Recent Topics on Human Science for Railways

Koji OMINO

Human Science Division

In order to improve railway safety, from a human factor point of view, the Human Science Division of the Railway Technical Research Institute in Japan, has been conducting research for the prevention of human errors, their education and training, and the countermeasures for railway accidents caused by the external factor. This paper outlines recent topics of research based on current issues facing railways.

Keywords: human science, human error, education/training, measures for external-cause accidents

1. Introduction

The Human Science Division of the Railway Technical Research Institute (RTRI) is engaged in research and development to support railway employees and to improve user environments for passengers onboard trains and in train stations from the perspective of human factors, and for the purpose of improving the safety, convenience, and comfort of railways. Among the research and development being carried out to support railway employees, a main part of our work relates to safety of operations, including the development of “human error prevention methods and education/training,” and proposed “error analysis and evaluation method,” “system improvements,” and “measures for external-cause accidents” drawn from a human factor perspective (Fig. 1). From the recent research outcomes of the Human Science Division, this paper introduces the outcomes of principal research on “human error prevention and education/training methods” and “measures for external-cause accidents.”

Fig. 1 Research and development to support railway employees involved in safety related operations

2. Human error prevention and education/training methods

To prevent human error, railway operators are carrying out education and training. The effect of training and education is not easy to maintain or improve, and needs to be part of an ongoing process with repeated training to ensure habits become entrenched, with reviews to ensure that it remains relevant. Given the investment of effort

required, many railway operators struggle to improve their training. As such, RTRI is working on the development of human error prevention and education/training methods. This section addresses (1) new measures to prevent drivers from exceeding speed limits, drawn from research into error prevention methods; and (2) training aimed at improving the safety of workers operating on or near railway tracks, and hazard perception, using data about the direction of eye gaze collected from driving simulator training.

2.1 Excess driving speed prevention measures

Driving over the speed limit is an error that can lead to a serious accident. Different measures have therefore been taken to tackle this problem from different perspectives, including hardware and software. One of the main causes of excess speed is driver forgetfulness: improving safety in this area therefore means adopting measures to prevent this. A proposal was therefore made to introduce a ‘Prospective Calling method’ (PC), which applies the human factor principle of confirmative action [1]. The principle includes two types of action: “Image Calling” and “Repeated Calling.” “Image Calling” has the effect of making it easier to remember to check speed at the right time, while “Repeated Calling” has the effect of making it easier to consciously maintain the need to check speed, in mind: both are simple actions that can easily be applied by drivers in the course of their everyday work (Fig. 2). “Image Calling” involves for example, a driver not only ‘thinking’ that they are within the speed limit etc., of a particular section, but actually confirming out loud that they are within the speed limit. “Repeated Calling” on the other hand, involves the driver repeating out loud the speed limit for the section they are in, when their attention is drawn away from keeping the speed limit by some other task, such as changing notch or acknowledging a signal.

A driving simulator experiment to explore the effectiveness of the two preceding PC measures on prevention of excess speed, was conducted with actual drivers. The simulated driving scenario included a section with a speed limit. The simulation was used to investigate whether it was possible to prevent the driver from forgetting the speed limit and prevent speeding, even when the driver had to suddenly deal with an abnormal situation in the preceding or current section. The results of the experiment

Fig. 2 Prospective Calling method

confirmed that the number of drivers who exceeded the limit decreased clearly compared to when no PC was performed.

2.2 On-track safety education/training

From the point of view of both safe transportation and prevention of work-related accidents, rule compliance is fundamental: both workers and managers must continuously show ingenuity and invest time and effort to achieve this. The study introduced in this section, describes the development of a new training program aimed at improving awareness of the need for rule compliance and actual rule compliance. Two rules that are applied to maintain safety of track work taking place in train intervals were used to develop this training: the rule requiring train schedules to be “double-checked” and the “early evacuation rule”. Both these rules are designed to prevent person-vehicle collision accidents. The first rule involves two members of the work-site team, for example the work manager and watchman checking the schedule of oncoming trains together before entering the track area. The second rule requires workers on the track to stop work and leave the track area at a specified time before arrival of the next train, which is predetermined by the operator (i.e. a few minutes before the train comes).

In the case of rule violations committed by staff who imagine that bending the rules is not too serious, it is difficult to raise their awareness about rule compliance through conventional one-sided education, although risk education is for their benefit. In addition, the risk that the training seeks to help avoid, is comprised of various factors. As such, a case analysis of track maintenance and electrical systems was conducted and an attitude survey was carried out among field employees. This revealed that training to encourage better rule compliance depended particularly on explaining the “processes leading up to an accident.”

Thus, we developed a VR experience-based pedagogical method to help learners understand the process leading to person-vehicle collision accidents [2]. This pedagogical method consists of two tasks: “Training with VR material (Fig. 3)” and “case application”. The “VR experience” is a

Fig. 3 Scene of training with VR material on-track safety training

role-playing task that requires the learner wearing the VR equipment to perform maintenance work while walking around in a VR space. The task helps the learner understand why it is vital to evacuate the track at the appropriate time by experiencing the events that lead to a person-vehicle collision accident (i.e. they see that it is hard to notice the approach of a train if a workers is absorbed in work). In the “case application task,” participants discuss past cases of person-vehicle collision accidents in groups, and then imagine transposing the elements leading to that accident to their own workplace, and consider what measures could be taken to avoid the accident.

Trials using this VR experience-based pedagogical method with field employees confirmed the assumption that a better understanding of the processes leading up to a person-vehicle collision accident could raise awareness about the importance of and improve actual rule compliance.

2.3 Hazard perception training

To prevent accidents, we are also working on the development of training tasks that increase the hazard perception sensitivity of workers. Hazard perception is the ability to quickly and accurately identify sources of hazards in the workplace. Factors that can significantly improve this ability include motivation to search for hazard sources and knowledge about them. The training that was developed to improve this ability therefore included a “successful experience task [3]” to increase motivation and a “scenario drawing task [4]” to improve knowledge.

The “successful experience task” uses the change blindness technique, which involves inserting blank images between frame-by-frame playback images so that the original images will be displayed in saccadic manner. This task uses the hazard sources embedded in some frame images, and requires the trainee to notice and point them out. By using the change blindness technique, the experiment can set so that unless the trainee intentionally searches for changes, a danger that everyone would notice in normal video, is easily overlooked [3]. For example, suppose that the change blindness images display a situation in which you are driving behind a truck. Even if a frame is inserted showing a falling object in the lane next to the truck, many people do not notice it. Using this technique, learners can experience how easy it is to miss a hazard source that in

ordinary viewing conditions would be obvious. The learners then receive explanations about the reasons why this happens. The trainees are then instructed to check images with different content again, presented in a similar fashion. Many of them succeed in finding the hazard sources. Finally, the learner is given an explanation of how a situation like in previous experiment where they failed to see the hazard, could easily occur in their own workplace, which increases their motivation to be more sensitive to spotting hazard sources.

The task to improve knowledge of hazard sources through “drawing a scenario” is explained using the example of a driver exceeding the driving speed limit. First, the learner draws schematically a station-to-station section defined as the subject matter and considers the processes that could lead to a dangerous event. They draw a railway line and, in there, write a hypothetical state of mind, objects, equipment, etc., combining to lead up to the event (Fig. 4). Then, they envision different situations; for example, they broaden their viewpoints by envisioning the situation of passengers, disordered train operation in relation to the timetable, the experience, a change in work partners, etc., and add explanations about these in their drawing. This allows them to pay attention to the hazardous sources from the perspective of human factors and, in addition, allows them to acquire knowledge through describing an actual situation. Active drivers who attempted the “scenario drawing task” list a greater number of processes that could lead to exceeding the speed limit, and were able to more surely locate points that should be listed as hazard sources.

Fig. 4 Example of scenario drawing task

2.4 Utilizing eye gaze data for driving simulator training

One current line of research and development aims to improve existing training carried out by railway operators using driving simulators, to make it more effective. Forward confirmation is a particularly important task that has to be performed by drivers, and eye gaze data is considered to be an effective means to review training. We are therefore studying a method to utilize an eye gaze detection function [5, 6]. First, to investigate the movement of the eye gaze that does not miss any abnormality, we conducted simulator training using a scenario including two abnormal situations occurring simultaneously: one where

a notification is received to say that “ATS ground coil has failed” coupled with subsidence of the adjacent line ahead. This tests revealed that there are two eye gaze movement patterns: eye movements that make it easier to notice abnormalities and those that do not. The gaze of drivers who noticed the subsided track was sweeping, and paused for longer while gazing forward (upper charts in Fig. 5). It would be effective if we could look back on the driving based on these findings, but it is also important to properly determine what sort of feedback should be given to them so that they can understand. The lower photographs in Fig. 5 show feedback examples. We believe that another effective method is to visualize the movement of the gazing point with an image. Currently, we are studying more effective feedback information and an optimal visualization method to promote intuitive noticing.

Fig. 5 Gazing point data (upper) and visualization (lower) in driving simulator training

3. Measures for External-cause Accidents etc

Measures to prevent railway accidents or appearance of obstacles on the track that are occur for non-railway reasons, are often difficult, because these factors are not controllable. This section describes outcomes of research on measures to prevent impacts on wildlife, particularly deer, which have frequently collided with railway vehicles in the past, and measures to prevent level crossing accidents, where the prior decrease in the number of accidents has drastically slowed and even leveled out.

3.1 Measures to prevent train-deer collisions

Collisions between trains and deer are increasing due to a rising deer population and the expansion of their habitat. Although railway operators have achieved some success in reducing accidents with the use of deer fences and allowing extra time for driving, the number of collisions has not decreased sufficiently. A new measure, has therefore been developed which uses a deterrent sound emitted from the train to frighten deer away from the track as a train approaches (Fig. 6) [7].

Measures that involve odors or light are less effective because either deer become accustomed to them, or they can be affected by seasonal factors or weather. RTRI believes that using sound may be a solution to these problems. Deer communicate danger amongst themselves by

Fig. 6 Measures for train-deer collision accidents using the acoustic deterrent

calling an alarm signal to alert each other. This was confirmed by emitting an alarm call to deer, which caused them to gaze toward the sound source. Based on this characteristic, a deterrent sound was developed which includes a deer alarm call followed by the sound of a barking dog, because deer tend to avoid dogs. In addition, we created a train-deer collision accident map using a geographic information system (GIS) based on the train-deer collision data, and also devised a method for selecting the sections where the sound should be emitted, considering type of vegetation and topography along the train route.

The deterrent sound was emitted from the front of the vehicle in the sections preselected using the train-deer collision map during winter nights when collisions were most frequent. As a result, deer sightings decreased by 45%. We are currently researching the practical application of the deterrent sound while repeating running tests similar to these.

3.2 Measures for level crossing accidents

At present, general measures for level crossing accidents have been implemented (e.g. replacing level crossings with elevated tracks, and installing obstacle detection devices that automatically detect a car stuck in the track area). More effort is required however to further reduce the number of level crossing accidents. We are therefore reassessing the actual circumstances surrounding level crossing accidents and studying ways to inform the general public. This section explains what has been found so far.

About half of level crossing accidents are pedestrian accidents on level crossings with automatic barrier machines and accidents caused by the stopping or stalling of road vehicles. In addition, a high percentage of people involved in level crossing accidents are elderly. In order to address these two findings, two pieces of research were conducted: “Walking Velocity Characteristics in Consideration of Railroad Crossing Warnings” [8] and “Risk Factors in Level Crossing Accidents Involving Older Drivers” [9].”

In “Walking Velocity Characteristics in Consideration of Railroad Crossing Warnings”, walking velocity was measured by filming pedestrians passing through one level crossing on one double track and on two level crossings on quadruple tracks with a video camera. A walking velocity distribution (pedestrian traffic model) was identified. This revealed that when a pedestrian entered the level crossing after the start of the warning sound, the walking velocity distribution shifted upwards, but some people did not

increase their walking velocity. In “Risk Factors in Level Crossing Accidents Involving Older Drivers”, investigations and experiments were conducted concerning the entry of automobiles into level crossings, and data was compared between elderly and younger drivers. It was found that when entering the level crossing, younger drivers were more likely to omit checking the space available at the other end of the level crossing or ignore warnings, while elderly drivers were more likely to fail to notice warnings.

Taking the above results of investigation into consideration, we are currently working on measures to prevent pedestrians from entering the crossing when the warning sound has begun (pedestrians crossing just before passage of a train). First, we are investigating the effects of (1) changing the timing of the warning notice before barriers come down (i.e. time from the start of warning sound to the start barriers coming down); and, (2) adding an automatic voice to the warning sound, to prevent pedestrians entering the level crossing. Our simulator experiment using CG images verified that shortening the warning time reduced the percentage of people entering the crossing as the warning sounded [10]. The experiment also demonstrated that adding a warning voice to the warning sound decreased the percentage of people determined to enter the crossing as the sound was emitted [11]. The next goal is to propose measures aimed at pedestrians crossing just before passage of a train passage at a level crossing by accumulating data like these, and in addition, examining the adverse effects of shortening the warning time and adding a voice to the warning sound.

4. Conclusion

This paper introduced recent human science research in railways, especially representative research and development to support railway employees involved in safety related operations. Besides these topics, other research is being carried out to include assumptions about unexpected events in crisis management, for disaster response, as we have become increasingly aware over the past years, of the need to be able to respond to the changing nature of disasters. Responding to accidents and disasters in increasingly unexpected circumstances, places enormous pressure on railway employees which is a likely source of human error. Therefore, work is being carried out to develop education/training and support systems to improve the ability of staff to cope with these abnormal situations [12]. Other research is devoted to examining vehicle requirements to improve collision safety in emergencies, to reduce injury to passengers and crew [13], and to improve evacuation guidance for passengers. We will continue to pursue human science based human factor research that can contribute to the maintenance and improvement of railway safety while taking into account changing needs over time.

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Author

Koji OMINO, Ph.D.
 Director, Head of Human Science Division
 Research Areas: Ergonomics