U.S. Department of Transportation
Federal Railroad Administration

Office of Research,
Development and Technology
Washington, DC 20590

Pilot Test of the Effect of Train Arrival Time Consistency on Driver Behavior at Highway Rail Grade Crossings

DOT/FRA/ORD-26/22

Final Report | September 2026

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
11 September 2026	December 2016	Technical Report

4. TITLE AND SUBTITLE
Pilot Test of the Effect of Train Arrival Time Consistency on Driver Behavior at Highway Rail Grade Crossings

5. FUNDING NUMBERS

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Railroad Administration
1200 New Jersey Ave. SE
Washington, DC 20590

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DOT/FRA/ORD-26/22

11. SUPPLEMENTARY NOTES
COR: Francesco Bedini Jacobini

12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public through the FRA eLibrary.

12b. DISTRIBUTION CODE

13. ABSTRACT
The Federal Railroad Administration (FRA) sponsored the John A. Volpe National Transportation Systems Center to develop an experimental procedure to understand the decision-making process of motorists at highway-rail grade crossings (HRGC) using a driving simulator. While the results of the initial pilot study on the effects of train arrival time were inconclusive, the experimental procedure that was developed may help inform future HRGC simulator studies. The first HRGC study using FRA's driving simulator sought to validate the theoretical framework of Dr. Tom Raslear, who investigated the impacts on driver behavior of train arrival time variability. Dr. Raslear's model predicted that increased variability in train arrival time at HRGCs may reduce the likelihood that a motorist will drive around active crossing gates. Federal regulations may have led to a public perception that trains arrive approximately 20 seconds after the onset of the warning device. The intention of this pilot study was to help FRA determine if a driving simulator provides an adequate environment to validate the proposed model. The results of this pilot effort may be used to help determine if a more complete study is warranted.

14. SUBJECT TERMS
Highway-rail grade crossing, grade crossing, safety, driver behavior

15. NUMBER OF PAGES
25

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

Acknowledgements

The authors thank Dr. Donald Fisher, Surface Transportation Human Factors Division, U.S. DOT John A. Volpe National Transportation Systems Center for his wisdom and guidance in the development and troubleshooting of this experiment.

The authors also thank the support staff from Realtime Technologies Incorporated for their help with the programming and troubleshooting of the driving simulation.

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Executive Summary

The Federal Railroad Administration (FRA) sponsored the John A. Volpe National Transportation Systems Center to develop an experimental procedure to understand the decision-making process of motorists at highway-rail grade crossings (HRGC) using a driving simulator located at Volpe with the capability to simulate different grade crossing configurations. While the results of the initial pilot study on the effects of train arrival time were inconclusive, the experimental procedure that was developed may help inform future HRGC simulator studies. The first HRGC study using FRA's driving simulator sought to validate the theoretical framework of Dr. Tom Raslear, who investigated the impacts on driver behavior of train arrival time variability (Raslear, 2015). Dr. Raslear's model predicted that increased variability in train arrival time at HRGCs may reduce the likelihood that a motorist will drive around active crossing gates. Federal regulations may have led to a public perception that trains arrive approximately 20 seconds after the onset of the warning device (Yeh and Multer, 2008). The intention of this pilot study was to help FRA determine if a driving simulator provides an adequate environment to validate the proposed model. The results of this pilot effort may be used to help determine if a more complete study is warranted.

Twenty Volpe employees completed the pilot study. Participants were asked to drive through a virtual world that contained several HRGCs. To study this model, it was important to develop an experimental procedure that provided participants with adequate motivation to consider driving around an active crossing gate, while still ensuring that drivers understood that such an act carried risk. Researchers found that a story-based scenario, a portion of which presented an extreme time pressure, was sufficient to generate violations from some participants and nearly all participates reported that they felt pressure to consider violating. This indicates that the experimental procedure that was used effectively motivated participants; however, the results of the experiment proved inconclusive.

After an initial pre-pilot with a larger set of conditions, pilot participants in the study were in one of two main conditions – a variable train arrival time condition or a consistent train arrival time condition. Every participant in the experiment drove through a total of 24 active HRGCs, but the timing of the train arrival at each crossing depended on the condition into which the participant was assigned. In the variable condition, the train would arrive 10, 20, or 30 seconds after the warning signal was activated, whereas in the consistent condition every train arrived exactly 30 seconds after the warning signal was activated (additional timing conditions would be considered in a full experiment; these conditions were selected for the pilot study as they represented the most likely conditions to elicit differential effects). Researchers looked for noncompliance among drivers based on the condition into which they were assigned. The pilot study found that participants were equally likely to violate crossings with consistent train arrivals times versus crossings with variable train arrival times. While the sample size of the pilot study was limited, the results may indicate that the differences in driver behavior at an HRGC with variable train arrival times may be difficult to detect in a simulator. At this time, based on the results from this preliminary pilot study, the research team cannot recommend moving forward with a larger experimental population. It remains possible that many participants would help to achieve the power necessary to empirically show the effects of warning time variability on driver compliance; however, the sample size required may be too large to be practicable or the difference may be slight enough that the recommended actions could be uncertain.

1. Introduction

The Federal Railroad Administration (FRA) sponsored the John A. Volpe National Transportation Systems Center (Volpe) to develop an experimental procedure to understand the decision-making process of motorists at highway-rail grade crossings (HRGC) using a driving simulator located at Volpe with the capability to simulate different grade crossing configurations. This simulator provided an opportunity to attempt to validate this theoretical model before attempting a field study. While the results of the initial pilot study on the effects of train arrival time were inconclusive, the experimental procedure that was developed may help inform future HRGC simulator studies.

1.1 Background

The Federal Railroad Administration (FRA) seeks to better understand the decision-making process of motorists at HRGCs. In 2015, FRA reported 2,068 incidents which occurred at an HRGC, resulting in 282 deaths and an additional 1,015 injuries. While full investigations are not conducted for every incident, a report by the Office of the Inspector general in 2004 indicate that driver error and poor judgement continue to play a significant role in HRGC accidents. In fact, of the 282 fatalities, 190 occurred at a crossing with active gates and 81 of the fatalities were reported as resulting from the driver going around the crossing gate. Of the 1,015 injuries, 518 occurred at a crossing with active gates and 154 of those injuries were reported as resulting from the driver going around the crossing gate (FRA, 2015).

There may be a variety of reasons why a vehicle operator may fail to comply with the warning devices present at a crossing. While some of these reasons may be fleeting, such as a temporary time pressure, others may be more engrained, such as learned expectations about train arrival times. From a 1998 study that observed vehicles at train crossings and surveyed violators, it was found that 68 percent of violators drove over the specific crossing at least 4 times per week and 19 percent crossed 2 to 4 times per week (Abraham, Datta, & Datta, 1998).

The current study expands on the results of Dr. Tom Raslear's Signal Detection Theory (SDT) research which investigated driver behavior at HRGCs (Raslear, 2015). This research provides a theoretical framework for predicting when a motorist may be most likely to violate a crossing based on expected train arrival times. Specifically, it predicted that variability in train arrival time may reduce the likelihood that a motorist will drive around active crossing gates. This is an important issue since many collisions at grade crossings involve motorists who drive around the gates of an active warning device (Raslear, 2015). Current Federal regulations (49 CFR 234.5) mandate that an active HRGC warning system indicate the approach of a train at least 20 seconds prior to the train's arrival, but longer times may also be permissible. Due to the rules implemented by the Federal Highway Administration (FHWA) and FRA, motorists have come to expect the train to arrive within approximately 20 seconds of the warning device onset (Yeh and Multer, 2008).

Some researchers have hypothesized that motorists are less likely to violate if the train arrival time is fixed as opposed to variable, often citing consistency as a way for a motorist to develop trust in the system and the system's reliability (Ogden, 2008; Jenness et al., 2006). The model proposed by Raslear (2015) predicts the opposite – variability may in fact increase compliance at a crossing. Specifically, Raslear showed that a motorist who is approaching an activated crossing may be *more* likely to proceed around the gates if they have previously experienced trains which arrive between 19 and 21 seconds after device activation (i.e., more consistent) when compared with a train arrival time that is between 10 and 30 seconds after device activation (i.e., more variable). In other words, consistent train arrival times with an average of 20 seconds are more likely to elicit violations than variable train arrival times around that same average of 20 seconds. While Raslear's model indicates that variability in train arrival times may increase compliance theoretically, this has yet to be shown empirically.

One of the challenges when performing a grade crossing study in a driving simulator is that in the real world drivers are for the most part compliant with active crossing gates. In a research simulator, presumably studying safety, drivers may be even less likely to behave in a risky manner and drive around an active gate. This does not mean that these risk-taking drivers don't exist; they simply may not be present in the sample available for a research study or these drivers may be more reluctant to exhibit their typical risk-taking behavior in the laboratory setting. In real-world driving scenarios, decisions to go around a gate may be influenced at a high level by expectations of train arrival times, but the decision to violate at that time is likely driven by a time-pressure. In other words, waiting for the train to pass would result in unacceptable delays in getting to some location. As such, incentives must be provided to encourage drivers to take risks that they otherwise may not have taken when driving in the real world, mimicking this subset of drivers who may dangerously go around a crossing gate under certain circumstances.

1.2 Objectives

The objective of this pilot test was to identify a strategy to effectively test the theory that motorists may be more compliant at highway-rail grade crossings with more variable train arrival times. Results from this pilot test will help FRA decide if a simulator study can empirically validate the model proposed by Raslear (2015).

1.3 Overall Approach

This pilot test was conducted in a driving simulator. The intention of this pilot study was to help FRA determine if a driving simulator provides an adequate environment to validate the proposed model.

1.4 Organization of the Report

The following report is organized into three sections. Section 2 discusses the methods used in the research, Section 3 presents the research results, and Section 4 provides a discussion of the results and the research team's conclusions.

2. Methods

The research team looked at noncompliance among drivers at active gate crossings. It has been hypothesized that drivers are more likely to be noncompliant if their previous experience at crossings has shown them that the train arrives consistently approximately 20 seconds after the warning device onset when compared with more variable arrival times. Due to the inherent danger of conducting this study in the field, the team used a driving simulator located at Volpe. Participants were asked to drive through a simulated world that contained four HRGCs. The team collected vehicular data such as speed, acceleration and deceleration rate, lateral lane position, and noncompliance rate.

2.1 Participants

Twenty licensed drivers from Volpe participated in this pilot study. Drivers from Volpe were selected for participation because using federal employees allowed the researchers to pilot test this study without requiring the Paperwork Reduction Act (PRA) process from the Office of Management and Budget (OMB). Given the novel nature of this experiment, this allowed researchers more flexibility to pilot test different scenarios as it was unclear which strategies were likely to be effective for inducing risk. Additionally, the experimental design relied on promoting risky behaviors in potentially risk-averse drivers. It remains unclear how such a design may translate to the real world where drivers with greater risk tolerance may behave differently. This very preliminary pilot allowed the research team to explore these possibilities so FRA could decide whether the results merit an expansion of the participant population to the public.

2.2 Equipment

The driving simulator, manufactured by Realtime Technologies, Inc. (RTI), consists of a quarter cab (Ford Fusion) placed in front of five screens subtending 210 degrees and 23 degrees vertically (Figure 1). The virtual environment is displayed on each screen at a resolution of 1920 by 1080 pixels and at a frequency of 60Hz.

Figure 1. RTI Driving Simulator

A participant sits in the cab and operates the controls, moving through the virtual world according to his or her inputs to the car (Figure 2). The audio is controlled by a separate system, which consists of four mid/high frequency speakers located at the left and right side of the cab (1 far left, 1 left center, 1 right center, 1 far right) and three subwoofers (1 left center, 1 center, and 1 right center). This system provides realistic road, train, and other vehicle noises with appropriate direction, intensity, and Doppler shift.

Figure 2. View of RTI Driving Simulator from Experimental Workstation

2.3 Experimental Procedures

The full experimental design included five conditions, each identical aside from the timing between the typical gate activation and train arrival. The five conditions were:

- *10 Second Fixed* – Every crossing was activated 10 seconds prior to the arrival of the train.
- *20 Second Fixed* – Every crossing was activated 20 seconds prior to the arrival of the train.
- *30 Second Fixed* – Every crossing was activated 30 seconds prior to the arrival of the train.
- *20 Second Variable* – Crossings differed in the timing when the gate was activated. One third of the crossings were activated 10 seconds before train arrival, one third were activated 20 seconds before train arrival, and one third were activated 30 seconds before train arrival.
- *30 Second Variable* – Crossings differed in the timing when the gate was activated. One third of the crossings were activated 20 seconds before train arrival, one third were activated 30 seconds before train arrival, and one third were activated 40 seconds before train arrival.

The pilot experimental design narrowed the focus of the study to include just two of these conditions to increase the power of the results due to the small sample size of the pilot (20 participants). The conditions selected for the limited pilot were the fixed and variable conditions that were logically most likely to yield different results, specifically *30 Second Fixed* and *20 Second Variable*.

Prior to starting the experiment, each participant was asked to drive the vehicle in a practice scenario. The goal of the practice drive was for participants to familiarize themselves with how the vehicle accelerated and braked and the sensitivity of the steering controls. During this practice drive, participants approached an active crossing and saw a train go through the crossing. They then approached a crossing which was already active and were informed by the experimenter that the gate had malfunctioned and they needed to go around the gate. It was made clear that this was safe for the purposes of this single instance, but all other crossings are functioning normally and when active they should expect a train. The purpose of having the participant drive around a gate was to show them that this was physically possible in the simulator and provide limited practice in completing that action.

Once this practice drive had been completed, drivers were asked to listen to a scenario read by the experimenter (full transcripts for the two different scenarios are available in Appendix A). The study was divided into two parts, three trials in each part, for a total of six trials across the two scenarios. For the first part, the participant was told that they need to commute to work. They are told that it is 8:40am and they need to be at their office by 9am. Their drive to work normally takes about 15 minutes and this considers the low 35 miles per hour speed limit and the many rail crossings along their path. They do not have access to a clock, but are informed of their time and progress after each of the three trials they will drive through. Their vehicle cannot go above 42 miles per hour and if they see a police vehicle they must obey the law or risk a five minute penalty at the end of the trial. This scenario was not intended to pressure drivers into violating a crossing as obeying both the speed limits and warning devices would result in arriving to their destination ahead of schedule. The goal of this portion of the experiment was two-fold; first, to familiarize the driver with the drive and second, to provide the driver with several crossings to experience the consistency or variation in train arrival timing (and thus establish an expectation of train arrival times).

Participants then drove through a series of three trials. Each trial used a straight road with a row of trees on either side of the roadway restricting viewing angles. Along this road the driver encountered four grade crossings the timing of which depend on the condition being run. The type of train (Passenger vs. Freight) and direction the train moved (left-to-right or right-to-left) were counterbalanced so the participant could not predict the type or direction of the train. Police vehicles were strategically placed alongside the roadway in the first four trials to discourage drivers from speeding (posted limit of 35mph) or from going around gates. The goal was to provide drivers with enough time to experience the crossing timing and build a sense of familiarity with this route. During this first part of the drive, the participant arrived at their destination with plenty of time to spare after obeying all posted signs and crossing warnings. This first scenario contained no time pressure and was strictly used to familiarize the participants with the route and to build their expectations about the train arrival times.

In the second part of the study a time pressure was introduced, though this was not known to the participant until they experienced the pressure in the scenario. Another scenario was read by the experimenter (full transcripts for the two different scenarios are available in Appendix A). They were told that they just arrived back at their house after returning from work one Friday, but they had forgotten their passport at their office, and they need the passport to go on their vacation. They were informed that the building will be closed and locked for the weekend in just 15 minutes and that they need to make it back to their office in time or else they will not be able to make their trip. They were informed that they will drive through the same three drives as in the first part, so they know that 15 minutes will be close to their expected time.

The differences between the two parts can be seen in Figure 3. At the end of each trial, the experimenter provided the participant with their time on the given trial, their overall time, as well as their pace to reach the destination in the allotted time. The virtual clock was used for two reasons: first, so the time spent between trials to start and stop the simulation and to report the time to the participant were not counted, and second to provide the experimenters with more control of the specific timing the participants hear. Being able to determine the times being provided to the participants allows experimenters to better control how strained the time is for participants in the later trials.

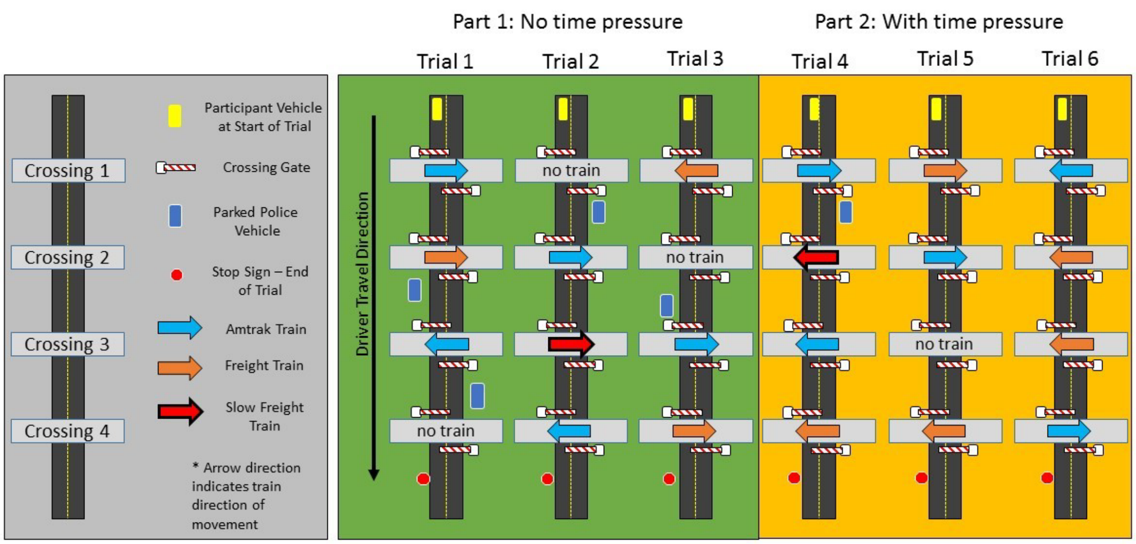

Figure 3. Schematic of Driving Conditions

The exact same order of trials is used in all five conditions. In the 10, 20 and 30 second fixed conditions, every crossing gate is activated the exact same amount of time prior to the arrival of the train at the crossing. In the 20 and 30 second variable conditions, the crossings vary in equal proportion between 10, 20, and 30 seconds between activation and train arrival for the 20 seconds variable condition and 20, 30, and 40 seconds between activation and train arrival for the 30 seconds variable condition. As mentioned above, since this experiment uses a virtual clock, the experimenter can control the exact timing provided to the participants – thus the approximate times in Table 1 will be true for all conditions. This allows the experimenters to use the same approximate timing constraints on all conditions regardless of small changes in overall true time between conditions. Pre-pilot testing revealed that participants felt that the times provided were real times in all cases and had no suspicion that the experimenters were manipulating these times.

Table 1. Approximate Drive Times Assuming Participant Obeys Posted Speed Limits and Compliant At All Crossings

	Part 1			Part 2		
	Drive 1	**Drive 2**	**Drive 3**	**Drive 1**	**Drive 2**	**Drive 3**
Start Time	**8:40 AM**			**5:45 PM**		
Drive Time	0:04:27	0:05:05	0:04:30	0:06:40	0:04:30	0:05:10
Total Elapsed Time	0:04:27	0:09:32	0:14:02	0:06:40	0:11:10	0:16:20
Virtual Clock	8:44:27 AM	8:49:32 AM	8:54:02 AM	5:51:40 PM	5:56:10 PM	6:01:20 PM
Pace	+0:02:13	+0:03:48	+0:05:58	-0:01:40	-0:01:10	-0:01:20

Pre-pilot testing of these scenarios raised one complication – to identify a way to prevent drivers from driving in the opposite lane of traffic. The scenarios did not include additional vehicle traffic to minimize the potential for the actions of another vehicle to influence the participants' decision-making at the crossing. If drivers chose to drive in the opposing lane, which was possible without oncoming traffic, they could go through the crossing at, or near, full speed. The ability to speed through a crossing without stopping removes some of the perceived danger of the crossing and even a 10 second waiting period may be long enough for a driver to feel comfortable speeding through. However, the addition of regular traffic has the potential to influence driver decision making in a way that may limit the researchers' ability to understand the effects of timing alone. The solution for this experiment was to add oncoming traffic only if a driver veers into the other lane of traffic. When a driver crosses the center line, which would happen when going around a gate, this would create an oncoming vehicle far down the roadway. The driver would not be able to perceive the sudden appearance of this car, which will arrive at the next crossing just prior to the participant's arrival at the next crossing, thus making it impossible for them to drive in the opposing lane without striking that vehicle. Minimizing the ability to drive in the opposing lane limited the driver's ability to drive around the gates at full speed.

The signal detection research on which this work is based predicts that the 20 second fixed condition would elicit gate violations more often and/or earlier in the experiment than the 20 second variable condition. While not explicitly tested in the work by Raslear (2015), the research team would also predict that the 10 second fixed condition would closely mirror the variable condition because the time is too short for the driver to ever feel comfortable or safe going around the gate. The 30 second fixed condition would also be expected to yield violations, much the way that the 20 second fixed condition had; and perhaps even more violations since the risk may be seen as even lower with longer wait times. The 30 second variable condition is less clear. If the 20 second fixed condition elicits violations, then it was expected the 30 second variable condition might also elicit violations, since the shortest time that the driver will experience is still 20 seconds.

3. Results

Prior to the launch of the pilot study, researchers performed a series of pre-pilot tests to establish the validity of the current methodology. These pre-pilot tests typically involved participants who were blind to the specifics of the experiment, but could help troubleshoot potential modifications to the experimental procedure. Several methods were attempted before the team determined the current design to be the most viable and likely to yield results (e.g., the addition of the conditional traffic described in Section 2).

In pre-pilot testing of the current study design, participants indicated that they felt pressure to consider violating the crossing in the time-pressure scenario because of the imposed time constraint. No pressure was felt in the first scenario and no violations were recorded. While not all pre-pilot participants did violate a crossing, they nearly universally claimed to have considered violating as the pressure to get to their goal location was sufficient.

These pre-pilot findings were important to ensure that the pilot test had the potential to elicit meaningful results. Without an adequate time pressure the experimental results would likely rely solely on the inherent riskiness of each participant in the simulator. By using an effective story and limiting the participants' freedom to drive in overtly risky ways (e.g., in the opposing lane of traffic, on the grass, or excessively fast) the team hoped to explore the impacts of train arrival times in settings where participants felt equal pressure to violate.

As of October 21, 2016, eight federal employees had volunteered and participated in the pilot study. Of these eight participants, six completed the full study and two dropped out due to simulator sickness. In neither the pre-pilot nor the pilot studies did any participant go around a gate during the trials with no time pressure. This indicates that drivers were not behaving overly riskily and they were taking the simulation seriously and following the scenario directions. Previous iterations of the study resulted in drivers violating even the first gate they encountered (before any understanding of train arrival time could be established), but the current study design eliminated this concern.

The results from the first six participants are included in Table 2 below.

Table 2. Preliminary Violation Results by Condition

Condition	Number of Participants	No-Time Pressure Violations	Time-Pressure Violations
10 Second Fixed	2	0 of 9 0 of 9	0 of 10 0 of 10
20 Second Fixed	1	0 of 9	5 of 10
30 Second Fixed	1	0 of 9	0 of 10
20 Second Variable	1	0 of 9	9 of 10
30 Second Variable	1	0 of 9	0 of 10

Of the first six participants only two violated during the time-pressure scenario – one in the 20 second fixed condition (predicted) and one in the 20 second variable condition (not predicted). Additionally, the one participant to run in the 30 second fixed condition (i.e., the condition most likely to elicit a violation based on theory) never violated. These findings, along with anecdotal comments offered by the participants raised questions of how many participants would be required to see reliable trends. Participant comments seemed to indicate that they were generally unaware of the train arrival timing manipulation. At this point, a decision was made to re-focus the pilot test on the two conditions most likely to provide different results: 20 second variable and 30 second fixed. If the model was to be validated in the simulator, the 30 second fixed condition would consistently provide the most time for participants to circumvent the gates (i.e., more violations) and the 20 second variable condition would result in increased compliance (i.e., fewer violations) due to the variability.

In November 2016, another 14 participants joined the experiment, resulting in 20 overall participants and 16 participants in the two main conditions: 8 in the 20 second variable condition, 5 male and 3 female participants with a mean age of 37.57 (S.D. 9.30), and 8 in the 30 second fixed condition, 5 male and 3 female with a mean age of 25.43 (S.D. 13.30). The results of this more focused pilot study is shown below in Table 3.

Table 3. Preliminary Violation Results by Condition

Condition	Number of Participants	Non-Time Pressure Violations	Time-Pressure Violations
30 Second Fixed	8	0 of 9 0 of 9 0 of 9 0 of 9 0 of 9 0 of 9 0 of 9 0 of 9	0 of 10 0 of 10 0 of 10 0 of 10 *2 of 10* 0 of 10 *2 of 10* 0 of 10
20 Second Variable	8	0 of 9 0 of 9 0 of 9 0 of 9 0 of 9 0 of 9 0 of 9 0 of 9	*9 of 10* 0 of 10 0 of 10 0 of 10 0 of 10 *7 of 10* 0 of 10 0 of 10

The results of this limited pilot test found an equal number of participants who violated in the two conditions. Were this experimental design capable of identifying a difference in driver behavior based on train arrival time, the team would have expected different violation rates in these two conditions (i.e., more violations in the fixed condition than in the variable condition). No participants violated a crossing in the non-time pressure scenario, indicating that each participant was listening to the story and acting appropriately. In the time pressure scenario, participants in both the fixed and variable condition violated 25 percent of the time (2 out of the 8 participants). The only difference that was found was that participants who violated in the 20 second variable condition were more likely to do so earlier in the scenario than those who violated in the 30 second fixed condition. While not the measure being considered for this pilot, this still counters the theory that a fixed arrival time may increase violations or cause participants to violate earlier in the experiment.

4. Conclusion and Discussion

The purpose of this pilot test was to identify an experimental design that would allow researchers to study the effects of gate timing on driver decision making. This pilot test underwent several iterations prior to the identification of the final experimental design. The results of the pre-pilot testing and the initial pilot test revealed that participants were responding to the time pressure appropriately (e.g., never violating in the non-pressure scenario and occasionally violating in the pressure scenario). This is critical as it shows that participants were taking the study seriously and were only violating when the pressure to do so was great enough and they felt that they could do so safely. However, data on the first 20 participants indicated that the limited participants available for the pilot study may not reveal strong enough differences across the five conditions. This may be due to several reasons:

- The team does not yet have sufficient data across these conditions. It is possible that running more participants would reveal a systematic difference between the conditions (either confirming the hypothesis or presenting an alternative view).
- While the pre-pilot and pilot data indicate that drivers experience the time-pressure of the story, this pressure may not be great enough, or alternatively too great. Without an adequate incentive to violate the crossing the experiment has the potential to result in overly cautious (i.e., floor effect) or overly aggressive (i.e., ceiling effect) driving behavior. Both scenarios make it more difficult to detect any differences between conditions. It is possible that by modifying the experimental script, changing the type of incentive (e.g., introducing a financial incentive), or changing the crossing type (e.g., from a gated crossing to a crossing with only lights and bells) researchers may see different results.
- The effects of train arrival variability on driver behavior, while present and accurate, may be quite small and difficult to detect using a simulator. It is possible that the hypothesis about consistent warning times eliciting more violations is true, but requires very specific circumstances. This may be because of an extensive familiarity with a specific crossing and the pattern of train arrivals for that crossing (which was not possible in a short simulator experiment outside of potentially priming the participants with footage prior to them entering the simulator – which was not attempted due to timing limitations). Or it may simply be that these added incentives to violate are incredibly small and would require an incredibly large number of participants to detect. And if detected, it is unclear if such a small real-world result would point toward an actionable solution.
- The inherent risk-aversion of an individual driver will always outweigh the pressures present in a simulated scenario. While an individual's risk tolerance may explain their likelihood to consider violating a crossing in the real world, the design of this experiment tried to create a scenario where all participants are pressured equally. However, given the unsafe nature of violating a crossing, it may be possible that no simulated pressure can overcome the individual differences in risk-aversion. If this is the case, an effective experiment would require selecting only participants who would consider violating a crossing in the real world (thus minimizing risk-based individual differences). A large enough subset of this population is unlikely to exist among the federal pilot population and may be difficult to identify in a larger study.

The value of limiting the focus of the pilot study to the two most extreme conditions was to see if this more focused design could reveal results that were too difficult to see across all five conditions. This also allowed the research team to increase the number of participants in a single pilot condition. However, despite hoping to uncover an effect with these two conditions, again no systematic difference was found.

At this time, given the results of this pilot test, the research team cannot recommend moving forward with a larger experimental population. While it remains possible that a large number of participants would help to achieve the power necessary to empirically test the warning time variability hypotheses, the early results may indicate that the required sample size may be too large to be practicable. Additionally, if the effect size is small (as would be the case if a large sample size is required to find reliable differences), the team questions recommending action based on such a small difference. Alternative methods to test this hypothesis may also be considered, as it may be possible that the simulated environment makes testing these risky behaviors too difficult. These alternative methods may include collecting video data at crossings with variable warning times or obtaining information about existing crossing warning time consistency and analyzing historical incident records. This type of field data collection would also have the benefit of verifying the true range of train arrival times, which was assumed to be normal in the theoretical paper on which this study was based.

If a decision is made to continue with the current experimental design, a greater number of participants must be run through the experiment in order to achieve enough power to draw conclusive results. This initial pilot study was conducted with federal employees from Volpe because a full PRA review is not required for federal employees, which provided the researchers with more flexibility to tweak the experimental design in this pilot phase. To move on to a second phase, one with a larger sample size from the general population, a PRA review must be conducted by the OMB.

If, based on the results of the final pilot test, FRA were to move forward with a full public study, additional next steps would be required, including publishing notice in the Federal Register and preparing an information collection request (ICR) package. While using the public would provide some opportunities not available when testing federal employees (e.g., using a financial incentive to encourage risk-taking), it is important to note that it is not clear how the findings of the pilot study would translate to this different type of incentive. This may be worth considering if an alternative approach is proposed for any subsequent simulator experimentation.

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Appendix A.
Experimental Script (Full)

Setup

- ☐ DO: Check that correct gearshift is installed in simulator

Pre-Study

SAY: "Hi! Thank you for participating in our study today. Before we get started, could you please read this informed consent form? Once you've read it through, please sign to acknowledge that you understand the risks and benefits of this study. If you have any questions about the study, feel free to ask me at any point."

- ☐ DO: Make sure participant signs consent form, sign and date it yourself

SAY: "Thank you! Before we get you started in the simulator, we would like you to fill out this pre-study questionnaire so we have a basic idea what kind of a driver you are. All information that we collect during this experiment will be anonymous and confidential. The data collected today from both the questionnaires or from the driving simulator will be associated with an ID number stored separately from any personally identifying information. Again, if you have any questions about anything in the questionnaire, please let me know."

- ☐ DO: Pre-study questionnaire completed

SAY: "Thank you. Now, if you'll please have a seat in the driving simulator we can get started. Before we get to the driving, please adjust the seat to a comfortable position and buckle your seatbelt. You can adjust the position of your seat with the controls, right down here, on the left hand side of your seat. You can also adjust the height of the steering wheel, if it doesn't feel right, with the control on the underside of the steering column. Now that you're positioned right, you will see the driving simulator start up a practice driving scenario. This practice drive is supposed to give you a chance to feel how your vehicle handles during the simulation. Things like how the brake feels and the how responsive the steering is."

Practice

- ☐ DO: Start the practice drive, then stand in front of the participant so they can hear the remainder of the instructions

SAY: "The brakes, gas, and gear selector are located in the same place you would normally find them in a car. The one major difference I want you to be aware of is that the rear and side-view mirrors are located on the screens here, here, and here [point to them]. When you are ready and feel comfortable, please shift into gear and drive down the road. As you drive forward, you will soon come to a grade crossing. Please stop once you reach the first crossing and then continue once it is safe to cross."

- ☐ DO: Wait for participant to approach the second grade crossing

SAY: “For this practice scenario the crossing gate you have just approached is malfunctioning. Because of this, the gate will stay down indefinitely. There is no train coming at this time on this track from either direction. I assure you that in this instance you are safe to drive around the gate. Seriously, this is just a malfunctioning gate. Whenever you are ready, please drive around this crossing gate and continue down the road until you hear a voice ask you to stop.”

- ☐ DO: Wait until participant comes to a stop at the stop sign.

SAY: “How do you feel? Do you feel comfortable with the feel of the car and the brakes? If you would like to get more of a feel for the car you are welcome to continue to drive up to the next crossing. Otherwise, we can stop the practice and get on with the first scenario. Before we continue, I just want to check to make sure you are not experiencing any motion sickness. Great, then let’s get started!”

Scenario/Story

SAY: “The study you are about to participate in has two separate parts. You are about to start part 1. For the first part of this study, please drive your car as you would if you were faced with the following situation. It is 8:40am on a Monday morning. You are about to leave for work and have to be in your office by 9:00am. Your commute is quite short; it normally only takes you about 15 minutes to get there. The speed limit throughout your entire drive is 35 miles per hour and there are often police cars along your route watching for violations. Your commute, which is down a straight road, takes you over several very active train crossings. And please note that your estimated 15 minute commute already takes into account that you will likely be stopped by several trains, since this is common. You don’t need to worry about parking since you have your own parking spot right next to your office’s front door.”

SAY: "There are a few other rules of the scenario that you need to know before we can begin.”

- “Your trip to work will consist of three different drives – each quite similar to the practice drive you just experienced.”
- “We will be starting and stopping the experiment between drives, and therefore the clock that we will use will not match up with the clock in the vehicle or on your wrist – we call this the “virtual clock”. This means that only I have the true amount of time you have left to get to work. You will not be able to see your time during the experiment, but I will inform you at the end of each drive of your overall time as well as how ahead or behind pace you currently are to arrive on time.“
- “This virtual clock will only run when you are in a drive. The drive technically will start as soon as you touch the accelerator at the beginning of each of the 3 drives and will stop as soon as your vehicle is at a complete stop at the stop sign and the vehicle is put in park at the end of the drive. It is at that time that I will tell you your current time.”
- “The vehicle you are driving has a governor and is prevented from going too far over 40 miles per hour. However, please note that as you go through the scenario the posted speed limit is 35 miles per hour throughout all the drives.”
- “If a police officer sees you break the law, you will be penalized 5 minutes on the virtual clock. A police officer can only see you if you can see them in front of you or clearly in your mirrors.”

- “Unlike in the practice scenario, during the remainder of the experiment all crossing gates are functioning properly. If any part of your car strikes a gate at a crossing you will be penalized 20 seconds at the end of that drive.”
- “If any part of your vehicle is struck by a train the experiment is instantly over and you have failed to get to work in time. Do not get hit by a train – your safety is your priority above all else.”
- To recap, you have 20 minutes on my virtual clock to get to work but it normally takes you just 15 minutes. That said, you like getting to work early. Don’t break the law in front of a police officer, or you will be penalized 5 minutes. Don’t strike a crossing gate or you will be penalized 20 seconds. And above all, do not get struck by a train, or the scenario is over immediately.”

SAY: “Do you have any questions about the scenario?”

☐ DO: All questions answered

Experiment

SAY: “Now that you understand the situation you are in, while we get the first drive up and running, I will go through the basics of your task one last time. You will go through a series of three drives similar to the practice drive you just drove. All crossing gates are functioning properly and as is the case in a real car, when you see train tracks you can expect a train. The speed limit is 35 miles per hour. You must get to the office within 20 minutes of virtual time, so you need to average under 7 minutes per drive in order to make it on time. I will keep you posted of your progress after you complete each drive.”

SAY: “Ok, you are now about to start your first drive. As soon as you touch the accelerator my clock will start. Please begin and safely start your drive to work.”

- “You just completed the first of three drives.”
- “That drive only took you [Drive Time] __ [4] minutes and __ [34] seconds to complete.”
- “You are currently [Pace] ___ [2] minutes and ___ [26] seconds ahead of pace to arrive at work on time.
- “Are you still feeling ok and ready to continue?”

☐ DO: Setup Trial 2 simulation

SAY: “Ok, we’re about to get started with the second drive. You can start driving whenever you are ready and as soon as you touch the accelerator my clock will start.”

- “You just completed the second of three drives.”
- “That drive took you just [Drive Time]__ [4] minutes and __ [2] seconds to complete.”
- “After that drive you are [Pace] ___ [3] minutes and ___ [36] seconds ahead of pace to arrive at work on time.”
- “Are you still feeling ok and ready to get started with the final drive of this first part?”

☐ DO: Setup Trial 3 simulation

SAY: "Ok – you are now ready to begin your third drive. The time is now [Time] [8:49AM and 42 second] which means that you have [Time Remaining] ___ [10] minutes and ___ [18] seconds left to make it to work on time. As soon as you touch the accelerator my clock will start."

- "You just completed the third of three drives and congratulations you made it to work with plenty of time to spare. "
- "That last drive took you only [Drive Time] __ [4] minutes and __ [29] seconds to complete, getting you to work [Time Remaining] early."
- "It took you [Overall Drive Time] [14] minutes and [30] seconds to complete your commute to work this morning. You made some good time!"

SAY: "You have just completed the first part of the study and congratulations again on making it on time during the first part. Whenever you are ready, we can move on to the second part of the study. Would you like to take a short break or are you ok to proceed on to the next part?"

☐ DO: Wait for a response – if they want to break, then wait for as much time as they need. If not, continue.

"We will now get started with the second part, which happens to drive along the same road you just drove. Please drive your car through the next three drives as you would in the following situation: It is now Friday at 5:45pm – woohoo! You are home from the office and your long work week is finally over! Even better, you are leaving for vacation tonight on a flight that leaves in just over 2 hours, at 8pm. Unfortunately, you just realized that you left your wallet and passport on your desk at work. You cannot get on your flight without them and your office closes and locks the doors for the weekend at 6pm, which is in just 15 minutes. Luckily your luggage is already packed and in your car and the airport is right next to your office – so all you need to do is get to your office before the doors get locked and you will make your flight with time to spare. Your commute to work, as you just experienced, normally takes you close to 15 minutes so you will likely be cutting it quite close."

"Just as before, the time will not start until you hit the accelerator on each drive and will stop as soon as it is in park at the end of the drive. All crossing gates are functioning properly and, as is the case in a real car, when you see train tracks you can expect a train. The speed limit is still 35 miles per hour throughout. Don't break the law in front of a police officer or you will still be penalized."

"Your office doors get locked in 15 minutes. Get there in time to get your wallet and passport so you can make your flight and have an amazing, well-earned vacation. I will keep you posted of your progress after you complete each drive."

SAY: "Ok, you are now about to start your first drive. As soon as you touch the accelerator my clock will start. Please begin and safely get to your office before the doors get locked!"

- "You just completed the first of three drives."

- "That drive took you [Drive Time] __ [6] minutes and __ [24] seconds to complete. That slow train really slowed you down."
- "You are currently [Pace] ___ [1] minute and ___ [26] seconds behind pace to get to your office before they lock the doors."
- "Are you still feeling ok? Ready to continue with the second drive to try to make up some time?"

☐ DO: Setup Trial 2 simulation

SAY: "Ok – you are now ready to begin your second drive. The time is now [virtual clock time], as soon as you touch the accelerator my clock will start."

- "You just completed the second of three drives."
- "That drive took you [Drive Time]__ [4] minutes and __ [42] seconds to complete, so you made up a little time there."
- "Still, after that drive you are [Pace] __ [36] seconds behind pace to get to your office before they lock the doors."

☐ DO: Setup Trial 3 simulation

SAY: "You have one drive left and the time is now [Time]. That means that you have only [Time Remaining] ___ [4] minutes and ___ [8] seconds to get to your office before they lock the doors. You can still make it. Do what it takes, but get there safely. As soon as you touch the accelerator my clock will start."

- "You just completed your final drive."
- Made it:
    - "That final drive took you [Drive Time] __ [4] minutes and __ [2] seconds."
    - "That means that your drive took you [Overall Drive Time] [14] minutes and [30] seconds and you made it on time! Congratulations!"
    - "You got your wallet and passport and enjoyed an amazing vacation! Well done."
- Didn't make it:
    - "That final drive took you [Drive Time] __ [4] minutes and __ [55] seconds."
    - "That means that your drive took you [Overall Drive Time] [15] minutes and [30] seconds and you got to your office after the doors were locked! I'm sorry, you didn't make it on time."
    - "By the time someone was able to come out and open the doors, you had missed your flight. Hopefully they have another flight out tonight and you can still make some of your vacation."

- ☐ DO: Bring participant to the conference table and ask them to fill out a post experiment questionnaire.

SAY: “Thank you so much for participating in this experiment. At this time, I cannot tell you too much more about the experiment as there are additional participants here at Volpe that will be participating. However, if you are interested in learning more about this study, please use the contact information provided in your copy of the consent form to let us know and we would be happy to follow up with you once this pilot is completed. Thank you for your time.”

Abbreviations and Acronyms

CFR	Code of Federal Regulations
HRGC	Highway-Rail Grade Crossing
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
OMB	Office of Management and Budget
PRA	Paperwork Reduction Act
RTI	Realtime Technologies Inc.
SDT	Signal Detection Theory