Recent Topics on Human Science for Railways

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The Human Science Division of the Railway Technical Research Institute in Japan, has been conducting research on prevention of human error and occupational accidents as well as into countermeasures for transport disruptions and ways to improve user environments in order to improve the safety, convenience and comfort of passengers using the railways. This paper outlines the recent accomplishments of the representative research on prevention of human error accidents and improvement of user environments.

Keywords: human science, human error, occupational accident, transport disorder, improvement of user environments

1. Introduction

The Human Science Division of the Railway Technical Research Institute in Japan (RTRI) is engaged in R&D that is useful to users and employees in order to improve railway safety, convenience, and comfort. As for our efforts to improve safety, we conduct R&D related to human error accident prevention and occupational accident prevention. As for our efforts to improve convenience and comfort for passengers, we are conducting R&D related to measures against transport disorder mainly for railway users and improvement of user environments, both including many of the research subjects that address safety improvement elements (Fig. 1). Out of these, this paper overviews the results of recent R&D related to human error accident prevention and improvement of user environments.

2. R&D related to human error accident prevention

To prevent human error accidents, RTRI is working on the development of error prevention and education/training methods and the analysis of error factors. As typical recent subjects, this section takes up the decision making skill evaluation method for error prevention training [1], the development of risk awareness improvement education/training tasks [2, 3], and the analysis of driving information records for error prevention related to stopping at a station [4].

2.1 Decision making skill evaluation method

This section describes a method for evaluating decision making skills to prevent accidents caused by misjudgment. Generally speaking, decision making is often thought of as company management decisions, but in psychology, daily decisions by individuals in field work are also included in decision making. The upper part of Fig. 2 shows a model that presents the flow of such decision making in four stages.

Our analysis of accident cases provided by a railway operator revealed that they included many decision making errors: in particular, there were many cases where individuals overestimated their own work and checks were therefore omitted. There are many known disincentives that induce bias in decision making, such as overestimation, and the upper part of Fig. 2 also shows the typical disincentives mentioned in this paper. The decision making skill in this paper means the ability to make appropriate decisions without being affected by disincentives, and we aim to propose an education/training method for this ability in the future. We first developed the decision making skill evaluation method required for education.

On the basis of findings of psychology and brain science, four decision making tasks that cause the effects of disincentives to appear in their results were created: tower task, which measures the tendency to emphasize short-term gain; checking necessity judgment task (Koutetsu task), which measures the tendency to overestimate one’s work results; BART task, which measures the tendency to make impulsive judgments; and abnormality scenario task, which measures the tendency to stick to a previous choice (lower part of Fig. 2).

The developed decision making skill evaluation method evaluates the level of decision making skill based on the results of tasks corresponding to each decision making stage. For example, in the brain function image obtained during the execution of the Koutetsu task, it was verified that the part of the brain which monitors the results of one’s own work, is active if it is performed properly; the effectiveness of the task was backed up also from the viewpoint of brain science. The software incorporating these four tasks had an additional function to display resulting scores after each task.

2.2 Development of risk awareness raising education/training tasks

To prevent accidents, we are also working on the development of training tasks which increase risk awareness among workers. Risk awareness is the ability to identify hazard sources quickly and
accurately within the work environment, and the factors greatly affecting its improvement include motivation to search for hazard sources and knowledge about them. Training aimed at raising this awareness, included the development of a ‘successful experience task’ [2] as a motivational training task, and the scenario drawing task [3] as a knowledge training task.

The “successful experience task” draws on a change blindness technique, which inserts blank images between frame-by-frame playback images so that original images appear in flickers. This task uses hazard sources embedded in some frame images and requires the trainee to notice and point them out. By using the change blindness technique, you can set it so that unless the trainee searches for them intentionally, it is easy to overlook the danger that everyone notices in a normal video.

For example, suppose that the change blindness images display a situation in which you are driving behind a truck. Even if a frame inserted between them displays a falling object in the lane next to the truck, many people do not notice this. In this way, they experience what it is like to fail to notice a hazard source, which would in normal circumstances be noticed. The subject is then given an explanation about how this failure to notice (oversight) can happen. In addition, they are given explanations about techniques and strategies which can help them avoid such oversight. The trainees are then instructed to check images of different content in a similar fashion. Many of them succeed in detecting the hazard sources. This increases their motivation to be risk aware. They are then presented with hazard sources relating to their workplace.

The “scenario drawing task” which improves knowledge of hazard sources is explained using an example where a driver is thinking about the dangers of over speeding. First, while drawing the process leading to the occurrence of a dangerous event, they consider the station-to-station section defined as the subject matter. They draw a railway line. Then, on the drawing they describe imagined states of mind, objects, equipment, etc. which may appear up to the event (Fig. 3). Then, they envision different situations; for example, they broaden their viewpoints by envisioning the situation of passengers, operational disruptions such as timetable changes, past experience, change of work partners, etc. and add these to the drawing with explanations. This allows them to pay attention to the hazardous sources from the perspective of human factors and, in addition, allows them to acquire the knowledge available to find them in the actual situation. Active drivers attempted the scenario drawing task. They were able to list a greater number of potential factors which could lead to over speeding and locate potentially hazardous points with more confidence.

### 2.3 Analysis of driving information records to prevent errors related to station stops

Among possible driving errors in actual train operation, the most common are related to station stops. Although there are cases where driving information records are used to prevent driver error and improve their skills, the effects of driving/maneuvering and station equipment on the occurrence of errors related to station stops has not yet been scientifically elucidated.

As such, the following were analyzed using driving information records: (i) differences in driving/maneuvering between drivers who have experienced a station-stop-related error and those who have not, and (ii) differences in equipment between stations where a station-stop-related error has occurred and those where it has not done.

A logistic regression analysis was performed for the experience of delayed braking errors with drivers as the target of the analysis. This clarified that the maximum service brake usage rate, the full brake loosening usage rate, and the standard deviation of the speed 200 m before the target position affected the occurrence of delayed braking errors. This led to the assumption that drivers who usually had a large variation in station approach speed and were unstable in driving operation to correct the variation were more likely to commit a delayed braking error.

Similarly, with stations as the target of analysis, another logistic regression analysis was performed for the occurrence of errors where the drivers made errors in stopping in the target position or in the number of cars in the train set (Stop Position / Cars errors). It revealed that the existence of a target stop position for a specific number of vehicles and the number of speed patterns affected the occurrence of Stop Position / Cars errors.

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Fig. 2  Four-stage model of decision making (upper) and decision making evaluation tasks (bottom)

Fig. 3  Example of scenario drawing task
The results of these analyses are considered to be useful, as basic knowledge, for instructing crew members using daily driving performance data.

3. Improvement of user environments

To promote the use of railways, we are engaged in R&D that helps improve user environments. This section presents the following subjects: as part of various barrier-free measures, a restroom color plan designed for individuals with low vision [5]; basic investigation on the station restroom cleaning which ensures a positive experience for anyone using station restrooms [6, 7]; and evaluation method for improving the crashworthiness of railway vehicles in an effort to achieve a safe and secure environment [8].

3.1 Restroom color plan considering individuals with low vision

Unlike people with complete visual impairment, low vision people act by utilizing their residual vision, thus barrier-free measures considering color planning are one of the points [5]. As such, to improve the usability of station restrooms assuming use by low vision people, experiments were conducted which clarified the luminance ratio required for low vision people to visually recognize the colored areas of currently used main building materials. In addition, a method for evaluating the visibility of restroom space was proposed while utilizing the luminescence distribution visualization technology (Fig. 4).

The visibility of various areas of restrooms was verified based on this evaluation method. As a result, a discrepancy was found between the material luminance ratio, which was the luminance ratio assumed from the physical property value of the building material (reflectance), and the actual luminance ratio, which was the luminance ratio observed in the actual lighting environment.

3.2 Basic investigation on station restroom cleaning

It has become clear that there is a gap between the actual state of restroom hygiene and user awareness. Thus, as a basic investigation contributing to station restroom cleaning, user perception of station restrooms was investigated. A fact-finding investigation was then conducted focusing on “smell,” which is one of the issues highlighted by results of the basic investigation.

First, in the perception investigation, after 50 participants were asked to visit an actual station restroom, they were asked to answer the question, “Do you want to use the station restroom again?” (hereinafter “Reuse?”) and other questions related to restroom cleaning. This investigation clarified that three factors strongly affected “Reuse?”: baseboard urine stain, smell, and urinal urine stain.

Thus, paying attention to “odor,” two stations were selected: a typical station with restrooms subjected to dry cleaning without sprinkling water and a typical one with restrooms subjected to wet cleaning with sprinkled water. The number of bacteria was measured in addition to the concentration of ammonia, one of the odor components of station restrooms. On the floors of dry-cleaning station restrooms, the sources were scattered in floor areas around the urinals or under wash basins, with few bacteria found. Meanwhile, on the floors of wet-cleaning station restrooms, the sources were localized in gratings (gutters), with many bacteria found.

These results suggest that effective cleaning methods from the user perspective, include removing urine stains and water droplets and reducing ammonia in floor areas around urinals and under washbasins (for dry-cleaning station restrooms) or in gratings (for wet-cleaning station restrooms).

3.3 Evaluation method for improving the crashworthiness of railway vehicles

A crashworthiness evaluation method assuming a crash at a level crossing was proposed in order to reduce damage in the unlikely event of an accident. The Japanese design standards for car body construction do not specify any indices for evaluating crashworthiness. Meanwhile, evaluation indices are defined in Europe and the U.S. [9, 10], but the design specifications for car body strength and for in-vehicle equipment such as seat structure are different from those in Japan. Thus, an evaluation index which reflects conditions in Japan and has a high correlation with the degree of injury to passengers and a method for evaluating the index, were proposed [11] by performing a crash analysis assuming a level crossing accident under various conditions, based on Japanese domestic accident statistics and vehicle specifications.

A numerical simulation was used to estimate the severity of seated railway passengers’ injuries that could occur if a train collided with a large dump truck. The simulation used a train model, a large dump truck model, and a passenger and a seat model (the accuracy of the train and truck models was verified to be high by a pre-simulation crash test); it analyzed passengers seated on a rotating transverse seat by using the vehicle speed, the crack position and angle, and the total weight of the truck as analysis parameters. As a result, the correlation coefficient between the severity of injury estimated under each condition and the integrated value of the impact deceleration generated in the car body (hereinafter “integrated deceleration value,” Fig. 5) was higher than the indices in Europe and the U.S. From the above, an integrated deceleration value was proposed as an evaluation index for crashworthiness. We can consider measures for reducing passenger damage by using the integrated deceleration value for evaluation against the deceleration waveform.
obtained by the crash analysis that is conducted during car body design.

4. Conclusion

This paper overviewed recent human science research in railways, especially representative achievements in R&D to support human error accident prevention and improvement of user environments.

Regarding the decision making skill evaluation method introduced at the beginning, we will carry out research that will lead to an education/training method utilizing the results of this study. Regarding the risk awareness improvement training task, we will work on application development to non-driver workplaces. Regarding the analysis of driving information records, the restroom color planning, the restroom cleaning investigation, and the crashworthiness evaluation method of railway vehicles, we will promote the utilization of accomplishments and findings toward railway operators and others.

In addition, in R&D related to occupational accident prevention, we are proposing in-track safety training methods for man-vehicle collision accident prevention [12]. In R&D on transport disorder countermeasures, we are working on proposals for improving the level crossing alarm sound and crossing rod movement to prevent level crossing accidents and for deer repellent sound to take measures for preventing impact accidents in wild deer [13].

Taking into account the needs of the railway business, we will continue to pursue human-science-based human factor research that can contribute to the maintenance and improvement of railway safety.

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