Recent Topics on Human Science Research for Railway Safety

Koji OMINO
Human Science Division

From the point of view of the safety, convenience and comfortability of railways, the Human Science Division of Railway Technical Research Institute has been conducting research on the safety management support and the improvement of car inside environment and station environment. This paper outlines recent human science research on education and training geared to prevent human error, human error analysis methods and countermeasures against outside factors threatening railway safety.

Keywords: human science, human error, education and training, train-deer collision accident

1. Introduction

RTRI’s human science research and development aims at enhancing railway safety, user-friendliness and customer experience, focus on safety management support and improvement of station/vehicle environments for passengers. Human error prevention is central to railway safety and disruption-free transport. RTRI has been active in these areas, making proposals to effectively investigate/analyse human error, and provide education/training to railway staff. Accidents that are beyond the control of railway systems, or due to external factors, such as collisions with wild animals and level crossing accidents, also constitute safety issues. RTRI has been conducting human science research to address these issues. This paper presents the results of some recent studies on education/training on human error prevention, human error analysis methods and measures against external factors compromising railway safety.

2. Recent studies on education/training for human error prevention

Typically, studies on education/training for human error prevention will examine train operation training and point and call checks. Operational training entitled, “Vocational training program for improving train driver abilities to cope with abnormal situations” [1] was proposed to help drivers handle abnormal situations appropriately, in highly stressful and circumstances where mistakes can easily be made. Another study was conducted to verify the “error prevention effects of point and call checks” [2] by making subjects experience first-hand the effect of actions which do not have an obvious link with ensuring safety, but are designed to prevent accidents, which normally do not occur very often. In the study, subjects were give tasks that had to be confirmed as part of the training for point and call checks, and an educational program based on those tasks was proposed. These training programs have since been used by railway operators and other organizations.

Human errors range widely, from simple mistakes that are made unwittingly to errors of judgment in situations where high mental concentration is required. Fairly number of types of education and training are needed against only some of these errors, which can be addressed through education and training. The effect of training however can wear off if it is simply repeated. Training methods therefore have to be constantly updated even for addressing the same errors. RTRI has therefore been researching education/training. In the following paragraphs, two of RTRI’s recent studies on communication errors - - “Learning Method of Communication Error Prevention” [3] and “The Training Method of Communication Skills for Train Dispatchers in Abnormal Situations” [4] - - are outlined together with a third study on errors of judgment “Fundamental Evaluation of Decision-making Task for Development of Training Method” [5], which is being started.

To study training methods that can help prevent accidents attributable to communication errors, data was collected and analysed on 1706 accidents and 97 potential incident reports involving communication errors; based on the collected data, a causal model for communication errors was developed representing an information error generation process. The model has shown that talk-back and confirmation talk are effective in preventing accidents attributable to communication errors. It was also found that, to ensure the effectiveness of talk-back and confirmation talk, the speakers involved must be able to detect factors in the information provided and received that could lead to communication errors, such as ambiguity or insufficient information, and ask for clarification. Based on the above, training materials for talk-back and confirmation talk skills (Fig. 1) and skills aimed at eliminating communication error contributors, were developed. The training material teaches trainees the relevant methods and key points for successful talk-back and confirmation talk, while the competence training is designed to improve the skills needed to detect ambiguity and lack of information, or communication error contributors, in what is said. Experiments conducted with general participants and railway employees to verify the effectiveness of the training material found that they were effective in reducing errors.

Communication errors are more likely to occur in abnormal situations, which formed the background for the development of “The Training Method of Communication Skills for Train Dispatchers in Abnormal Situations.” The training method was designed to ensure that accurate information is shared smoothly, in abnormal situations, among train dispatchers responsible for train operation control, and those responsible for operation scheduling for crews and vehicles,
and was also designed to be easy to use by dispatchers. Trainees go through simulated communication scenarios of abnormal situations and then hold review sessions by watching the video of the training just completed. A 45-item check list for communication skills, used as part of the training, is effective in enhancing awareness and confirming fulfillment rates in everyday operations, and is designed to facilitate the acquisition of communication skills. Since the training method was introduced, dispatchers have shown stronger awareness of the importance of communication skills and achieved higher fulfillment rates in everyday operations.

For crisis management, studies and other work is underway to find ways to predict what has so far been considered unpredictable. When trying to avert danger or dealing with accidents, railway employees are put under severe psychological stress, which makes them vulnerable to mistakes in decision making. Even in ordinary operations, railway employees may skip a simple check leading to a wrong decision. There appears to be a considerable difference between misjudgements made under severe psychological stress and those made in the course of ordinary operations. However, in both situations, the cognitive factors skewing the decision-making process need to be parried with skills to minimizing this distortion. A study entitled “Fundamental Evaluation to Decision Making Task for Development of Training Method” was conducted to identify the judgement distorting factors and to develop a set of experimental tasks (operations) that would enable evaluation of an individual’s decision-making thought process.

A total of 278 decision-making errors derived from railway accident analysis data were analysed to identify specific circumstances that led to those errors and the related decision-making processes. In more than 60% of cases confirmation played a role and in over 70% of cases short-sighted judgment (lack of awareness about the consequenc es of an action) was involved. Based on these findings, two operational tasks were developed: the first (Fig. 2) features a scene where a decision needs to be made on whether or not a post-operation confirmation can be skipped whereas the other requires a decision to be made whilst considering both short-term (which become evident soon) and long-term benefits (which gradually become evident). Another operational task featuring abnormal scenarios in which it is difficult to make decisions, was also developed.

Experiments using functional magnetic resonance imaging (fMRI) confirmed that during each of the three tasks, areas of the brain corresponding to decision making activity became active, indicating the relevance of the decision-making tasks.

Future work will look at applying these operational tasks to devise a method for evaluating decision making skills and an education/training method for improving decision making skills.

3. Recent studies on human error analysis methods

The “Human Factor Analysing Technique to Improve Safety Management” [6] developed by RTRI to analyse factors underlying human errors, has been used by many railway operators. This method, however, is time consuming when a large volume of errors have to be processed. To cut the time required for analysis, a new method based on risk information was proposed in the study entitled “Method to Support Safety Management using Potential Incidents Reports [7].” In the conventional method, “deviations” from targets set by the system are fully analysed. In the new method, errors presenting a greater risk are identified using risk data, including accidents and potential incident reports, and an analysis is made focusing on those identified errors. In addition, a “Why-Why” analysis support tool was developed to assist the logical investigation of background factors underlying the human errors which have been identified. This tool presents the potential factors in response to the question “Why?,” based on the results of an analysis of error cause-and-effect relationships observed in 900 example cases, and allows the analysis to be implemented efficiently in accordance with a consistent logic. Furthermore, a flow chart to determine human factor measures was developed. The flow chart consists of 9 steps to check suitability and conditions needed for implementation aimed at consciously improving the organization of work, in addition to temporary corrective measures such as reminders given to the parties concerned, when evaluating measures in the light of results from background factor analysis. This new proposal aims to improve the way in which analyses are carried out. The results of the study are reflected in the revised teaching materials that RTRI has started issuing from this fiscal year.

When analysing the human errors as mentioned above, sufficient information on the behaviours of the parties concerned, the generation status, etc. needs to be collected. To this end, interview-based investigations are conducted on
site with the parties concerned. Given that there was no standard method to carry out these interviews, duplication tended to occur in the reports and investigations, because of a lack of information. For this reason, “the Railway Technical Research Institute hearing investigation technique to analyse the background factors of an accident” [8] was developed taking into account mental attitudes and offering a list of points to remember when conducting the hearing investigations, based on knowledge from the “Active Listening techniques” and “cognitive interview method in psychology.” This hearing investigation technique is described in detail in the manual. In order to encourage adoption of this technique, a motivation- and experience-based training program was also drawn up. The significant effectiveness of this method was confirmed through follow-up studies.

Section 2 of this paper presents education and training programs to prevent communication errors being the direct cause of accidents. There has been concern that the lack of everyday communication in the workplace might be contributing to a corporate culture that tends to induce human errors. There are calls therefore to improve this type of corporate culture. A possible solution could be found in a related study, which although not about education and training, is entitled “Method for Estimating the Supervisor’s Ability to Promote Communication in the Workplace” [9], and is outlined below.

Interviews and questionnaires conducted with crews found a relationship between the both numbers, the one of occasions on which crew members were consulted by their supervisors (assistants, leaders, etc.) and the other of their conditions which were realized abnormal by the supervisors. Another analysis was furthermore conducted to identify supervisors’ attitudinal and behavioural traits which increase the number of opportunities for communication with the members and an evaluation method were developed to assess supervisor communication skills by using a 34-item checklist which prescribes 5 traits. Concretely, supervisor behaviour and attitude are evaluated using the corresponding rating based on a five-point scale - action taken to increase opportunities to talk to team members, action taken to understand individual team members, attitude shown when consulted, attitude during consultation and interview, and attitude during and after communication. In addition, a feedback tool was developed that automatically calculates the ratings following completion of the evaluation checklist that includes the respondent’s strong and weak points and attitude and behaviour that team members would like to see in supervisors. Follow up on the application of these methods showed that more than 90% of those contacted provided positive comments including ease of operation and understanding, and 90% showed motivation for improvement.

4. Recent studies on measures against external factors compromising railway safety

RTRI has been pursuing studies on external factors affecting the railways, such as collisions with wild animals and level crossing accidents that compromise railway safety. Collisions with deer are increasing year by year to the point that something must be done. Drivers are under increasing stress to avoid collisions, and a collision, when it occurs, increases subsequent workload on crews and track maintenance staff, as well as inconveniencing passengers. Although railway companies are taking a range of measures [10] to prevent collisions, such as putting up deer fences and setting up slow-speed sections, the increasing deer population and other factors are making it difficult to reduce collisions. To turn the situation around, RTRI has been conducting a study entitled “Development of an Acoustic Deterrent to Prevent Deer-train Collisions” [11]. Based on the premise that deer produce warning calls or communicate warnings to each other, research was conducted to devise possible methods using such acoustic means to entice deer away from the track when a train is nearing.

Experiments showed that both domesticated and wild deer were alerted by the warning calls that were emitted. Making use of this characteristic, deterrent sounds consisting of warning calls and dog cries, which deer dislike, were compiled together and experiments carried out to verify the effectiveness of the result. Sensors installed on a fence where it ended, were designed to set off the deterrent sound upon detection of deer to prevent them from entering the track. Observations revealed that deer, upon being detected and hearing the sound, were seen to hesitate when attempting to enter or running away. A deterrent sound unit was installed on the front end of a train running on a commercial line to test the sound during peak train-deer collision period. Prior to the test, past train-deer collision points were identified through GIS data mapping and, while factoring in wayside vegetation and topography, test sections were selected. The train was run while the deterrent sound was being emitted in the test sections. Compared with the normal 13.6 sightings (per 100 km) without the sound, deer were spotted only 7.5 times with the sound, showing a 45% decline. Based on these results, the deterrent sound can be considered an effective means to minimize train-deer collisions. The research will be continued to clarify the extent to which deer may become accustomed to the deterrent sound with the ultimate objective in mind of putting the sound system into service.

Level crossing accidents, which disrupt scheduled railway transport, primarily involve road traffic, an external non-railway factor. Railway operators have been taking every conceivable measure including track elevation wherever possible to eliminate level crossings and installation of obstruction detecting devices that automatically detect motor vehicles stuck on the track. However, there are too many level crossings for this type of accident prevention to be used everywhere. Faced with this difficulty, reducing level crossing accidents further requires ingenious ideas. As part of this effort, studies are planned according to collection of relevant information and indications about the profiles of people using level crossings. The first step is therefore fact-finding research and detailed analysis of level crossing use, which are currently underway.

Approximately half of level crossing accidents occur on level crossings with automatic barriers where pedestrians or motor vehicles become trapped between the barrier and the train. As a large share of all level crossing accidents involve seniors, studies such as, “Walking Velocity Characteristics in Consideration of Railroad Crossing Warning” [12] and “Risk Factors of Level Crossing Accidents by Older Drivers” [13] have been conducted to analyse phenomena involving pedestrians and motor vehicles remaining stranded on the track after a crossing with automatic barriers has closed.

QR of RTRI, Vol. 59, No. 3, Aug. 2018
In the study “Walking Velocity Characteristics in Consideration of Railroad Crossing Warning,” pedestrian walking velocity was measured using video cameras at three level crossings, one on a double track and the other two on a quadruple track. Based on measured walking velocities of 4726 people, probability distribution parameters were assumed and a walking velocity distribution (pedestrian traffic model) was identified. The walking velocity distribution of pedestrians who entered the level crossing after warning started showed faster paces. Some pedestrians, however, did not increase their walking speed. The longer the level crossing, the faster the walking speed, similar to the trend found with pedestrians crossing pedestrian crossings. Future studies will examine the possible impact of congestion on the track on walking velocity distribution, the path taken by pedestrians, motor vehicles and other traffic using the level crossing.

The study “Accident Risk Factors related to Older Drivers at Level Crossings” looked at issues associated with motor vehicles entering and exiting the level crossing through investigation and experiments, and compared the behaviour of elderly drivers with that of younger drivers. It was found that when entering the level crossing, young drivers were more likely to omit checking the space available at the other end of the level crossing or ignore warnings, while senior drivers were more likely to fail to notice warnings. When trapped between the lowered barriers, senior drivers were more likely to lift the barrier by hand or push the emergency button and then re-enter the level crossing, which means they were staying on the track.

5. Conclusion

Studies on human error have primarily relied on subjective methods where psychosomatic states are evaluated based on self-reporting in interviews and questionnaires. In addition to those methods, RTRI has also been exploring persuasive alternatives that actively use physiological data such as brain waves, heart rates and perspiration to correlate psychological and physiological data to work performance. An ongoing study on monitoring driving state using physiological parameters tries to investigate what psychosomatic conditions provoke the loss of driver performance and induce human error, in order to propose methods for predicting such situations.

In addition, projects are underway to develop a driver drowsiness monitoring system, track monitoring technology to help drivers see ahead, and a system for sending notifications if an abnormal situation is detected. As part of its human science research, RTRI has been developing a driver drowsiness evaluation system that monitors drivers for drowsiness and psychosomatic conditions, without putting any stress on them, to assist driving and prevent accidents.

Railway systems continue to evolve as supporting technologies progress. This in turn leads to the assumption that systems will grow in complexity, requiring appropriate solutions for people working with those systems. As such, designing systems with human sciences in mind is expected to become more and more important. RTRI will continue to pursue its research into human factors that are of growing importance in an age of human science-based system design.

References

[1] Omino, K., and Endoh, H., “Practical System for Implementing Vocational Training Program for Improving Train Driver Abilities to Cope with Abnormal Situations,” RTRI Report, Vol.27, No.3, pp.17-22, 2013 (in Japanese).
[2] Masuda, T., et al., “Error Prevention Effects of Point and Call Checks,” RTRI Report, Vol.28, No.5, pp.5-10, 2014 (in Japanese).
[3] Nakamura, R., et al., “Learning Method of Communication Error Prevention,” Quarterly Report of RTRI, Vol.59, No.3, pp.217-220, 2018.
[4] Hatakeyama, N., et al., “Training Method of Communication Skills for Train Dispatchers in Abnormal Situations,” Quarterly Report of RTRI, Vol.57, No.2, pp.138-143, 2016.
[5] Kitamura, Y., et al., “Fundamental Evaluation of Decision-making Task for Development of Training Method,” Quarterly Report of RTRI, Vol.59, No.3, pp.212-216, 2018.
[6] Miyachi, Y., “Human Factor Analysis Method for Improving Safety Management,” Quarterly Report of RTRI, Vol.49, No.1, pp.53-58, 2008.
[7] Miyachi, Y., et al., “Method to Support Safety Management using Potential Incidents Reports,” RTRI Report, Vol.30, No.9, pp.5-10, 2016 (in Japanese).
[8] Miyachi, Y., Kaburagi, T., and Okada, Y., “Hearing Investigation Technique and Educational Program for Analysis of Background Factors of Accident,” Quarterly Report of RTRI, Vol.57, No.2, pp.133-137, 2016.
[9] Miyachi, Y., Murakoshi, A., and Hatakeyama, N., “Method for Estimating the Supervisor’s Ability to Promote Communication in the Workplace,” RTRI Report, Vol.31, No.11, pp.5-10, 2017 (in Japanese).
[10] Shimura, M., et al., “Study of Behavior of Sika Deer Nearby Railroad Tracks and Effect of Alarm Call,” RTRI Report, Vol.29, No.7, pp.45-50, 2015 (in Japanese).
[11] Shimura, M., et al., “Development of an Acoustic Deterrent to Prevent Deer-train Collisions,” Quarterly Report of RTRI, Vol.59, No.3, pp.207-211, 2018.
[12] Suzuki, D., et al., “Walking Velocity Characteristics in Consideration of Railroad Crossing Warning,” RTRI Report, Vol.31, No.11 pp.29-34, 2017 (in Japanese).
[13] Inoue, T., et al., “Risk Factors of Level Crossing Accidents by Older Drivers,” RTRI Report, Vol.31, No.11, pp.23-28, 2017 (in Japanese).

Author

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