National University Rail Center - NURail
US DOT OST-R Tier 1 University Transportation Center

NURail Project ID: NURail2019-MTU-R17

Understanding Attention Management and Driver Decision Behavior at Short-Storage Rail Crossings

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26-08-2020

Grant Number: DTRT13-G-UTC52

DISCLAIMER

Funding for this research was provided by the NURail Center, University of Illinois at Urbana - Champaign under Grant No. DTRT13-G-UTC52 of the U.S. Department of Transportation, Office of the Assistant Secretary for Research & Technology (OST-R), University Transportation Centers Program. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation's University Transportation Centers Program, in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

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TECHNICAL SUMMARY

NURail Project No. NURail2019-MTU-R17 Final Report August 26, 2020

Title

Understanding Attention Management and Driver Decision Behavior at Short-Storage Rail Grade Crossings

Introduction

The goal of this project was to focus on understanding driver attention and decision-making behavior at short-storage highway-rail grade crossings (HRGCs) compared to non-short storage HRGCs. While rail safety has improved from the mid-1990s to 2010 (Yeh & Multer, 2008)), the decreasing trend has flattened over the last 10 years (Tey, et al., 2013). Locations with nearby highway intersections (short-storage) have proven to be challenging for safe traversal. Since majority of HRGC crashes are caused by human behavior, we believe research on short-storage may provide new insights to understand driver challenges in those locations.

There is limited past research at short storage or limited space crossings, especially on driver behavior aspects. Short-storage HRGCs are those crossings with a highway or intersection that is close to a rail track, such that there is limited space for vehicles to stop after the track. The size of the limited space (red in Figure 1) is typically not specified, but one 2002 HRGC working group report defined it as under 100 ft (HRGC working group, 2002). Other reports have described short storage as being under 200 feet of space between the railroad tracks and a highway intersection, or when signal preemption was used to clear the intersection prior to train arriving at the HRGC.

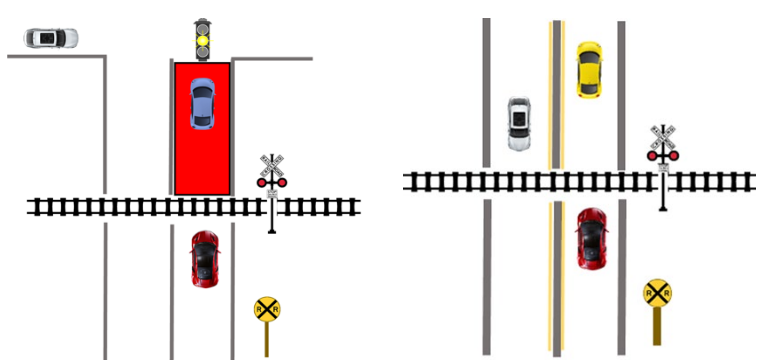


Figure 1. Example of *SS-HRGC crossing (left) and Non-SS-HRGC (right). The red rectangle represents the limited area of storage for queued vehicles*

We conducted a large literature review and found that short or limited storage has been occasionally mentioned in articles, or as an example of a type of challenging HRGCs. However, to the best of our knowledge, no research to date has systematically analyzed the effect of crossing types, short or limited storage compared to non-short-storage on the frequency of incidents, driver decision behavior, or attention to safety concerns. We pursued research supporting two different tracks under this research program: 1) work with real world data, such as the Federal Railroad Association, to identify conditions during short-storage crossing incidents, and 2) work on lab studies to understand attention management and decision making using actual crossing scenes. This final report highlights these two studies conducted and analyzed between September 2019 and August 2020.

Our goal was to identify factors that impact driver decisions in short-storage space crossings using a combination of archived real-world data from the FRA database and lab experiments. After describing the overall goals of the projects, we summarize the methods and key findings from the two studies.

Task 1: We conducted a literature review and found none had systematically measured or manipulated HRGCs types (e.g., short-storage vs. non-short storage) and evaluated driver behavior. We also examined three years of FRA safety data reports (2017-2019) to capture a corpus of 996 highway-rail incidents across six states. We examined the pattern of incidents at short-storage HRGCs to understand how they differ from non-short storage crossings.

Task 2: We conducted a controlled experiment in order to determine whether the short-storage crossing type or presence of obstruction affected drivers' safety concerns. Our experiment complemented insights from the FRA database into people's processing of a variety of information at short-storage HRGCs and suggested factors for scenarios to test driver responses in future driving simulator studies.

Our planned **Task 3** was not completed because in-person, driving simulator pilot study (planned for Spring/Summer 2020) could not be done due to the COVID-19 pandemic. Therefore, we expanded Task 1 to include three years of FRA data rather than a single year as originally planned. This allowed a systematic analysis of short-storage HRGCs.

The goal of this research program is to begin to explore the effect of short-storage HRGCs on safety. We extend previous rail-safety research, in order to understand what drivers notice, and how they make decisions in short-storage space crossing situations with the goal of providing new insights into human behavior when developing future safety improvements.

Task 1: Evaluating the effect of short-storage HRGCs on real-world highway-rail incidents

Previous research has suggested that short-storage HRGCs are more complex and cognitively challenging, but this type of crossing has not been systematically analyzed in the Federal Rail Safety Database or in controlled, lab experiments using simulations. This project begins by exploring the nature of incidents and incidents at short-storage HRGCs. What is the base rate of short-storage HRGCs impact on real world incidents and accidents? Currently, this information is not readily available in the FRA database, so compiling it for the three-year period will be useful to research and operational personnel. We examined FRA incident and accident reports from 2017-2019 with several goals. First, it is not known how many short storage incidents occur each year, relative to all highway-rail crossings. Second, we sought to characterize the nature of incidents at short-storage HRGCs in terms of motorist characteristics, environment context, motorist decision behaviors, and incident outcomes (e.g., train strike vs. vehicle strike, injury severity). Third, we quantitatively compared the frequency distribution of motorist behaviors and outcomes of incidents at short-storage HRGCs to those at non-short-storage HRGCs.

Specifically, do short-storage and non-short-storage HRGC incidents differ in terms of the motorist characteristics, driver pre-crash decision behavior, and outcome (train strike vs. vehicle strike, and injury severity). If they do, it might suggest new research areas, different interventions, and different countermeasures for consideration.

Our literature review examined research over the last 30 years in rail-highway safety and found that short-storage is occasionally mentioned in the literature (Ambros, et al., 2019; Campbell, et al., 2015; Marshall & Berg, 1997; Simpson, 2010), but never systematically examined. To close the gap, we focus on these research questions:

R1: What are the characteristics of short-storage HRGC incidents?

R2: Does the frequency of short-storage and non-short storage HRGC incidents differ in terms of motorist characteristics or size of vehicles involved?

R3: Does the frequency of short-storage and non-short storage HRGC incidents differ in terms of driver pre-crash decision behavior?

R4: Does the frequency of short-storage and non-short storage HRGC incidents differ in terms of incident outcome?

METHODS STUDY 1

Data for this analysis came from the FRA safety database and Google Earth images and were compiled by three research assistants and a graduate student. Incidents records from 2017-2019 were extracted from the Federal Railroad Administration (FRA) Safety Information database. Starting with all 6,561 highway-rail incidents for the last three-years, we then filtered for public highway-rail grade crossing (HRCG) incidents across six US states: Florida, Indiana, North Carolina, New York, Pennsylvania, and Washington and 1,099 records remained. We chose these six states for two reasons: a) these six states represent variety of HRCGs driving experiences (rural, suburban, city), and they were the same six states used in the Naturalistic Driver Study (NDS) (Lautala et al., 2018). Of the 1,099 records, 103 were removed either because they were not vehicle-rail incidents (e.g., cyclists) or the record lacked sufficient information for analysis. The resulting corpus of data were 996 FRA records representing short storage and non-short storage crossings.

Limited or *short storage* is not a code or field in the FRA safety database, but there are several fields that indicate a potential short-storage HRGC (i.e., narrative, preemption field). By reviewing these fields, about 250 potential short-storage HRGC incidents were identified. However, we still needed to confirm these involved short-storage HRGCs. Two research assistants pulled and reviewed the Google Earth images from the year of the incident for all 996 incidents and a) determined if they involved short-storage HRGCs, b) measured the distance from the rail crossing edge to the intersection, and c) noted the location of obstructions, if any. For the purpose of this first study on short-storage HRGC incidents, we defined short storage or limited space as crossings with fewer than 200 feet of space between a highway intersection and the tracks.

The factors from the database used in the analysis are below. It should be noted that we did collapse some into fewer categories that made sense to combine.

- ***Vehicle Size.*** Small vehicles (cars, pickup, motorcycles). Large vehicles (buses and semi-truck).
- ***Pre-crash behavior/Motorist Decision*** included four levels: motorist did not stop, moving over track, stopped on track, blocked/trapped)
- ***Strike*:** Train striking vehicle. Vehicle striking train.

- ***Injury severity*** categories based on 3 levels in the FRA database: no injury, injury and fatality.

RESULTS STUDY 1

We used chi-squared tests which measure the degree of association between two categorical variables to quantitatively evaluate the incident distributions between short-storage and non-short storage HRGCs.

R1: Characterizing short-storage HRGCs incidents: Frequency and Size of Space

From the 996 incidents across the six US states, 20.3% involved short-storage HRGCs and 79.7% involved non-short-storage HRGCs. This base rate of 20% of rail-highway incidents happening at short-storage HRGCs and 80% at non-short storage HRGCs was consistent across all three years in our sample (2017, 2018, 2019). The length of short-storage space was another descriptively interesting characteristic. In our sample, the median was 48 feet, while the average was 71.4 feet (*SD*=55.46).

Next, to address R2 and R3, we compared short-storage HRGC and non-short storage HRCG incidents in terms of motorist characteristics, pre-crash behavior (stop, go through or around gate, did not stop), and outcome (train strike, vehicle strike) to identify systematic differences in the distribution for the two crossing types.

R2: Does the frequency of short-storage and non-short storage HRGC incidents differ in terms of motorist characteristic or the size of vehicles involved?

We found differences between incidents at short-storage and non-short storage HRGC for motorist's age, but none due to motorist gender or the size of the vehicle they were driving.

Average age of drivers in short-storage HRGCs incidents was higher (Mean= 46.5 years, *SD*=18.3), than for non-short storage HRGC incidents (Mean = 42.9 years, *SD*=17.2), t-test t(770)= 2.1, *p*=.03. Motorists in the 996 incidents were predominantly male (69.4%) and the gender split (69% male, 31% female) did not depend on the crossing type, $X^2(1) = 0.87$, *p*=.35.

Collapsing age into three groups (young drivers < 29 years, middle age 30-59, and older drivers 60 years and up), the distribution of ages across and non-short storage HRGCs incidents was different, $X^2(1) = 6.92$, *p*=.03. Older drivers (60 years and up) made up a higher percentage of short-storage HRGC incidents (26%) than non-short storage HRGCs incidents (18.8%), while younger drivers made up a 30.7% of the non-short storage HRGCs incidents and only 21.7 % of the short-storage incidents, with no difference for middle age drivers. As has been argued in other articles, short-storage HRGCs require more attention and cognitive effort to analyze in general; therefore, this finding that short-storage HRGCs may affect older adults at a higher rate is interesting and consistent with that idea.

Limited storage space impacts the number of vehicles that can fit between intersection and HRGC, therefore we examined whether *vehicle size* was related to crossing type and it was not. Short-storage HRGC and non-short storage HRGCs incidents did not differ in terms of vehicle size, $X^2(1) = 1.83$, *p*=.17. For both crossing types, 81.4% of the incidents involved smaller vehicles (e.g., cars, van) and 18.4% involved larger vehicles (e.g., tracker trailers, buses).

R3: Does the frequency of short-storage and non-short storage HRGC incidents differ in terms of motorist pre-crash, decision behavior?

Driver decision making leading up the highway-rail intersection may highlight differences between short-storage and non-short storage HRGCs incidents. We found that decision behavior did statistically differ depending the type of HRGCs (Table 1). A chi-squared test showed that motorists' pre-crash decision behaviors were associated with the *Type of crossing* (short-storage vs. non-short storage HRGCs), $X^2(3) = 29.28$, $p=.0001$. For non-short storage HRGCs incidents, 58% of motorists were *moving across the rail* crossing at the time of the incident, compared to 38% in short-storage HRGCs. In contrast, motorists in short storage HRGCs incidents (42%) were more likely to be *stopped on the tracks*, compared to non-short storage HRGCs incidents (28%).

Table 1. Distribution of pre-crash behavior by short storage and non-short storage HRGCs

	Type of Highway-Rail Grade Crossing	
Motorist Behavior	Non-short storage (NSS)	Short-Storage (SS
Moving across rail	58%	38%
Go around/thru gates	12%	16%
Stuck on the track	2%	3%
Stopped on the track	28%	42%
	100% (n=798)	100% (n=198)

R4: Do short-storage and non-short storage incidents differ in terms of the outcomes?

Short-storage and non-short storage HRGCs differed in type of outcome related to train strike versus vehicle strike, but did not differ in terms of injury severity. Short-storage incidents resulted in train strikes to a higher degree than non-short storage incidents, $X^2(1) = 15.87$, $p=.001$. As can be seen in Table 2, for short-storage HRGCs, 91.3% of the incidents resulted in a train striking a vehicle, and 8.7 % involved vehicles striking a train. In contrast, for non-short storage HRGCs, 78.8% of the incidents resulted in a train striking a vehicle, while 21.2% involved a vehicle strike.

Table 2. Percentage of Train Strikes versus Vehicle Strikes in Incident Data

	Type of Highway-Rail	**Grade Crossing**
Outcome	Non-short storage (NSS)	Short-storage (SS)
Train strike	78.8% (623)	91.3% (181)
Vehicle strike	21.2% (178)	8.7% (17)
Total	100% (n=798)	100% (n=198)

Using the injury severity categories from the safety database, which had three levels of injury severity: no injury, one or more injuries (but no fatalities), and fatality, a chi-squared test indicated no association with crossing type (short-storage vs. non-short storage), X^2 (1) = 2.43, p=.257. Injury severity did not depend on crossing type, 67.1% of incidents resulted in no injuries, 26% of incidents resulted in one or more injuries, and 6.9% resulted in fatalities.

Study 2: Effect of Short-storage crossing type on number, severity, and content of safety concerns (Task 2)

Based on the FRA safety database analysis, which showed that incidents at short-storage HRGCs and non-short storage HRGCs differed in some systematic ways, our lab experiment examined attention and safety concerns to determine if HRGC crossing type impacts the number and type of safety concerns participants identify.

Perceived Safety Hazards and Driving Experience

Most hazard perception research has focused on hazard detection or hazard response time (e.g., braking time), comparing drivers with different levels of experience (c.f., Mourant & Rockwell, 1972; Plummer et al., 2019). We are not the first to suggest that people's lack of attention can lead to vehicle-train incidents. Prior hazard perception research has focused on driver behavior, but has not examined driver safety judgments at rail crossings systematically or with short-storage HRGCs, in particular. The current study begins to bridge this gap. We demonstrated that drivers pay attention to different information in short-storage HRGCs and non-short storage HRGCs. This study is a first step in quantitatively understanding driver behavior at short-storage HRGCs and our goal is to use the results to inform our future research both in the laboratory and simulator scenarios and in analyzing naturalistic driving data (c.f., Lautala et al., 2018). We conducted a lab experiment in which participants annotated driving scenes and a subset were passively eye tracked. The initial behavioral analyses were presented at the *Michigan Department of Transportation Conference* (Linja et al., 2020), while a longer paper was accepted to the Human Factors and Ergonomics Society meeting (Linja et al, 2020).

Contributions of this research

In this experiment, we systematically compared driver safety concerns between short-storage HRGCs and non-short storage HRGCs. To the extent that safety concerns differ, it would suggest that drivers pay attention to different information at different crossing types. In addition, a subset of the participants were passively eye-tracked. The current study extends previous research in several ways. First, we extend hazard perception research to include rail crossings. Second, while previous studies typically used verbal protocols (c.f., Katrahmani, et al., 2016) or response times (c.f. Beanland & Wynne, 2019), our study focused on the initial situation assessment. We analyzed the frequency and content of the driver safety concerns and whether the concern represented dynamic or static information. Our research questions were:

R1: Does the number of safety concerns or average severity depend on rail crossing type, obstruction, or driver safety knowledge?

R2: Does the content of safety concerns differ depending on rail crossing type?

To address these key questions, we conducted a controlled experiment using a within-subjects experimental design (to allow each driver to serve as their own control). We showed participants images with two types of rail crossings (short-storage and non-short storage), and involved two environmental conditions (obstruction present or absent). Our goal was to explore the impact of these factors on the number of safety concerns, the severity of those concerns, and the content of the concerns.

METHODS

Participants. Forty-eight college-aged drivers (59% male), average age of 19 years (*SD* = 0.84), with 3.88 years (*SD* = 1.1) of driving experience completed the 60-minute study for course credit. Participants were recruited based on driving experience, which resulted in 18 rural and 30 urban drivers.

Safety Concern Task. We based our safety concern paradigm on previous threat detection research and used the Psychology Experiment Building Language for the experiment platform (PEBL, Mueller & Piper, 2014) (Figure 2). We identified a range of short-storage HRGCs and non-short storage crossings from the 2011-2013 Naturalistic Driving Study (Lautala et al. 2018). The final set of images was pulled from Google Earth and included: 4 short-storage HRGCs, 4 non-storage HRGCs and 3 filler driving images with no HRGC. Half the rail crossing images included visual obstructions at the crossing, while the other half did not.

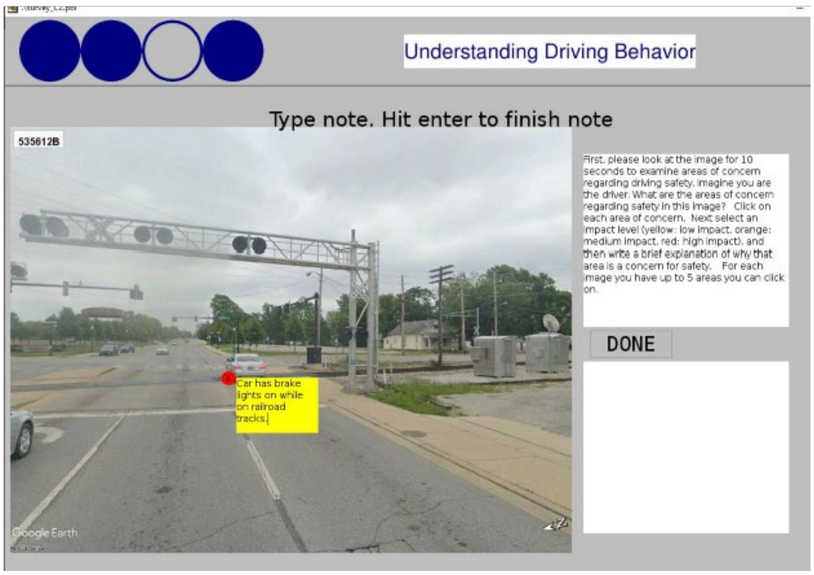


Figure 2. Safety Concern Task Example Screen.

Participants completed this study individually in the lab via computer. Participants were randomly assigned to one of three random image order conditions and made judgments and annotations on eleven images described above. Participants imagined they were the driver in the vehicle from the perspective of the image, and identified what they would be concerned with in terms of safety. Then, participants clicked on a safety concern, described it, and rated how concerned they were (i.e., Low, Medium, High), and briefly explained their concerns. After completing annotations for all eleven images with up to five safety concerns per image, participants completed a short questionnaire about their driving experience (rural vs. urban) and a seven-item safety knowledge test adapted from Landry et al. (2018) that was updated to include short-storage HRGC signage.

Eye tracking. Twenty participants were passively eye-tracked using a Tobii X-120 eye tracker during the safety concern task. Our analysis focused on a 10-second scan of each image before participants started annotating the image. Our goal was to examine fixations in the two crossing types. Figure 3 shows the five areas of interest for one image. Figure 4 shows an example heat map (i.e., darker for areas the participant spent more time fixating on during the 10 second scan at the beginning of each image).

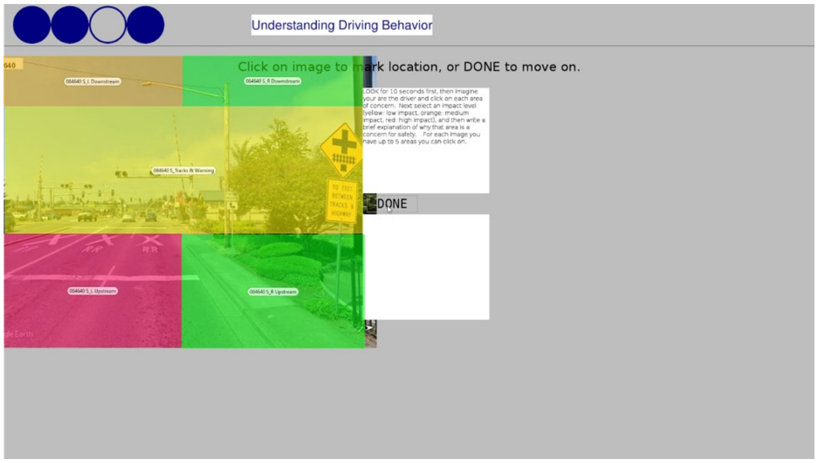


Figure 3. Areas of Interest used for eye-tracking fixation analysis.

Figure 4. Heat Map of one participant's fixations.

Coding Scheme. Participants generated a total of 1,230 safety concerns. We developed a coding scheme to analyze the content of each safety concern and whether it represented dynamic or static information (Table 1). Then, two independent raters coded each safety concern in terms of whether it referred to dynamic or static entities across four categories: vehicles, rail related objects, non-rail related signage, and environment. After achieving a high interrater reliability (Cohen's Kappa = .93) across these eight categories, each rater coded half of the remaining safety concern data.

Table 1. ***Safety Concerns Coding Scheme with Examples***

	Dynamic	**Static**
Vehicles	Vehicles in or entering the lane	Parked vehicles on the side of the road
Rail related	Gate, cross bar, signals, train	Rail pavement warnings or railroad sign
Non-rail related signage	Traffic light	Stop sign, road sign
Environment	Airplane, construction work	Buildings, trees

Results

These analyses evaluated whether participants' safety concerns depended on the type of rail crossing.

R1: Do drivers report different numbers of safety concerns or average severity of concerns based on the rail crossing type? Does it depend on the presence of obstruction or driving experience?

Participants reported more safety concerns in short-storage HRGC images than in non-short storage HRGC crossing images, but the number did not depend on the participant's driving experience (rural or urban), or whether there was obstruction present in the image (Figure 5).

We analyzed the number of safety concerns using a 2 *Rail Crossing type* x 2 *Obstruction* x 2 *Driving Experience* mixed-factorial ANOVA design. In support of R1, there was a main effect of *Rail Crossing Type* on the average number of safety concerns reported, F (1,46) = 21.23, $p < .001$, Cohen's d effect size = .34. Participants reported more safety concerns on average for short-storage HRGCs (M = 3.10) than non-short storage HRGCs (M = 2.7) (Figure 3). There was a marginally significant main effect of *Obstruction* on safety concerns, F(1,46) = 3.46, p = .069 (Figure 5). There was no effect of *Driving Experience*, F (1,46) = 0.14, p = 0.96, indicating rural and urban drivers reported similar numbers of safety concerns.

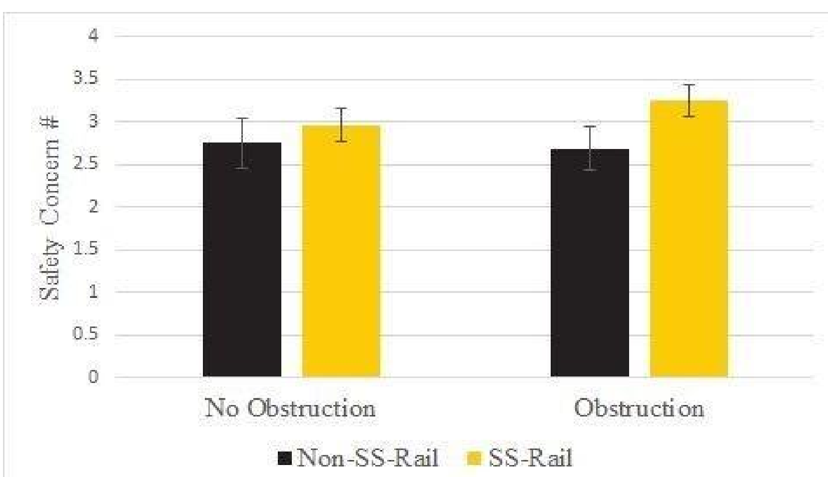


Figure 5. Effect of rail crossing type and presence of obstruction on average number of safety concerns.

Not only did participants report more safety concerns for short-storage rail crossings than non-short storage crossings, the safety concerns were rated more severe on average. We analyzed the average severity ratings (scale 1-3) per safety concern using a 2 *Rail Crossing Type* x 2 *Obstruction* x 2 *Driving Experience* mixed factorial ANOVA. In support of R2, there was a main effect of *Rail Crossing Type* on severity rating, F (1,46) = 12.41, p = .013.

Participants gave higher severity ratings on average for SS-Rail crossing images (M = 1.85), than for the Non-SS-Rail crossing images (M = 1.7). Participants' severity ratings did not depend on the presence of *Obstruction*, F (1,46) = 1.27, p = .265, or *Driving Experience*, F (1,46) = 0.96, p = .331.

Using a median split of the knowledge scores, participants with higher knowledge of the railroad rules identified marginally more safety concerns, regardless of rail crossing type, than those with lower knowledge of rules. However, their knowledge did not impact their severity ratings.

Next, we analyzed the content of the safety concerns. Each safety concern received one code and 44 safety concerns were not included in the analysis because they did not have enough information to code or were in *other* category.

Overall, 41% of the safety concerns described static objects in the image that were not moving or changing (e.g., stop sign, parked car, tree), while 59% referenced dynamic safety concerns (e.g., traffic light that might change, car might switch lanes, etc.).

R2: Do the types of concerns differ depending on rail crossing type?

To evaluate R2, we compared the frequency distribution of four types of safety concerns for short-storage HRGCs and non-short storage HRGCs, separately. A chi-squared test of independence indicated no relationship between type of *Static Safety Concerns* and *Rail Crossing Type*, χ2 (3) = 4.42, p = .11 (Table 2). Participants were paying attention to similar static information in both crossing contexts.

Table 2. ***Distribution of Drivers Generated Static Safety Concerns by Rail Crossing Type.***

Crossing Type	**Vehicles (e.g., parked cars)**	**Rail Signage**	**Non-Rail Signage (e.g. Stop sign)**	**Environment (buildings, trees)**	**Total**
Non-SS-HRGC	2 (0.8%)	140 (56.9%)	36 (14.6%)	68 (27.6%)	246 (100%)
SS-HRGC	0 (0%)	156 (58.2%)	52 (17.3%)	55 (24.2%)	263 (100%)

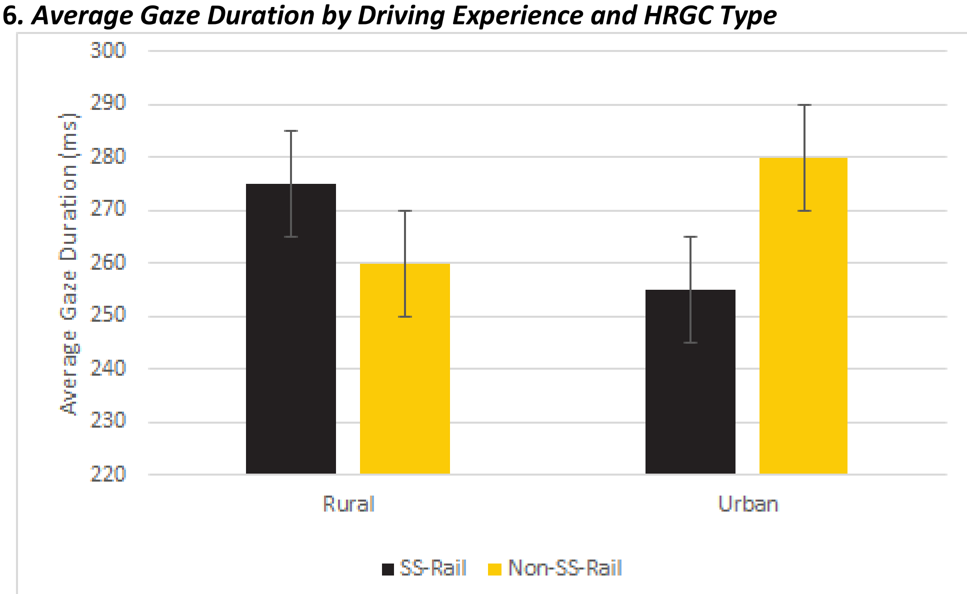
In contrast, *Dynamic Safety Concerns* were associated with *Rail Crossing Type*, χ2(3) = 87.26, p = .0001, indicating that participants paid attention to different safety concerns depending on the rail crossing type (Table 3). For SS-Rail crossings, there was a more even split between traffic (42.6%) and rail related cues (36.8%), than for Non-SS-Rail crossings. In contrast, for Non-SS-Rail crossing images, participants noted traffic concerns (76%) more often than rail-related signage and trains (15.7%). Participants noted more safety concerns on rail related dynamic concerns (36.8%) in SS-Rail crossings as expected. Interestingly, this means participants focused less on traffic in SS-Rail crossings images when compared to Non-SS-Rail crossing images.

Table 3. ***Distribution of Dynamic Safety Concerns by Rail Crossing Type***

Crossing Type	**Traffic**	**Rail Related** (Signage/trains)	**Non-Rail Signage (e.g., stop sign)**	**Environment**	**Total**
Non-SS HRGCs	238 (76.0%)	49 (15.7%)	8 (2.6%)	18 (5.8%)	313 (100%)
SS-HRGCs	155 (42.6%)	134 (36.8%)	53 (14.6%)	22 (6.0%)	364 (100%)

Eye-tracking. Before identifying safety concerns in each image, participants scanned each scene for 10 seconds and were eye-tracked for this period. We compared whether driver experience (rural/urban) and HRGC type, affected eye-movements during those 10 seconds using a mixed-factorial ANOVA. Results indicated that there was an interaction between Rural/Urban driving experience and HRGC Type on gaze duration, $F(1,7202)=5.82$, $p=.016$. As Figure 6 shows, rural drivers had longer average gaze durations during short-storage images than urban drivers, while urban drivers exhibited longer gaze durations on average for non-short storage images than rural drivers. One possible interpretation is that it reflects lower experience with short-storage HRGCs.

Figure 6. ***Average Gaze Duration by Driving Experience and HRGC Type***



In addition to gaze duration, we compared how fixation counts by HRGC using eye tracking fixation counts (Figure 7). Results indicated that urban drivers looked more frequently in short-storage than non-short storage, while there was no difference for rural drivers. The initial eye tracking analyses adds to the safety concern study and together provided additional insights for the research and the design of interventions.

Limitations and Future Research

These studies are the first involving short-storage HRGCs and provide some important initial findings. However, they only begin to understand driver decision behavior at short-storage HRGCs compared to non-short storage HRGCs. The results suggest drivers are noticing information unique to the short-storage situation.

We cannot evaluate at this time whether the base rate of accidents is higher or lower than expected based on the total number of crossings. In other words, we do not know the base rate of short storage crossings in these six states to compare the 20% incident rate we identified in the FRA database. Either way, the 20% is a substantial rate and improving the safety outcomes of these types of incidents alone would improve overall rail-highway safety and reduce costs (because it would reduce the number of train strikes).

Our lab experiment was a proof-of-concept and would need to be replicated to improve the generalizability of the result. That said, our experimental design was sufficiently powered to detect a difference for crossing type (e.g., 48 participants in both crossing type conditions), so we do expect the differences between short-storage HRGCs and non-short storage HRGCs to replicate. We examined 11 images (including the 3 filler images) because that was the max number participants could annotate in an hour without fatigue based on our pilot tests. We also started with a range of natural short-storage HRGC images and non-short storage HRGCs from the NDS data set as a starting point to establish if there were differences. Future research could expand on the range of images and establish that these results generalize to city short-storage HRGCs.

Summary

Our two studies provide data indicating that short-storage HRGCs are different than non-short storage HRGCs on several dimensions on driver decision behavior and attention and require further research.

Study 1: The distribution of incidents that occur at short-storage HRGCs differ from those at non-short storage HRGCs. Short-storage HRGCs affected older drivers at a higher rate and resulted in different rates of train strikes, and driver behaviors. Short-storage HRGC incidents did not differ from non-short storage HRGC incidents in terms of gender or injury severity.

Study 2: Based on the results of our controlled experiment, drivers were sensitive to the type of HRGCs (short-storage or non-short storage) when assessing safety concerns. Participants identified more safety concerns and rated those concerns as more severe, on average, for short-storage HRGCs than non-short storage HRGCs. However, this effect of rail crossing type on safety concerns did not depend on whether there was visual obstruction of the tracks, driving experience (rural or urban), or driver knowledge of the rail crossing rules of the road (which was consistently high). This suggests drivers are scanning and noticing differences in the short-storage HRGCs compared to the non-short storage crossings which is important for safety research and for future intervention research.

In addition to the total number of concerns and severity of those concerns, content analysis of participants safety concerns revealed differences only for *dynamic* safety concerns (e.g., traffic, lights) related to short-storage HRGCs and non-short storage HRGCs. Drivers' safety concerns shifted from traffic in non-short storage HRGC images to rail-related signals and trains in short-storage HRGC images. Drivers may be overwhelmed at short-storage HRGCs because of the potential dangers and the shift in safety concerns may reflect these differences. It also suggests that drivers noticed the additional dynamic features in the short-storage highway-rail grade crossing environments, which complements previous hazard perception research (Beanland & Wynne, 2019; Horswill & McKenna, 2004; Huestegge et al., 2010). This first step in this research was to establish if people were noticing hazards that were related to short-storage, more research is needed. Our results could be used to inform on hazard countermeasures (Lerner, et al., 1990) and hazard perception training for new drivers (McDonald, et al., 2015).

Publications

Linja, A., Lautala, P., Nelson, D., Veinott, ES (2020, March) Driver's hazard perception at short storage rail crossings. Presented at the Michigan Dept of Transportation (MDOT) Traffic Safety Conference, Lansing, MI. MDOT.

Linja, A., Lautala, P, Nelson, D., Veinott, ES (2020, October) Rail safety: Examining the effect of driving experience and type of crossing on safety concerns. To be presented at the *Human Factors and Ergonomics Society Meeting*, Chicago, IL: SAGE.

Linja, A., (2020, September) Effect of Short-Storage Highway-Rail Grade Crossings on Driver Decision Behavior and Safety Concerns: Real-World Analysis and Experimental Evidence. *Master's Thesis* Cognitive and Learning Sciences, Michigan Technological University. (Defending in mid September)

In addition to these publications, we have several other planned submissions this fall.

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