Development of Human Factors Education Program Based on Error Experiences in Simulator for Train Drivers

Train driving is basically a one-person duty; therefore, error prevention skills of each train driver are essential to maintain safe operations. In this research, we developed a new education program aiming to enhance train drivers’ ability to take effective measures to prevent human errors by understanding error mechanisms. This education program features simulator training with error-inducing scenarios and review of error experiences from human factors perspectives. Since its effectiveness has been confirmed, this program is now included in periodical driver training carried out at JR East.

**Keywords:** Human error, Error mechanism, Training using simulator, Driver education

### Introduction

In order to secure railway safety, education and training up to now for railway workers have focused on acquiring and improving knowledge and skills. However, it has been pointed out especially in the fields of aviation and medicine that safety cannot be secured only by improving those technical skills.

For example, even a surgeon with excellent skill might see disappointing results if he or she does not achieve sufficient communication with the nurses and anesthesiologist on the operating team or if situational awareness of the patient’s condition is incorrect. Such social or cognitive skills that complement technical skills are called “non-technical skills”.

In the field of railways too, we have to educate and train personnel on non-technical skills as well as technical skills if we are to raise the level of safety.

In this research, we focused on the job of drivers as it is a one-person job where securing safety greatly depends heavily on personal ability in situational awareness of individual drivers, and we developed an education program that aims for them to improve their ability in formulating measures to prevent errors (hereinafter, “error-prevention skill”) based on understanding of the mechanism by which human errors occur. Error-prevention skill is the ability to notice signs of human error that can occur in the current situation and prevent that error from occurring. In this sense, error-prevention skill is part of the non-technical skill related to situational awareness. It is expected that individual drivers will acquire the ability to formulate effective measures for each specific situation based on that understanding. For example, based on the understanding that people easily forget what they were originally doing when distracted by another job interfering with that, they might develop a solution of changing the work method in an important situation to prevent interruption or to keep their attention.

### Analysis of Current Situation

To find current trends in errors of our drivers, we categorized errors by drivers involved to accidents and incidents that occurred from fiscal 2009 to 2011 according to the error categorization method of James T. Reason. The categorization results revealed that Lapses of memory (forgetfulness), accounting for 48% of the total, occurred more frequently than Slips of action (careless mishandling, etc.) and Mistakes (lack of knowledge, application of wrong rules, etc.). Possible countermeasures against lapses include 1) strongly keeping the subject in mind (continuously repeating to oneself or writing down to keep in long-term memory, keeping in shape to raise alertness, etc.) and 2) working to remind oneself of the subject even after temporarily forgetting it (setting an alarm, using a check list, etc.). Since measures to keep a subject in mind and working to remind oneself of the subject even once after forgetting complement to each other, measures formulated from both viewpoints are more effective.

In this research, we focused on drivers’ most frequent lapse incident: speeding at temporarily speed restricted sections due to track work and the like, where drivers perform all driving operations as usual except in that section, so they sometimes forget about the sections or overlook signs notifying of the section when being distracted by other things. To figure out how well drivers take countermeasures to this kind of incidents, we surveyed 143 drivers in a free response format about their own measures.

A researcher at the Safety Research Laboratory who once was a driver assessed the measures taken by the drivers surveyed, finding that only 42% of drivers took measures that could be seen as effective from both the viewpoints of strongly keeping a subject in mind and reminding themselves after forgetting. The survey found that measures by the majority of the drivers were not sufficient to prevent lapses. Measures tend to be based on mentalities such as “being alert” and “driving carefully”, which cannot effectively prevent errors. In this research, we hence decided to develop an effective education program focusing on lapses, which frequently occur and still are not sufficiently dealt with by drivers.
3 Development of the Education Program

3.1 Structure of the Education Program

The aviation industry developed pioneering crew resource management training (CRM training) for education on non-technical skills using simulators, and that was later expanded to the field of medicine. CRM training has participants experience abnormal situations on a simulator with an aim of improving their teamwork, communication, situational awareness, and the like. Participants such as the captain and the copilot handle abnormal situations by utilizing all available resources during training and receive feedback after the training to improve their non-technical skills. It is said that knowledge obtained in failure experiences is effective in education as practical learning resources. Based on such findings, we decided to use driver training simulators at training centers located in all branch offices of JR East. This education program makes drivers have error-experiences in the simulator settings and then review their experiences from human factors perspectives with instructors in order to foster error-prevention skills. The structure of this education is shown in Fig. 1. All drivers of JR East receive simulator training every two years.

Fig. 1 Structure of Education on Error Prevention

Review in this education program has two parts: review at training centers right after the simulator training and review at crew offices at a specified period after the simulator training. The former utilizes the motivated mind of the trainees immediately after experiencing the error. That gives a good opportunity to make the trainees understand the reason why they made an error and how they could have prevented it by learning human error mechanisms. On the other hand, the latter is follow-up review to maintain the educational effect for the trainees. In this review, the drivers discuss their current efforts and measures to prevent errors, and they receive advice from instructors as needed. To support effective and smooth review, we created education materials on human factors both for drivers and instructors. The details are as follows.

3.2 Development of Error-inducing Scenarios (Lapses)

JR East’s driver training simulator was developed and introduced in 2000. It has many scenarios including ones inducing slips of action, but scenarios that induce and make the trainees experience lapses of memory—the most frequent error for train drivers—had not been developed up to now.

In this research, we thus developed scenarios that induce the error of exceeding the speed limit due to lapses. The scenarios now include speed restricted sections, and rolling stock failure and other interruptions occur while trainees are driving a train in a speed restricted section. The trainees might forget that they are still in the speed restricted section when they restart driving after dealing with the interruption (Fig. 2). We also developed a switch box with which we can cause rolling stock failure, activation of the train emergency stop system, receiving of an earthquake early warning, and other interruptions at any location in the speed restricted section during the simulator training (Fig. 3).

![Fig. 2 Scenario for Inducing Lapses (Exceeding Speed Limit)](image)

![Fig. 3 Switch Box to Cause Interruption](image)
3.3 Education Materials on Human Factors for Drivers
In this education program, drivers review their error experience after the simulator training. To deepen their understanding of human errors and increase the effectiveness of discussion during review, we created education material for drivers (Fig. 4). The materials are provided in a comic book style to give the drivers an easy-to-understand explanation of the basics of human errors. They consist of the following three parts.
1. Interesting trainees in prevention of errors
2. Introduction of the types of errors and mechanisms by which they occur
3. Explanation of underlying factors of errors
By reading through the materials before reviewing, the trainees can understand the basics of human errors and have deeper discussions in the review.

3.4 Education Materials for Instructors
In this education program, instructors at training centers and at crew offices who facilitate the reviews play an important role. In order to give the drivers appropriate feedback after training and effective follow-up as needed, those instructors need to have in-depth understanding of human errors and have instruction skills. We thus created education materials for instructors with an aim of enhancing their ability to instruct about human errors (Fig. 5). The materials consist of the following three parts. As the materials are for instructors, they include a wide range of information about the framework of the education program, focus points of measures to prevent errors, and points in guidance, in addition to the mechanisms by which errors occur.
1. Aims of education about error prevention
2. Framework of and points in guidance on education about error prevention
3. Mechanisms by which errors occur and points to focus on in countermeasures per type of error
By instructors learning in advance using these materials, they can give appropriate guidance in the reviews at training centers and crew offices.

4 Results
As criteria of measuring the effects of the education, we referred to the four assessment levels of an educational program advocated by Kirkpatrick.7)
- Level 1: Reaction
- Level 2: Learning (improvement of knowledge and skills)
- Level 3: Behavior (change of behavior)
- Level 4: Results (improvement of business results)
Since Level 4 requires long-term evaluation, we measured the effectiveness of the education program in terms of Level 1 to 3 in this research.

4.1 Level 1 (Reaction of Student)
To evaluate the response of trainees in this education program, we carried out interviews of instructors at crew offices who were in charge of follow-ups. Their comments informed us of the following reactions of the trainees.
- Even experienced drivers seem to have recognized that they have weaknesses in terms of errors. They showed much reaction to the fact that they exceeded the speed limit in the speed restricted section in the simulator training. They also understood the meaning and effect of the countermeasures.
- Drivers seem to have realized in the error experiences that they tend to pay less attention to one of two events when both events occur simultaneously.

4.2 Level 2 and 3 (Improvement of Knowledge and Skills, Change of Behavior)
To check improvement of knowledge and change of behavior of drivers who undertook the education program, we evaluated the change in measures for preventing errors due to lapses for
32 drivers before and after undertaking the program. Those drivers also received a review at their crew offices. The review was performed about one or two months after the training at training centers.

Table 1 shows the results of categorization of the drivers into the two groups in terms of their measures to prevent errors due to lapses.

- Group A: Drivers who are taking effective measures based on focus points for preventing errors due to lapses
- Group B: Drivers who are not basing measures on focus points for preventing errors due to lapses, or who are taking no countermeasures

With “strongly keeping a subject in mind”, which is one of the important focus points for preventing lapses, we observed a significant change before and after undertaking the education program. More specifically, the number of drivers in Group A increased from 21 before the program to 26 after the program. In contrast, we could find no significant difference with “working to remind oneself after forgetting”.

### Table 1 Change in Error Prevention Skill (n = 32)

<table>
<thead>
<tr>
<th>Measures on lapses</th>
<th>Before training (No. of persons)</th>
<th>After training (No. of persons)</th>
<th>X value</th>
<th>P &lt; .10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Strongly keep subject in mind</td>
<td>Group A: 21</td>
<td>Group B: 11</td>
<td>3.463</td>
<td>*</td>
</tr>
<tr>
<td>2) Work to remind oneself after forgetting</td>
<td>Group A: 13</td>
<td>Group B: 19</td>
<td>0.719</td>
<td></td>
</tr>
</tbody>
</table>

### Conclusion

In this research, we developed an education program to have drivers understand the mechanism by which errors occur and focus points of countermeasures so as to improve their ability to formulate on their own appropriate measures to prevent errors (error preventing skill). The results of measurement of the educational effect proved that it has a certain degree of effect on change in behavior to prevent lapses. Consequently, the program has been used at all of branch offices of JR East since fiscal 2013, and still in use.

In order to continue efforts in which drivers deepen their knowledge of human errors and think up and execute appropriate countermeasures on their own, we will continue to support instructors in charge of reviewing to improve guidance ability.

We have developed scenarios where drivers can experience errors due to lapses—the type of error they most frequently encounter—but we still have to improve their skills in preventing errors that occur less frequently but can cause serious impact once occur. We plan to further develop education programs using error experiences for important error types other than lapses.

### Reference:

7. Donald L. Kirkpatrick, Evaluating Training Programs: The Four Levels (Berrett-Koehler, 1994)