger drivers (n = 30, M = .97, SE = .032), although as the result hovers near the standard alpha value of .05, no strong claims can be made in either direction.

Those who received guided practice with automated feedback did not differ (difference = .11, p = .354, Wald 95% CI = -.06, .27) from younger drivers.

However, drivers who had an equal amount of practice time but no feedback (n =50, M = .48, SE = .091) had a significantly lower proportion of valid trials (difference = .49, p < .001, Wald 95% CI = .23, .74) than did younger drivers.

Drivers who received automated feedback did not differ significantly from those who received human feedback (difference = .12, $p = .450$, Wald 95% CI = .35, .10).

Table 3.1 Estimated Marginal Means for data validity analysis. Group means are the proportion of valid trials for that condition.

Estimates

Condition	Mean	Std. Error	95% Wald Confidence Interval	
			Lower	Upper
Automated Feedback	.86	.060	.74	.98
Human Feedback	.74	.081	.58	.90
No Feedback	.48	.087	.31	.65
No Practice (Older)	.44	.091	.26	.62
No Practice (Younger)	.97	.032	.90	1.03

Table 3.2 Parameter estimates for data validity analysis. The four beta values shown for the named conditions are the odds ratios for contributing **valid** data relative to the no-practice group of younger drivers. Therefore, a non-significant *p*-value indicates a group that performed similarly to younger drivers. Interpretation example: No Practice (Older) drivers were more likely to contribute an invalid data point than younger drivers by a factor of 3.608. Because both predictor and outcome variables are categorical and therefore have no measurement units, the odds ratios function as standardized effect sizes.

.Parameter Estimates

			95% Wald Confidence Interval		Hypothesis Test		
Parameter	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	3.367	.9994	1.408	5.326	11.352	1	.001
Automated Feedback	-1.552	1.1173	-3.742	.638	1.930	1	.165
Human Feedback	-2.334	1.0836	-4.458	-.210	4.640	1	.031
No Feedback	-3.447	1.0586	-5.522	-1.373	10.606	1	.001
No Practice (Older)	-3.608	1.0653	-5.696	-1.521	11.474	1	.001
No Practice (Younger)		.	.	.	.	.	.
(Scale)	1						

Dependent Variable: Dilemma Zone
Model: (Intercept), Condition

a. Set to zero because this parameter is redundant.

Table 3.3 Pairwise comparisons of proportions of valid trials (estimated marginal means) for data validity analysis.

Pairwise Comparisons

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	df	Sequential Bonferroni Sig.	95% Wald Confidence Interval for Difference	
						Lower	Upper
Automated Feedback	Human Feedback	.12	.101	1	.450	-.10	.35
	No Feedback	.38[a]	.106	1	.002	.10	.66
	No Practice (Older)	.42[a]	.109	1	.001	.12	.72
	No Practice (Younger)	-.11	.068	1	.354	-.27	.06
Human Feedback	Automated Feedback	-.12	.101	1	.450	-.35	.10
	No Feedback	.26	.119	1	.122	-.04	.55
	No Practice (Older)	.30	.122	1	.073	-.02	.61
	No Practice (Younger)	-.23	.087	1	.052	-.46	.00
No Practice (Younger)	Automated Feedback	.11	.068	1	.354	-.06	.27
	Human Feedback	.23	.087	1	.052	.00	.46
	No Feedback	.49[a]	.093	1	.000	.23	.74
	No Practice (Older)	.53[a]	.096	1	.000	.26	.80

Pairwise comparisons of estimated marginal means based on the original scale of dependent variable Dilemma Zone

a. The mean difference is significant at the .05 level.

Simulator Sickness Results

To examine whether training had any effect on simulator sickness or attrition rates, regression analyses were conducted. A logistic regression using whether or not a participant dropped out due to simulator sickness was conducted, with condition as a predictor and SSQ score as a covariate. No effects were found (all $p > .28$). We also regressed condition on SSQ score to see whether sickness as indexed by the SSQ varied by condition, and the model was not significant ($F = 2.52$, $df = 1$, $p = .12$).

S

Discussion of Data Validity Results

In our analysis, we sought to answer three questions. The first was a matter of verifying that in our sample, our no-practice control group of older drivers demonstrated the expected age differences relative to a no-practice group of younger drivers. This was indeed the case, as we discovered while testing our first prediction, and as illustrated in **Error! Reference source not found.**. The graph depicts a simplified, overhead view of the road leading up to an intersection. The thick, vertical white bars represent the stop bar where participants would stop if the signal were red. The x-axis shows distances from the stop bar, in feet, with the stop bar being at 0 on the x-axis, and vertical red lines showing the interval considered to be the dilemma zone. The plotted points show the distance from the stop bar where participants were on each individual trial at the moment of yellow light onset, with points in the dilemma zone shown in red, and points outside the zone in yellow. The results reported above and illustrated in this graph confirm that a serious data validity problem exists, as fewer than half of the trials from older participants in the no practice group were valid (see Table 3.1), and naturally leads to our next question, addressed by our second, third, and fourth predictions, of whether any of the three practice groups improved beyond the no-practice older drivers to the point where they were no longer significantly different from younger drivers.

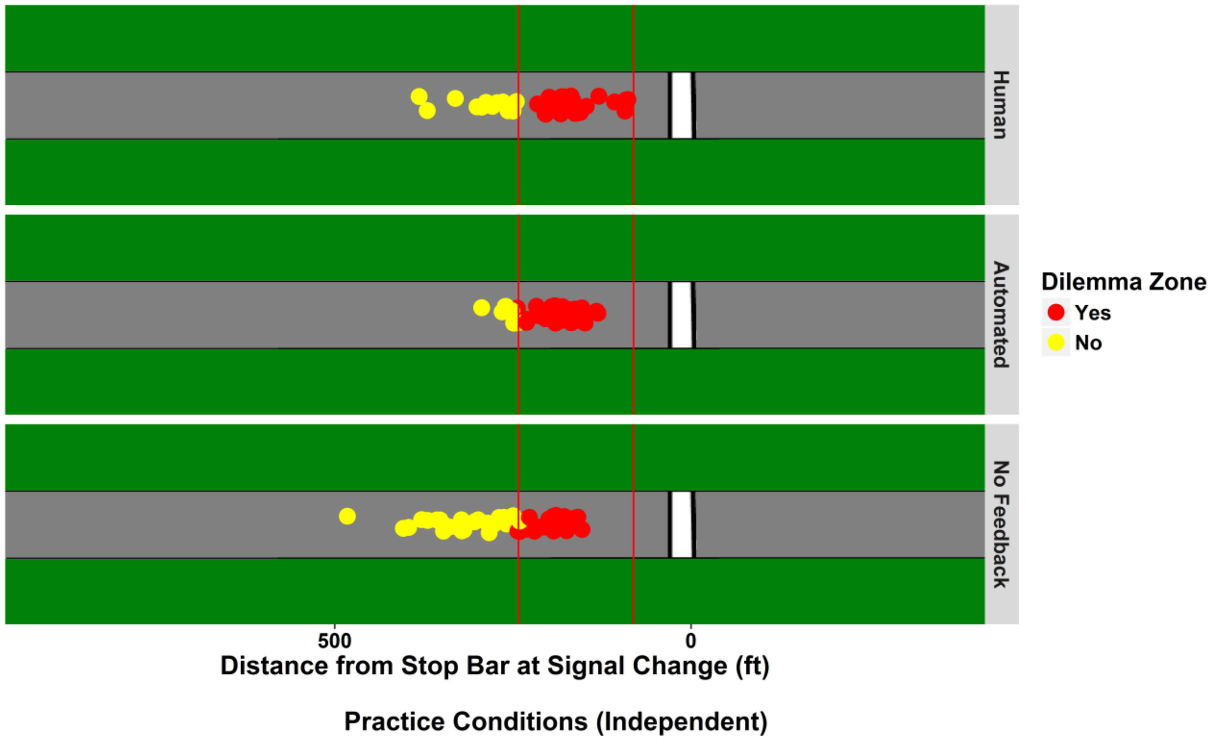

Figure 3.1 Distances from the stop bar at yellow light onset for drivers in the practice conditions, who received human, automated, or no feedback. Each point is one trial. The vertical red lines bound the dilemma zone.

The older participants in the practice group with no feedback drove the same scenarios as the two groups who received guided practice, for an equated amount of time. They received the same instruction about simulators, but in a massed block of instruction rather than spaced throughout practice. The massed instructions and lack of feedback were the only differences between this group and the human and automated feedback groups. They served as an additional control for the guided practice conditions, as it is natural to expect that practice alone should afford some improvement from a simple practice effect. A post-hoc comparison shows that in fact, the no feedback group (*n* = 50, M = .48, SE = .87) appeared virtually identical to the group of older drivers who did not practice at all (difference = .04, *p* = .751, Wald 95% CI = .21, .29). Further, the no feedback group differed from the automated (*n* = 49, M = .86, SE = .06, difference = .38, *p* = .002, Wald 95% CI = .10, 66), although not the human (*n* = 49, M = .74, SE = .08, difference = .26, *p* = .122, Wald 95% CI = -.04, .55) feedback condition, suggesting some superiority to the automated over the human feedback group despite the two groups having been shown not to differ from one another.

Finally, we wanted to know whether the type of guidance during practice mattered. As stated in our final prediction, we expected that the human feedback group would show better data validity outcomes. This was because we were not certain the automated feedback would suffice without the additional contribution of human judgement – an experimenter might detect comprehension issues with some participants that were unforeseen during programming of automated feedback, for instance, or judge from participants' body language that they may be confused and decide to clarify an instruction. Also, we had thought perhaps participants would not respond as well to automated instructions. That turned out not to be the case, however, as reported in the results section and shown in Figure 3.1. In fact, the lower variability (see Table 3.1) in the automated condition hints at greater consistency in helping participants to acquire simulator handling skills. Perhaps this is reflective of the inescapably greater consistency of the automated condition in presenting participants with exactly the same stimuli, inflections in the voice of the recorded instructions, and so forth. A human experimenter running dozens of participants through an experiment, no matter how experienced and professional, cannot be perfectly consistent. Thoughts may wander, or a lack of sleep may alter experimenter behavior, while the machine will simply do as it is programmed, for every single participant.

Summary of Simulator Sickness Results

There was no effect of condition on either reported simulator sickness symptoms or on dropout rate. It should be noted that although our sample size was ample, we experienced a remarkably low rate of attrition due to simulator sickness (16.5%). The DriveSafety simulator in this experiment uses a smaller array of monitors, so is less immersive than the simulator used in our previous experience; this may have contributed to the low dropout rate. In fact, at the conclusion of his chapter regarding aspects of simulators and scenario design in relation to simulator sickness, Stoner (2011) makes recommendations for optimal design and the very first suggestion is to use a narrow field of view, as the wider field of view and higher resolutions screens tend to increase vection and optic flow. It is possible therefore that in our study, only the most susceptible participants experienced troubling levels of symptoms.

4. Project Conclusions

Although our results uncovered no effects on simulator sickness, our findings do strongly support adding a skills training component featuring both instruction regarding the differences and guided practice to driving simulator studies with older participants. Older participants' behavior in the simulator is extremely variable. In a paradigm such as the dilemma zone study we used, a manipulation check to determine whether participants who were supposed to be exposed to a specific set of circumstance did indeed experience that manipulation is fairly straightforward, and it is certainly possible to protect the integrity of the data by excluding trials the manipulation check shows to be invalid. However, manipulation checks are a *post-task* way to verify that the manipulation took place, meaning that additional recruitment would be required to replace lost data. The cost of such an approach would be immense. This can easily be seen in Figure 4.1, which depicts the raw data in a scatterplot which represents an overhead view of a composite intersection. The stop bar is at the top of the scatterplot, represented by zero on the y-axis, with the negative distance values indicating that participants have not yet reached the stop bar. The points are participants' distances from the stop bar at yellow light onset, with one x-axis value belonging to each participant's trials. The dilemma zone is indicated by the horizontal red lines.

Figure 4.1 Scatterplot of distances from the stop bar at yellow light onset. Zero on the y-axis represents the stop bar, and the horizontal lines outline the dilemma zone. Points plotted at the same x value are from the same participant.

As we established, attrition due to simulator sickness is known to be high among older participants. If the current study had only been comparing younger and older participants on this task with no practice for either group (yellow and red groups on the plot, respectively), over half of the data from the remaining older participants who did not get sick and drop out would have had to have been replaced, after already having had to replace those who did drop out. This plot does visually minimize the scope of the problem, however, in that the younger group was a smaller sample, so that there doesn't seem to be a large difference in the number of valid trials seen in the plot for the red and yellow clusters. Looking at the proportions of valid trials from Table 3.1, and multiplying by the sample sizes for those conditions, we see that there are 29 trials in the dilemma zone for the youngers (n = 15) and 22 for the olders (n =25), and that if a sample of 25 youngers had the same proportion of valid data, they would have contributed 48 valid data points as opposed to the olders' 22 valid points; a glaring difference.

Furthermore, it is possible for simulator experiments to be designed in ways that make it difficult to make a manipulation check; such designs should be avoided if older participants are being studied, as such a large proportion of potentially invalid data would make it unlikely to detect all but the largest of effects, as well as undermining the confidence of any inferences made. Put another way, the amount of noise introduced by older participants' lack of skill in bringing their life skills into a virtual environment can make it difficult to investigate an effect, both by reducing the amount of meaningful data and by obscuring it. Experimenters should address this either with training before the experiment, or careful measures after the experiment to identify and exclude invalid data. Although it extends the length of an experiment, we contend that the former solution is far more viable and beneficial for both researchers and participants.

Our results suggest that automated feedback, which we modeled after our scripted human feedback, is more effective than human feedback when both groups are compared to younger participants. However, the two feedback conditions are not significantly different from one another, suggesting that guided practice with human feedback be considered as an option when automated feedback is not possible. The findings additionally showed that practice alone did not suffice for older drivers to improve their simulator handling skill, and that a more proactive approach was required.

5. Limitations

The design chosen for studying data validity was highly specific to one driving behavior. Although well suited for the questions under investigation due to lending itself to an unambiguous operational definition of valid data, the effect of guided practice may not generalize to other driving behaviors. Mitigating this is that our training did not directly teach them to drive in a particular way that we were going to observe, but rather was heavily focused on inducing participants to deliberately attempt to make their simulator driving the same as their real-life driving.

Further, we saw a clear impact of unskilled simulator handling in our study, but our outcome measure was extremely sensitive to it. There may be designs whose dependent variables are robust enough not to be as affected by the variance a lack of skill introduces into driving behaviors.

Although it is clear that guided practice elicited behavior which was more externally valid than that exhibited by the no feedback and no practice groups, due to the study design it is uncertain whether the benefit is derived from the feedback during practice, or the information and instructions being spaced throughout the training and presented at relevant times as opposed to either being absent altogether or presented in a massed block at the beginning of the study, or whether the effect is due to both factors in combination. It could be that rather than an effect of feedback during practice, these results are showing an effect of spaced vs. massed instructions as well as a lack of effect of presence vs. absence of massed instruction.

Finally, this study had one of the lowest overall attrition rates (16.5%) due to simulator sickness that we have experienced in our lab, and much lower than the range of 35% - 75% reported by Trick & Caird (2011). This provided us with a very low number of discontinuing participants to observe, despite the overall large N of 115. Should the DriveSafety simulator we used continue to have such low attrition rates, any further research we may conduct on simulator sickness would need to be on a different simulator.

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7. APPENDIX A

Protocol for Guided Practice Simulator Training Study -- Human Feedback Condition

The text below is exactly as printed out for experimenters to read, with the exception that information specific to the study (i.e., a filename) has been replaced with a generic description of what appeared there, enclosed in brackets and asterisks. For example, [******* select scenario ********]

The blue text is to be read aloud to the participant, with occasional phrases in red to indicate when special emphasis needs to be conveyed to the participant. Experimenters are trained to speak clearly and at a moderate pace, with pauses after important pieces of information to allow participants time to process what they are hearing. Black, italicized text in brackets indicates *[an action for the experimenter to take]* during the experiment, and is formatted this way to be visually distinct from the text the experimenter is reading aloud.

Please follow this protocol to the letter. If you make a mistake or if anything unusual occurs, note it down in the comments column on the run sheet.

BEGIN THE STUDY

1. ***This is a real car seat – please adjust it so that you are comfortable and can reach the pedals and steering wheel.*** *[Demonstrate if needed.]*

2. *Use the chain to measure the correct distance from screens to nose – move the screens rather than the chair, because they have already adjusted it for comfort. Ask them not to adjust the chair again without letting you know so you can remeasure.*
3. Ask the participant for their birth date and put it in the run sheet, then give them the consent form and a pen. Say: ***Please read the consent form thoroughly before signing.***
4. While they are reading, enter their gender and the start time into the run sheet.
5. Copy the participant information from the calendar to the run sheet tab for their age group, and enter your information.
6. KEEP THE RUN SHEET OPEN and the laptop on the little table behind the car seat – you will need it throughout the training
7. [****** instructions for starting the simulator scenario ******]
8. Once they sign the consent form, answer any questions they may have and check to be sure they signed it. Put it in the appropriate spot in the blue tray.
9. Read the following instructions word-for-word to the participant. Answer any questions the participant may have after you've read the

instructions. **Do not vary the wording. Always read from the script.**

The controls in the simulator are like those in a real car. The gas pedal is on the right and the brake is on the left. The gear shift is down here *[Show them]* ***and it's an automatic transmission. Many people cannot see the speedometer because the steering wheel is in the way, so your speed will be displayed at the bottom of the center screen.***

Because this is not a real car, it lacks certain kinds of feedback you would normally use while driving. Many people have trouble adjusting to braking without inertia, monitoring speed, and steering in the simulator, so I will now take you through a series of brief practice scenarios designed to help with this process. Even if you find you have no trouble adjusting or have done many experiments with us, please don't be offended if I tell you things you already know. It is important for the experiment that you follow all the instructions I give you during this scenario so that everyone experiences the exact same practice. Thank you for bearing with us. I'll begin the scenario now, but please don't start driving until instructed to do so.

[Click Start]

Do you have any questions before we begin?

Okay. During the training segments, we will focus on certain specific things – getting used to the brakes without inertia and monitoring speed without inertia, and stopping the car at the stop bar, which is that thick white pavement marking just before the crosswalk markings, and steering.

One more thing – you know how some people tend to get carsick? In the same way, some people can experience discomfort in the

simulator. Most people are fine, but all the same, I'm going to check in with you after each segment by asking you three short questions about any discomfort, and we'll do it once right now.

Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response in the run sheet.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

In this first practice segment, you will accelerate to 50 miles an hour as soon as you can, then use the brake while paying attention to the landscape. Even though it doesn't feel like you are slowing down, if you are looking for it you will be able to see that you are slowing down. Keep slowing down until you are stopped, and then remain stopped while I explain the braking practice. To make it simpler, I will be reminding you what to do next as you are driving. Remember, your speed is shown on the screen. *[Point to it.]*

When you have reached the end of the segment the vehicle will automatically start to slow down and the screen will fade to black. Do you have any questions? Please shift into Drive now, and begin.

[As they are driving, time the instructions appropriately, but do not vary the wording.]

Accelerate to 50 miles an hour as quickly as you can.

Gently brake and watch the scenery to judge whether you are slowing down.

Keep slowing till you are at a complete stop.

Great. Please wait till I let you know it's time to drive again. Now we're going to do some practice with both braking and monitoring speed. Again, you'll need to watch the speed display and the scenery to tell if you're speeding up or slowing down since your body won't feel any changes in speed. When I say to begin, you will accelerate to 50 miles an hour again, then brake to 20 miles an hour. Just do that over and over again until I let you know to come to a stop again. I know it gets repetitive but bear with me; I have to repeat the instructions to speed up and slow down through this whole stretch. Once again, when you have reached the end of the segment the vehicle will automatically start to slow down and the screen will fade to black. Do you have any questions? All right, begin driving now.

[Each time they reach 50 mph, say, ***use the brake to slow to 20 miles an hour.*** *Each time they reach 20 mph, say,* ***and speed up to 50 again.*** *After the third time they reach 50 mph, say,* ***and now, come to a complete stop.*** *Once they have stopped, say,* ***Perfect – now speed up to 50 once more and just keep driving until the scene fades away.****]*

Please take your feet off the pedals and shift into Park.

Ok, time to check in… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

In this next segment, you'll be focusing on braking and stopping as if you were in a real car. You'll drive through some intersections with stop signs, and at each one I want you to see if you can stop at the

same distance from the stop bar as you would in real life, on the first try. Accelerate to 50 miles per hour between intersections.

Once again, when you have reached the end of the segment the vehicle will automatically start to slow down and the screen will fade to black. Do you have any questions?

Ok, shift into drive.

When they should start braking for the intersection, say, ***See if you can stop at the same distance you would in real-life on the first try.****] (If they did so at the first intersection, you can say …* ***on the first try again****.)*

Please take your feet off the pedals and shift into Park.

All right, checking in… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

Great. This next one is very simple – you're just going to stay in the left lane and follow the road at 50 mph around some gentle curves. Just start getting a feel for how the simulator responds to steering on curves.

Once again, when you have reached the end of the segment the vehicle will automatically start to slow down and the screen will fade to black. Do you have any questions? Go ahead and drive.

Please take your feet off the pedals and shift into Park.

Checking in again… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

Ok, now you're going to drive a straight stretch of road at 50 mph, and change lanes a number of times. Steering a simulator can feel weird, because you won't feel a pull to the left or the right like you would in a real car. It's good to use the smallest motion of the steering wheel that you can to get the change of direction you want.

Once again, when you have reached the end of the segment the vehicle will automatically start to slow down and the screen will fade to black. Do you have any questions? Go ahead and accelerate to 50 now, and I'll let you know when to change lanes. *[Have them change lanes a few seconds after they've driven a straight, smooth line after the previous lane change. They should change lanes back and forth three times, for a total of six lane changes.]*

Please take your feet off the pedals and shift into Park.

Checking in again, and then we have just two more practice segments to go… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort***

anyplace else – would you rate that as none, slight, moderate, or severe? *[Record their response.]*

Next you'll be driving a stretch of road that curves a little more sharply than before. Just focus on steering smoothly and gently around the curve.

Once again, when you have reached the end of the segment the vehicle will automatically start to slow down and the screen will fade to black. Do you have any questions? You can start now, and again, drive at 50 mph.

Please take your feet off the pedals and shift into Park.

Checking in again … Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

Ok, this is the last practice segment. You'll be putting all the skills you've been practicing to work together here. You'll be making two turns, focusing on smooth, gentle steering. You'll take the left fork you see in front of you and then proceed to the stop sign at 50 mph, changing lanes along the way. Come to a stop at the stop bar, and then make a right turn. And like before, you'll get reminders of what to do next while you drive.

Once again, when you have reached the end of the segment the vehicle will automatically start to slow down and the screen will fade to black. Do you have any questions? Ready?

[If they have any questions, answer them. Guide them through the segment with the following instructions, spaced appropriately.]

Ok, go ahead and take the left fork, then speed up to 50 mph.

Move over into the right lane.

Stop at this intersection, as close to the stop bar as you would in real life.

Now just turn right and keep going.

Please take your feet off the pedals and shift into Park.

Now I just want to check in one more time before we move on to the main task: Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

Ok, that's it for practice – now we'll move on to the main task. Would you like to have some water or visit the restroom first?

RUN MAIN TASK

Read the following, word for word, to the participant:

You are now going to complete a full driving scenario. During the practice scenario you just completed, you changed speeds a lot to get used to how the brakes feel, and how to monitor speed when it doesn't feel like the speed is changing. This scenario will be different. You'll be driving as if you were on a normal drive in a new place, guided by a GPS system. The speed limit is 45 miles per hour. If you go too fast, you'll hear a siren – to make it stop, just slow back down to 45. Intersections are just like you practiced – it's very important to stop as close to each red light as you would in real life.

Remember, it's very important that you treat intersections and lights as you would in a real-life driving situation. ***You are going to meet a friend at a café downtown on Market Street. The route has been programmed into your GPS. You will hear instructions from the GPS telling you where to turn. Please obey all traffic rules and speed limits. The speed limit on all roads is 45 miles per hour.***

Once again, when you have reached the end of the segment the vehicle will automatically start to slow down and the screen will fade to black. Do you have any questions before we begin? Ok, you may begin driving.

[Once any questions have been answered:] ***All right, I'll turn out the light now and the scenario will begin shortly. You'll need to shift into Drive again when it tells you to begin, just like you did in the practice scenario. Also, please remember to position your hands on the steering wheel in the way you felt made the simulator handle most like your own car.***

Turn off the lights, close the door, and then click start.

Wait for the participant to complete the scenario. Make sure to keep an eye on the participant while they complete it in case anything unusual happens or they signal for your help.

Please take your feet off the pedals and shift into Park.

Great, and now for our final check-in! … Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

8. APPENDIX B

Protocol for Guided Practice Simulator Training Study -- Automated Feedback Condition

The text below is exactly as printed out for experimenters to read, with the exception that information specific to the study was (i.e., a filename) has been replaced with a generic description of what appeared there, enclosed in brackets and asterisks. For example, [******* select scenario ********]

The blue text is to be read aloud to the participant, with occasional phrases in red to indicate when special emphasis needs to be conveyed to the participant. Experimenters are trained to speak clearly and at a moderate pace, with pauses after important pieces of information to allow participants time to process what they are hearing. Black, italicized text in brackets indicates *[an action for the experimenter to take]* during the experiment, and is formatted this way to be visually distinct from the text the experimenter is reading aloud.

Please follow this protocol to the letter. If you make a mistake or if anything unusual occurs, note it down in the comments column on the run sheet.

BEGIN THE STUDY

1. ***This is a real car seat – please adjust it so that you are comfortable and can reach the pedals and steering wheel.*** *[Demonstrate if needed.]*
2. *Use the chain to measure the correct distance from screens to nose – move the screens rather than the chair, because they have already*

adjusted it for comfort. Ask them not to adjust the chair again without letting you know so you can remeasure.

3. Ask the participant for their birth date and put it in the run sheet, then give them the consent form and a pen. Say: ***Please read the consent form thoroughly before signing.***
4. While they are reading, enter their gender and the start time into the run sheet.
5. Copy the participant information from the calendar to the run sheet tab for their age group, and enter your information.
6. KEEP THE RUN SHEET OPEN and your laptop on the little table behind the car seat – you will need it throughout the training
7. [****** instructions for starting the simulator scenario ******]
8. Once they sign the consent form, answer any questions they may have and check to be sure they signed it. Put it in the appropriate spot in the blue tray.
9. Read the following instructions word-for-word to the participant. Answer any questions the participant may have after you've read the instructions. **Do not vary the wording. Always read from the script.**

The controls in the simulator are like those in a real car. The gas pedal is on the right and the brake is on the left. The gear shift is down here *[Show them]* ***and it's an automatic transmission. Many people cannot see the speedometer because the steering wheel is in the way, so your speed will be displayed at the bottom of the center screen.***

Because this is not a real car, it lacks certain kinds of feedback you would normally use while driving. Many people have trouble adjusting to braking without inertia, monitoring speed, and steering in the simulator, so I will now take you through a series of brief practice scenarios designed to help with this process. Even if you find you have no trouble adjusting or have done many experiments with us, please don't be offended if I tell you things you already know. It is important for the experiment that you follow all the instructions I give you during this scenario so that everyone experiences the exact same practice. Thank you for bearing with us. I'll begin the scenario now, but please don't start driving until instructed to do so.

[Click Start]

Do you have any questions before we begin?

Okay. During the training segments, we will focus on certain specific things – getting used to the brakes without inertia and monitoring speed without inertia, stopping the car at the stop bar, which is that thick white pavement marking just before the crosswalk markings, and steering.

One more thing – you know how some people tend to get carsick? In the same way, some people can experience discomfort in the simulator. Most people are fine, but all the same, I'm going to check in with you after each segment by asking you three short questions about any discomfort, and we'll do it once right now.

Ask these questions and record them after each segment

Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response in the run sheet.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

[After segment 1:]

Ok, time to check in… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

[After segment 2:]

All right, checking in… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

[After segment 3:]

Checking in again… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

[After segment 4:]

Checking in again, and then we have just two more practice segments to go… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

[After segment 5:]

Checking in again … Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

[After segment 6:]

Now I just want to check in one more time before we move on to the main task: Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

[After main task:]

Great, and now for our final check-in! … Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

9. APPENDIX C

Protocol for Guided Practice Simulator Training Study -- No Feedback (Free Practice) Condition

The text below is exactly as printed out for experimenters to read, with the exception that nformation specific to the study was (i.e., a filename) has been replaced with a generic description of what appeared there, enclosed in brackets and asterisks. For example, [******* select scenario ********]

The blue text is to be read aloud to the participant, with occasional phrases in red to indicate when special emphasis needs to be conveyed to the participant. Experimenters are trained to speak clearly and at a moderate pace, with pauses after important pieces of information to allow participants time to process what they are hearing. Black, italicized text in brackets indicates *[an action for the experimenter to take]* during the experiment, and is formatted this way to be visually distinct from the text the experimenter is reading aloud.

Please follow this protocol to the letter. If you make a mistake or if anything unusual occurs, note it down in the comments column on the run sheet.

BEGIN THE STUDY

The controls in the simulator are like those in a real car. The gas pedal is on the right and the brake is on the left. The gear shift is down here *[Show them]* ***and it's an automatic transmission. Many people cannot see the speedometer because the steering wheel is in the way, so your speed will be displayed at the bottom of the center screen.***

Because this is not a real car, it lacks certain kinds of feedback you would normally use while driving. Many people have trouble adjusting to braking without inertia, monitoring speed, and steering in the simulator, so you will now have a chance to drive some brief practice scenarios designed to help with this process. Even if you find you have no trouble adjusting or have done many experiments with us, please don't be offended if I tell you things you already know. It is important for the experiment that you listen to all the information I give you before this scenario so that you can use the information as you practice. I'll begin the scenario now, but please don't start driving until instructed to do so.

[Click Start]

Okay. You will be driving a number of practice segments. You should only make a turn if you hear a GPS instruction telling you to turn. At the beginning of each segment, I will give you a brief description of what type of road you will be driving on so you know what to expect. At the end of each segment, the car will automatically slow and the screen will fade to black.

As you drive, focus on several things – getting used to the brakes without inertia, monitoring speed without inertia, and stopping the car as close to the stop bar as you would in real life. The stop bar is that thick white pavement marking just before the crosswalk markings. Because there is no inertia, you have to look for changes in speed instead of feeling them. It's very important to spend a lot of time getting used to how the brakes feel. A lot of people start to brake, don't feel anything, and then slam on the brakes and make the tires squeal. Instead, go fast – we suggest 50 miles an hour – and then use the brake and watch the speedometer and the landscape around you to see the effect. Even though it doesn't feel like you are slowing down, if you are looking for it you will be able to see that you are slowing down. You should speed up and slow down over and over again during practice and get comfortable with the brake.

You should experiment with different grips on the steering wheel. It is smaller than a normal steering wheel and very sensitive, so you might have better control with a 10 & 2 grip than a 9 & 3 grip. Use whatever grip makes the simulator handle most like your own car. Focus on

using small, gentle motions while steering. Spending some time practicing changing lanes can also help you get used to the steering. Many people stop a long distance away from the intersection and then creep slowly up to it. Instead, at each intersection, try to stop as close to the white line as you would in real life.

Finally, there will be a GPS instruction that lets you know when you will need to turn. Remember to be aware of how sensitive the steering wheel is.

Do you have any questions?

One more thing – you know how some people tend to get carsick? In the same way, some people can experience discomfort in the simulator. Most people are fine, but all the same, I'm going to check in with you after each segment by asking you three short questions about any discomfort, and we'll do it once right now.

Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response in the run sheet.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

All right. So once more, focus on getting used to the brake, monitoring your speed, and gentle steering, and stop as close to the intersections as you would in real life. Remember, your speed is shown on the screen. *[Point to it.]* ***The speed limit is 50mph for all of these practice segments.***

This first segment is a long, straight roadway. You will not be making any turns. Please shift into Drive now, and begin.

Please take your feet off the pedals and shift into Park.

Ok, time to check in… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

This segment will be a long straight road with a number of stop sign intersections. You will not be making any turns. Please shift into Drive now, and begin.

Please take your feet off the pedals and shift into Park.

All right, checking in… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

Great. This next segment is some curving sections of highway. Begin when you're ready.
Please take your feet off the pedals and shift into Park.
Checking in again… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

Next is a long, straight stretch of highway.
Please take your feet off the pedals and shift into Park.

Checking in again, and then we have just two more practice segments to go… Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

Next you'll be driving a stretch of road that curves a little more sharply than before. You can start whenever you're ready.

Please take your feet off the pedals and shift into Park.

Checking in again … Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

Ok, this is the last practice segment. You'll take the left turn you see in front of you and then make a right turn at a stop sign. The GPS will direct you. Ready?
[If they have any questions, answer them.]

Please take your feet off the pedals and shift into Park.
Now I just want to check in one more time before we move on to the main task: Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

Ok, that's it for practice – now we'll move on to the main task. Would you like to have some water or visit the restroom first?

RUN MAIN TASK

Read the following, word for word, to the participant:
You are now going to complete a full driving scenario. During the practice scenario you just completed, you changed speeds a lot to get used to how the brakes feel, and how to monitor speed when it doesn't feel like the speed is changing. This scenario will be different. You'll be driving as if you were on a normal drive in a new place, guided by a GPS system. The speed limit is 45 miles per hour. If you go too fast, you'll hear a siren – to make it stop, just slow back down to 45. Intersections are just like you practiced – it's very important to stop as close to each red light as you would in real life.

Remember, it's very important that you treat intersections and lights as you would in a real-life driving situation. You are going to meet a friend at a café downtown on Market Street. The route has been programmed into your GPS. You will hear instructions from the GPS telling you where to turn. Please obey all traffic rules and speed limits. The speed limit on all roads is 45 miles per hour. Do you have any questions before we begin? Ok, you may begin driving.

[Once any questions have been answered:] ***All right, I'll turn out the light now and the scenario will begin shortly. You'll need to shift into Drive again when it tells you to begin, just like you did in the practice scenario. Also, please remember to position your hands on the steering wheel in the way you felt made the simulator handle most like your own car.***

1. Turn off the lights, close the door, and then click start.
2. Wait for the participant to complete the scenario. Make sure to keep an eye on the participant while they complete it in case anything unusual happens or they signal for your help.

Please take your feet off the pedals and shift into Park.

Great, and now for our final check-in! … Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

10. APPENDIX D

Protocol for Guided Practice Simulator Training Study -- No Practice (Main Task Only) Condition

The text below is exactly as printed out for experimenters to read, with the exception that nformation specific to the study was (i.e., a filename) has been replaced with a generic description of what appeared there, enclosed in brackets and asterisks. For example, [******* select scenario ********]

The blue text is to be read aloud to the participant, with occasional phrases in red to indicate when special emphasis needs to be conveyed to the participant. Experimenters are trained to speak clearly and at a moderate pace, with pauses after important pieces of information to allow participants time to process what they are hearing. Black, italicized text in brackets indicates *[an action for the experimenter to take]* during the experiment, and is formatted this way to be visually distinct from the text the experimenter is reading aloud.

Please follow this protocol to the letter. If you make a mistake or if anything unusual occurs, note it down in the comments column on the run sheet.

BEGIN THE STUDY

The controls in the simulator are like those in a real car. The gas pedal is on the right and the brake is on the left. The gear shift is down here *[Show them]* ***and it's an automatic transmission. Many people cannot see the speedometer because the steering wheel is in***

the way, so your speed will be displayed at the bottom of the center screen.

Because this is not a real car, it lacks certain kinds of feedback you would normally use while driving. Many people have trouble adjusting to braking without inertia, monitoring speed, and steering in the simulator, so I will now take you through a series of brief practice scenarios designed to help with this process. Even if you find you have no trouble adjusting or have done many experiments with us, please don't be offended if I tell you things you already know. It is important for the experiment that you follow all the instructions I give you during this scenario so that everyone experiences the exact same practice. Thank you for bearing with us. I'll begin the scenario now, but please don't start driving until instructed to do so.

[Click Start]

Do you have any questions before we begin?

Okay. During the training segments, we will focus on certain specific things – getting used to the brakes without inertia and monitoring speed without inertia, stopping the car at the stop bar, which is that thick white pavement marking just before the crosswalk markings, and steering.

One more thing – you know how some people tend to get carsick? In the same way, some people can experience discomfort in the simulator. Most people are fine, but all the same, I'm going to check in

with you after each segment by asking you three short questions about any discomfort, and we'll do it once right now.
Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response in the run sheet.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*

RUN MAIN TASK

Read the following, word for word, to the participant:

You are now going to complete a full driving scenario. During the practice scenario you just completed, you changed speeds a lot to get used to how the brakes feel, and how to monitor speed when it doesn't feel like the speed is changing. This scenario will be different. You'll be driving as if you were on a normal drive in a new place, guided by a GPS system. The speed limit is 45 miles per hour. If you go too fast, you'll hear a siren – to make it stop, just slow back down to 45. Intersections are just like you practiced – it's very important to stop as close to each red light as you would in real life. ***Remember, it's very important that you treat intersections and lights as you would in a real-life driving situation.*** ***You are going to meet a friend at a café downtown on Market Street. The route has been programmed into your GPS. You will hear instructions from the GPS telling you where***

to turn. Please obey all traffic rules and speed limits. The speed limit on all roads is 45 miles per hour.

Once again, when you have reached the end of the segment the vehicle will automatically start to slow down and the screen will fade to black. Do you have any questions before we begin? Ok, you may begin driving.

[Once any questions have been answered:] ***All right, I'll turn out the light now and the scenario will begin shortly. You'll need to shift into Drive again when it tells you to begin, just like you did in the practice scenario. Also, please remember to position your hands on the steering wheel in the way you felt made the simulator handle most like your own car.***

Turn off the lights, close the door, and then click start.

Wait for the participant to complete the scenario. Make sure to keep an eye on the participant while they complete it in case anything unusual happens or they signal for your help.

Please take your feet off the pedals and shift into Park.

Great, and now for our final check-in! … Would you rate discomfort in your head, including your eyes, as none, slight, moderate, or severe? *[Record their response.]* ***How about stomach discomfort – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]* ***And any discomfort anyplace else – would you rate that as none, slight, moderate, or severe?*** *[Record their response.]*