U.S. Department
of Transportation

Federal Railroad Administration

Research Results

RR 09-04
March 2009

Effects of Active Warning Reliability on Motorist Compliance at Highway-Railroad Grade Crossings

SUMMARY

Understanding why motorists do not comply with signals at active grade crossings will aid the Federal Railroad Administration (FRA) to develop safety improvements at highway-rail grade crossings. This research is focused on willful noncompliance—when a motorist consciously and deliberately ignores activated warning signals and drives around the lowered gates (see Fig. 1).

Previous research suggests that willful noncompliance is caused by the perception that the warning signal is unreliable. This perception may be the consequence of two different types of failures: a *false activation*, when a warning signal is activated but no train is at the crossing; or a *miss*, which is a failure of the warning signal to activate when a train approaches. Two experiments were conducted to examine whether motorists were able to detect changes in warning device reliability, and if so, what was the effect on their subsequent decisions? Signal detection theory was applied to describe the decisions made.

The results indicated that participants were able to detect changes in the reliability of the warning device, and they were better able to do so when reliability was high. As participants' perceived the warning device to be less reliable, they were more likely to deliberately ignore it, probably because they perceived little risk to their safety. Thus, motorist behavior may be influenced positively by improving warning device reliability. From an engineering perspective, the research suggests that incorporating good maintenance practices and correcting signal malfunctions in a timely manner can improve driver compliance with active warning systems. From a cognitive science perspective, understanding the combination of factors motorists use to judge warning system reliability can help to enhance grade crossing safety.

Photo courtesy of Public Education and Enforcement Research Study

Figure 1. Motorist maneuvering around lowered gate arms.

BACKGROUND

Driver error is a significant contributor to accidents at highway-railroad grade crossings. In fact, the Office of the Inspector General attributed 94 percent of grade crossing accidents and 87 percent of grade crossing fatalities from 1994 through 2003 to risky driver behavior or poor judgment. In 2003 alone, motorists who failed to stop at a grade crossing, drove through a grade crossing, maneuvered around activated automatic gates, or stopped their vehicles on the crossing accounted for 93 percent of grade crossing accidents and 83 percent of fatalities [1].

In the past, safety at grade crossings has been improved through engineering methods, such as closing grade crossings or upgrading the warning devices at a crossing. However, to be effective, countermeasures must engage the driver. Thus, the Federal Railroad Administration (FRA) is interested in understanding factors that contribute to driver decisions at grade crossings and sponsored the John A. Volpe National Transportation Systems Center (Volpe Center) to conduct research addressing why motorists sometimes ignore grade crossing warnings.

Researchers focused on motorist compliance at active crossings protected by flashing lights and two quadrant gates. At these crossings, the warning device provides information about whether a train is approaching. When the warning device is activated, a motorist must stop at the crossing and wait for it to pass. However, the results of observations suggest that the credibility of the warning signal contributes to motorists' decision whether to stop or proceed at a grade crossing [2]. Warning device credibility is developed over time from several factors, one of which is its reliability. This is the number of times that the warning device correctly informs motorists of the presence (or absence) of an approaching train. An active warning device is subject to two potential failures: a *false activation*, which is the presentation of a warning when no train is approaching, and a *miss*, which is the lack of a warning when a train is approaching.

Warnings are generally never 100 percent reliable. Previous research on warnings indicates that operators respond more slowly and less frequently if a warning is perceived to be unreliable. This is symptomatic of the "cry wolf" syndrome, such that one tends to ignore warnings that one believes to be presented in error [3]. Thus, the goal of this research was to develop an understanding at a theoretical level about how warning device reliability contributes to motorist decision making.

OBJECTIVE

The Volpe Center conducted two studies to examine the effects of reduced warning reliability on motorists' compliance to flashing lights and gates at grade crossings. Interest was in two ways in which poor warning reliability manifests itself: false activations and misses. The results are intended to provide insight into motorists' decisionmaking to predict when warnings might be ignored and to develop effective countermeasures to protect against such behavior.

METHODS

Signal detection theory (SDT) was applied to describe motorists' decisions at grade crossings, based on earlier work conducted by Raslear [4]. SDT involves the use of a discrete choice task to model one's ability to detect a *signal* against a background of *noise*. In the grade crossing environment, the signal is the train, which provides visual and auditory cues as to its presence (e.g., alerting lights and the sound of the horn). Noise consists of other information at the grade crossing that may compete with the signal, such as the flashing lights, gates, and sounds at the crossing or inside the vehicle that combine to make the train more difficult to detect.

SDT proposes that there are two basic states of the world (signal and noise) and two possible human responses ("I detect a signal" versus "I do not detect a signal"). In the general grade crossing situation, the two states of the world are that a train is close or that it is not, and the motorist has the choice of stopping or proceeding. A motorist's action at a grade crossing can be described in a two-by-two signal-response matrix, as shown in Table 1.

SDT provides two different measures that separate how easy the signal is to detect from motivational factors that influence the decision. One measure is *sensitivity*, which describes the ability to distinguish between signal and noise; it may be influenced by increasing the

Table 1. Signal-Response Matrix for a Motorist at a Grade Crossing.

	State of the World	
Motorist Response	**Train is close**	**Train is not close**
Yes (Stop)	**Valid Stop** (motorist stops at crossing)	**False Stop** (motorist stops unnecessarily)
No (Proceed)	**Accident** (motorist does not stop)	**Correct Crossing** (motorist safely crosses tracks)

detectability of the train or by reducing the level of noise at a grade crossing. The other measure is *response bias*, which represents the motorist's willingness to indicate "yes, there is a train" or "no, there is no train"; it is affected by changing motivations regarding the value of stopping or proceeding at a grade crossing.

The Volpe Center conducted two experiments to examine whether motorists were sensitive to changes in the reliability of the warning device and if so, what the impact was on motorists' decisions to stop or proceed. The reliability of the warning signal was measured by its positive predictive value (PPV), that is, the probability that an activated warning signal truly indicates that a train is approaching. The PPV rate depends on the rate of false activations and misses, which varies from one grade crossing to another. In both experiments, participants viewed a series of static images of actively protected gated grade crossings and made a decision whether to stop or proceed. Participants were not told the PPV rate but developed their own expectations of its value based on feedback provided after each decision. In the first experiment, the images showed the gate in the lowered position only. In the second experiment, the images included both active and inactive gates, and a train horn sound was added on some of the images to indicate train arrival. For both of these experiments, in some cases, the gate was lowered (or raised) in error. Because motorists generally make decisions in real time, participants also drove a simulated vehicle through a course with 24 active grade crossings in the second experiment.

Participants' performance was measured by their rate of compliance, their sensitivity, and response bias. Sensitivity and response bias was calculated as a proportion of valid stops and false stops at a grade crossing. As shown in Table 1, a *valid stop* describes the case when a train is close, and the motorist stops correctly. A *false stop* is the case when no train is approaching, but the motorist stops at the crossing anyway. This action may be because a warning signal was presented incorrectly, or because the motorist was being cautious.

FINDINGS

The results of both studies showed that participants' likelihood of complying with the warning device dropped as its reliability decreased. Participants in the first study were sensitive to changes in the PPV rate only when it was high; as the PPV rate decreased, participants were no longer able to distinguish between proper warning activations and false ones. In the second experiment, the addition of a train horn, which provided an auditory cue in conjunction with the visual cue of the lowered gate, increased sensitivity to whether a train was approaching. However, its benefit could also be attributable to the fact that unlike the gate, the horn was perfectly reliable.

Participants' behavior in the driving simulator tended toward proceeding rather than stopping. If motorists perceive that a warning system is unreliable due to a high number of previous false activations, they may violate the lowered gates because they do not believe train arrival is imminent. This risky behavior to proceed may also be partly due to incentives offered for completing the driving task as quickly as possible. Although these incentives may have encouraged violations, it offers insight into how motivations dictate behavior.

The results of this research suggest that improving motorists' perception of signal reliability may improve compliance. The results are consistent with those reported in the theoretical literature and observations from field studies of motorist behavior at active grade crossings. Unfortunately, it is not possible to empirically define the precise warning reliability required to achieve a desired level of compliance. From an engineering perspective, high warning reliability can be achieved through improvements in track circuitry and train detection equipment, incorporating good maintenance practices, and identifying and correcting signal malfunctions in a timely manner. From a cognitive science perspective, additional research is needed to investigate factors that motorists use to judge warning system credibility.

On the basis of the results of the current experiments, the following areas for research are recommended:

- Examine the value provided by different external cues regarding a train's arrival at the crossing,
- Develop a decisionmaking model of compliance based on the expected value of information when a warning is presented and the expected value of information when no warning is presented,
- Examine the interaction between the motorist and warning signal using a model of distributed team signal detection,
- Understand motorists' cost-benefit structures that determine their response at a crossing, and
- Investigate how motorists' expectancies, regarding the likelihood of a train at a crossing, factor in compliance.

KEY REFERENCES

[1] Office of the Inspector General (2004). *2004 Audit of the Highway-Rail Grade Crossing Safety Program* (Report Number: MH-2004-065). Washington, D.C.: Federal Railroad Administration.

[2] Yeh, M. and Multer, J. (2008). *Driver Behavior at Highway-Railroad Grade Crossings: A Literature Review from 1990-2006* (DOT/FRA/ORD-08/03). Cambridge, MA: DOT Volpe National Transportation Systems Center.

[3] Parasuraman, R. and Riley, V. (1997). Humans and automation: use, misuse, disuse, and abuse. *Human Factors, 39*, 230-253.

[4] Raslear, T.G. (1996). Driver behavior at rail-highway grade crossings: A signal detection theory analysis. In A. A. Carroll and J. L. Helser (Eds.), *Safety of highway-railroad grade crossings*. Research needs workshop. Volume II – Appendices (Report No. DOT/FRA/ORD-95/14.2, DOT-VNTSC-FRA-95-12.2, pp. F9-F56). Washington, DC: U.S. Department of Transportation.

ACKNOWLEDGMENTS

This research was conducted by the Volpe Center under an interagency agreement with FRA's Office of Research and Development. Special thanks go to Prism Technologies for their expertise in developing the simulation and to the many participants of the study.

CONTACT

Thomas Raslear
Staff Director, Human Factors Research Program
Federal Railroad Administration
Office of Research and Development
1200 New Jersey Ave, Mail Stop 20
West Building, 3rd floor
Washington, DC 20590
202-493-6356
Thomas.Raslear@dot.gov

Jordan Multer
Behavioral Safety Research and Demonstration Division (RVT-81)
Research and Innovative Technology Administration
Volpe National Transportation Systems Center
55 Broadway
Cambridge, MA 02142
(617) 494-2573
Jordan.Multer@dot.gov

KEYWORDS: Warning reliability, highway-rail grade crossing, traffic control devices, grade crossing safety, active crossings, motorist compliance