Development of Safety Training Method Encouraging Strict Rule Compliance to Prevent Person-Vehicle Collisions

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By conducting opinion surveys among on-site railway personnel, the authors demonstrated that training about “processes” and raising awareness about how non-compliance of rules leads to accidents, is necessary in order to promote further rule compliance. On the basis of this result, three pedagogical tasks based on group discussion and four pedagogical tasks for hands-on experience were developed. Six educational programs combining these seven pedagogical tasks were trialed and the following findings were confirmed: satisfaction among trainees on the educational programs was high; attitudes to rule compliance among participants continued to improve even one month after the training; the extra workload and responsibility imposed on site managers tasked with conducting the training was within the limits of what was considered acceptable for their role.

Keywords: person-vehicle collisions, safety training method, rules compliance, active learning

1. Introduction

Track maintenance work is generally carried out at night when no trains are running. However, minor inspection work is sometimes carried out during operating times, when the interval between trains is very long. Although safety in these situations has been improved by the mechanization of work and the introduction of management systems, interventions are still sometimes needed, which requires human judgment and action, such as double-checking of train schedules to confirm when trains will be passing, in order to evacuate the area in time. These interventions are governed by “rules for preventing person-vehicle collisions”, and the contents and procedures in these rules are taught as part of staff training.

When unsafe behavior occurs, it generally falls into one of several categories: “lack of knowledge and/or skills”, “unintended errors (carelessness)”, and “violation of rules” [1]. Of these, this study examines ways to prevent “violation of rules”. Rule compliance generally depends on individuals understanding the reasons why the rules are necessary and exist in the first place [2]. The reason safety-related rules exist, such as those to prevent person-vehicle collisions, is to avoid the risks (danger) that would arise if that rule was not observed. Nevertheless, it has been shown that it is the subjective evaluation of the risk to be avoided that determines whether a rule is violated [3]. Therefore, this study aims to develop a safety training method to cultivate strict compliance with rules to prevent person-vehicle collisions by educating individuals about the potential risk that could arise in case of non-compliance.

Rule compliance is also influenced by workplace culture: non-compliance is more likely to occur when it is tolerated by managers and colleagues [2]. Since track maintenance work is often carried out by teams, developing team-based training programs that are attended by colleagues who usually work together, can be conducive to fostering a culture of safety in the workplace. The purpose of this study was therefore to develop a training method that can be implemented in the workplace, and where site managers give the training themselves. Specifically, the developed method was designed so that it could be implemented in a conference room on a railway site, without using a large device such as a simulator.

2. Development of training method encouraging strict rule compliance

2.1 Examination of education content

In the field of risk management, risk is a combination of “the probability of occurrence of harm” and “the severity of the harm”. The probability of occurrence of harm can be estimated taking into account “the frequency and duration of exposure to the hazard”, “the probability of occurrence of a hazardous event” and “the technical and human possibilities to avoid or limit the harm” [4]. When these four parameters are applied to railway maintenance work, “the severity of harm” is “the impact of an accident”, “the frequency and duration of exposure to the hazard” is “the frequency of entering the railway track”, “the probability of occurrence of a hazardous event” is “the probability of non-compliant behavior”, and “the technical and human possibilities to avoid or limit the harm” is “the possibility of non-compliant behavior leading to an accident”. Among
these four parameters, it is thought that awareness of "the impact of an accident" and "the possibility of non-compliance leading to an accident" can affect rule compliance and can be improved by education.

On the other hand, in the field of psychology, it has been pointed out that risk perception consists of two dimensions: "feared risk" and "unknown risk" [5]. When applied to railway maintenance work, there are two types of "feared risk": "the danger on the track": that the railway track is a dangerous place; and "the fear of an accident": which is that accidents are the feared event.

On the basis of the above, candidate components of risk that need to be taught are listed in Fig. 1, in order of the sequence of events leading up to an accident: "danger on track" (basic fact) that the railway track is a dangerous place, "the process leading to an accident" (process) that non-compliance with rules leads to accidents, "fear of an accident" (result) where the accident is the feared event, and "consequences of an accident" (impacts) (Fig. 1).

![Fig. 1 Components of risk related to non-compliance with rules [6]](image)

We conducted opinion surveys among on-site railway personnel to examine which components of risk (Fig. 1) should be educated in order to ensure compliance with the rules for preventing person-vehicle collisions.

For the survey, we picked two rules for preventing person-vehicle collisions: "double-check train schedule to check time of next train" and "early evacuation". Two groups were chosen: a 'complete compliance behavior group' which had fully complied with the rule in the previous week; and a 'incomplete compliance behavior group'; their attitude to rule compliance and awareness of components of risk were compared (Table 1).

The results of the comparison (Figs. 2 and 3), revealed a stronger attitude to rule compliance in the ‘complete compliance behavior group’, than in the ‘incomplete compliance behavior group’. This result indicates that attitude to rule compliance is related to actual rule compliance behavior and confirmed that improving attitudes to rule compliance should be effective to ensure actual rule compliance.

Furthermore, awareness about "the process leading to an accident" was higher in the complete compliance group than in the incomplete compliance group (Figs. 2 and 3). This result indicates that, among the four components of risk (Fig. 1), "the process leading to an accident" should be taught to ensure compliance with the rules. On the other hand, there was no difference in awareness about the other three components of risk between the complete compliance and the incomplete compliance group (Figs. 2 and 3). This result indicates that further education to improve awareness about these particular components would not be effective, since it would only have a low influence on improving compliance with rules.

### Table 1 Items in survey to explore attitude to compliance and awareness of components of risk

| Attitude to compliance | Danger on track | Process leading to an accident | Fear of an accident | Impacts of accident |
|------------------------|-----------------|--------------------------------|---------------------|---------------------|
| "I will strictly comply XX rule." | "I'm afraid to work inside the track." | "If you do not do XX, it is dangerous." | "If you do not do XX, it leads to an accident." | "A person-vehicle collision would seriously disrupt my workplace." |
| "I will definitely implement XX." | "It's dangerous inside the track." | "The feared event is a person-vehicle collision." | "A person-vehicle collision would have a serious impact on my family." | "A person-vehicle collision would cause significant inconvenience to passengers." |

| Component | Average value | 
|-----------|--------------|
| Complete compliance behavior | 6 |
| Incomplete compliance behavior | 5 |

**p<0.01, *p<0.05 (paired t-test)**

Respondents: 50 employees on track maintenance site and 47 employees on electrical site (Survey conducted in railway company A in April 2018)

### Fig. 2 Relationship between attitude to compliance or awareness of risk and compliance behavior (Double-checking of train schedule)

![Fig. 2](image)

### Fig. 3 Relationship between attitude to compliance or awareness of risk and compliance behavior (Early evacuation)

![Fig. 3](image)

**p<0.01, *p<0.05 (paired t-test)**

Respondents: 46 employees on track maintenance site (Survey conducted in railway company B in May 2018)

### 2.2 Developed training method

Table 2 shows the seven pedagogical tasks that were developed.

(a) **Case Application**

- **Aim:** Help learners understand that non-observance of the rules could lead to an accident in their workplace.
- **Procedure:** The task unfolds in three stages: first individual work using the worksheet, and then a group discussion (Fig. 4). Time required 30 minutes.
- **Pedagogical resource:** Case Application Worksheet (Fig. 5).

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Table 2  Seven pedagogical tasks

| Type                 | Pedagogical tasks                                      | Target rule to be taught                              |
|----------------------|--------------------------------------------------------|-------------------------------------------------------|
| Group discussion     | (a) Case Application                                    | All rules for preventing person-vehicle accidents     |
|                      | (b) Hypothetical Variation in factors                   |                                                       |
|                      | (c) Imagined Impact of Accident                         |                                                       |
| Hands-on experience  | (d) Experiencing Error Through Misreading               | Double-checking of train schedule                      |
|                      | (e) Role Playing Experience                             | Early evacuation etc.                                 |
|                      | (f) Experiencing Loss of Track of Time                  |                                                       |
|                      | (g) Training with VR Material (scenario with signal/no signal) |                                                       |

- (c) was developed to be done as a warm-up task at the start of the training.

Read examples of noncompliance from other worksites that lead to an accident

Applying the circumstances of the accident in the example to your own workplace, and fill in the worksheet

Fig. 4  Procedure for Case Application

Q1 Why did the person think that they did not need to observe the rule on XX in this case?
Q2 From the reasons given in Q1, select one that could also apply to your own workplace.
Q3 Under what circumstances would the reason for not following the rule selected in Q2, lead to an accident in your workplace? In a worst case scenario, what could be the consequences of this action?
Q4: What could you do to prevent the unwanted consequences (accident) described in Q3?

Fig. 5  Case Application Worksheet

(b) Hypothetical Variation in Factors
- **Aim:** Help learners understand that the accumulation of rule “violation” and “variation in factors (unusual situations and errors)” could lead to an accident.
- **Procedure:** 3 steps of group discussion (Fig. 6). Time required 30 minutes.
- **Pedagogical resource:** Office supplies such as sticky notes, imitation paper, and writing instruments

(e) Role Playing Experience
- **Aim:** Help learners experience that “Anyone can misread anything.”, and understand that “If you do not double-check the train schedule, it can lead to an accident”.
- **Procedure:** Two people, one in charge of work and one in charge of watching for trains and double-checking the train schedule following the “instruction card” [8]. In this task one person should notice that the other has misread the timetable information and point out it. Time required 25 minutes.
- **Pedagogical resource:** A typical train schedule and an “instruction card”. The instruction card may include, in addition to the information necessary to double-check the next train (e.g. current time, current position, etc.), an instruction to “Misread the time of the next train intentionally”. Alternatively, the train diagram may be com-

Fig. 6  Procedure for Hypothetical Variation in Factors

Consider the impact of accidents on “yourself”, “workplace”, “company”, “family” and “customer”

Fig. 7  Procedure for Imagining Impact of Accident

- **Pedagogical resource:** Office supplies such as sticky notes, imitation paper, and writing instruments.

(d) Experiencing Error Through Misreading
- **Aim:** To experience that “Anyone can misread anything.”, and understand that “If you do not double-check the train schedule diagram, it can lead to an accident”.
- **Procedure:** After reading the sequence of numbers and alphabets within the time limit (3 minutes) to find as many “13” and “122D” as possible, and mark them (Fig. 8). Time required 20 minutes.
- **Pedagogical resource:** The task paper (Fig. 8) which simulates reading a train schedule diagram. In the trial, 96.2% of the participants (225 out of 234) experienced one or more reading errors [8].

Fig. 8  Worksheet for to experience making an error because of misread information [8]

Within 3 minutes, find as many “13” and “122D” as possible, and mark them
piled to intentionally include a mistake. The misreading error used in the task should be based on past near miss cases.

(f) Experiencing Loss of Track of Time

− **Aim:** Help learners experience “loss of notion of time when engrossed in another task”. This should demonstrate to learners that if they fail to evacuate on time, they may become focused on the work in hand and lose track of time.

− **Procedure:** Participants are required to perform the following two tasks at the same time while watching the video projected on the screen (Fig. 9). Time required 5 minutes.
  Task 1: Participants measure 1 minute without a watch
  Task 2: Participants write down which of the items “coming out of the box” they “may bring to work” (until Exercise 1 is completed).

− **Pedagogical resource:** Software used for helping learners experience loss of track of time (Fig. 9). In the preliminary trial, 98.9% of the participants (93 out of 94) concentrated on task 2 and experiencing the difficulty of completing this task 2 whilst keeping track of time for task 1.

![Fig. 9 Screen shot of software used in task to help learners experience loss of track of time](image)

(g) Training with VR Material

− **Aim:** Help learners experience “loss of notion of time when engrossed in another task”. This should demonstrate to learners that if they fail to evacuate on time, they may become focused on the work in hand and lose track of time.

− **Procedure:** A participant will take the role of the work manager, walk around in the VR (Virtual Reality) space, and perform bolt inspection work. In the scenario, it is necessary to evacuate safely and have a colleague (worker) evacuate in the VR space. Time required 5 minutes for each scenario.

− **Pedagogical resource:** VR training software (Fig. 10) to prevent person-vehicle collisions. The software includes two scenarios:

  **Scenario with signal**
  Even after the evacuation signal appears, a colleague (worker) in the VR space continues to work, so it is necessary for the participant playing the role of site manager to call out and ask the worker to move away from the track.

  **Scenario with no signal**
  While a participant is inspecting a bolt, a train approaches without an evacuation signal (noticing the approaching train is particularly difficult when the participant is concentrating on the work).

![Fig. 10 Training with VR Material](image)

3. Training method trial

3.1 Method

The pedagogical tasks were organized into an educational program, designed to maximize pedagogical impact within the limit of extra work that could be tolerated at a railway worksite. Each educational program was trialed with on-site personnel involving track maintenance or electrical installations (Table 3) [6]-[9].

An RTRI researcher or site manager was tasked with delivering the program. A “Manual” was compiled to allow delivery of the program simply by being read. Before site managers delivered the content in their workplace, they were first given the chance to attend a demonstration by a research about how to deliver the program.

| Program No | Pedagogical task | Target rule being taught | Content delivery | Number of Participants |
|------------|-----------------|--------------------------|------------------|-----------------------|
| P1*        | (a) Case Application | Double-checking schedule | researcher | 46 |
| P2         | (c) Imagined Impact of Accident (a) Case Application | Checking operational status | researcher | 54 |
| P3         | (c) Imagined Impact of Accident (a) Case Application | Early evacuation | 24 site managers | 259 |
| P4-1       | (d) Experiencing Error through Misreading Experience | Double-checking schedule | 24 site managers | 263 |
| P4-2*      | (e) Role Playing Experience | Double-checking schedule | 4 site managers | 16 |
| P5-1*      | (g) VR (with no signal) (a) Case Application | Early evacuation | researcher | 48 |
| P5-2*      | (g) VR (with no signal) (a) Case Application | Early evacuation | 2 site managers | 24 |
| P6*        | (g) VR (with signal) (a) Case Application | Early evacuation | researcher | 11 |

*The trials were conducted from September 2016 to November 2018. For trials marked with *, additional survey was conducted one month later.

1: the participants who are in charge of track maintenance
2: the participants who are in charge of electricity

3.2 Participant satisfaction

Participant satisfaction is a factor that contributes to pedagogical effect, which in turn influences the motivation to continue applying the learnt content in practice after the training. Immediately after the training, participants were asked to rate meaningfulness of the entire educational program and each of the pedagogical tasks in the educational...
program using a 5-point Likert scale with possible answers ranging from “not meaningful at all” to “very meaningful”.

The results of this survey showed that the percentage of positive evaluations (responses including “very meaningful” or “somewhat meaningful”) for each pedagogical task was 76-93%, indicating a high degree of satisfaction (Fig. 11).

However, the variation among “very meaningful” responses was quite marked ranging between 17 to 47%. In particular, program P5-1 (VR (scenario with no signal) + Case Application) was highly rated (47%), but another part of the same VR task (g) was poorly rated (17%). Reading participant feedback on P6, it turned out that there was a problem in the response accuracy of the VR software to the voice of participants calling out to their colleagues (workers) in the VR space. Therefore, we modified the software so that the person delivering the training could move the scenario on to the next step manually using the PC, in response to the voice of the participant.

The rate of responses which included “very meaningful” was calculated for each pedagogical task in the program. The result showed a variation from 16 to 67%. Among the most highly rated pedagogical tasks were (g) VR (scenario with no signal) (67% for P5-1, 50% for P5-1) and (e) Role Playing Experience (52% for P4-1, 53% for P4-1).

3.3 Attitude towards rule compliance

In Section 2.1, it was stated that improving attitudes to rule compliance was an effective way to improve actual rule compliance. Therefore, we investigated improvements attitude to rule compliance after the program. Just before and immediately after the education, the participants were asked to respond to the question “I will strictly comply with the rule for XX” (XX means the name of the rule) on a 5-point or 7-point Likert scale, with possible answers ranging from “not applicable at all” to “very applicable”.

As a result, the average value on attitude to rule compliance improved by a statistically significant margin after all the training program trials.

Furthermore, as a result of an additional survey conducted one month after the education, in program P4-2 (Experiencing Error through Misreading + Role Playing Experience), P5-1 and P5-2 (VR (scenario with no signal) + Case Application), P6 (VR (scenario with signal) + Case Application), a statistically significant improvement was seen in the average value of attitude to rule compliance one month after the training (Fig. 12). In program P1 (Case application), it was not possible to confirm any improvement in attitude to rule compliance one month after the training, but it is possible that the average value before training was already high so there was little room for improvement.

3.4 Implementation workload

This research sought to develop a training method which could be delivered by site managers in the workplace. Therefore, following the training, we investigated the sense of burden felt by site managers in charge of conducting the training. We asked them about “preparation workload” and “training delivery workload” (using a 5-point Likert scale with possible responses ranging from “not tough” to “very tough and unacceptable”).
of respondents selected “very tough and unacceptable” for “preparation workload” and “training delivery workload”. The above-mentioned programs P3, P4-1, P4-3, and P5-3 include all of the developed pedagogical tasks, (a) to (g). These results confirmed that the sense of burden when the site managers were in charge of delivering the training was within the operational permissible range.

4. Conclusions

This research had the purpose of developing a safety training method to encourage compliance with rules for preventing person-vehicle collisions.

According to opinion surveys among on-site railway personnel, the authors clearly showed better compliance required training to raise awareness that “noncompliant action leads to accidents”.

Consequently, three pedagogical tasks based on group discussion and four experiential tasks were developed. Six training programs combining these seven pedagogical tasks were trialed and the following findings were confirmed: the satisfaction level among those participating in the training was high; attitude to rule compliance among participants was still at the improved level one month after the training; the sense of burden on site managers who were asked to deliver the training was deemed to be with the limits of what was admissible in their position.

We will continue to consider ways to maintain and promote the effects of this training method in the longer term.

References

[1] Iida, S. and Nagai, Y., TQM Seven Tools for Medical Care, Japanese Standards Association, Tokyo, JAPAN, pp. 141-163, 2012 (in Japanese).

[2] Komatsubara, A., “Mechanism of Violations and their Ergonomic Measures,” Safety Engineering, Vol. 47, No.4, pp. 194-200, July 2008 (in Japanese).

[3] Adachi, U., Usui, S., et al., “A study of psychological factors in nursing violations,” Japanese Journal of Applied Psychology, Vol. 35, No.2, pp. 71-80, 2010 (in Japanese).

[4] Japanese Standards Association, “Machinery Safety Risk Assessment Principles B9702 (ISO14121),” JIS Handbook 58-4, Risk Management, 2009 (in Japanese).

[5] Okamoto, K., An Introduction to Risk Psychology Human Error and Risk Image, Saiensu-Sha, Tokyo, JAPAN, 2004 (in Japanese).

[6] Murakoshi, A., Miyachi, Y., Hayama, K., “The Effect of VR Training Method for Promoting Compliance with the Rules in the Railway Track,” The Japanese Journal of Ergonomics, Vol. 55, Supplement, p. 1B1-6, 2019 (in Japanese).

[7] Murakoshi, A., Miyachi, Y., “A Learning Method for Preventing Violation of the Rules in Track Maintenance,” The 32nd annual convention of the Japanese Association of Industrial/Organizational Psychology, pp. 185-188, 2016 (in Japanese).

[8] Murakoshi, A., Miyachi, Y., “Development of Experiential Safety Education Program to Promote Compliance with ‘Double Check Rule of Train Schedule Diagram’ in Railway Maintenance Work,” The Japanese Journal of Ergonomics, Vol. 55, No.2, pp. 25-32, 2019 (in Japanese).

[9] Murakoshi, A., Miyachi, Y., “A Learning Method for Preventing Violation of the Rules in Track Maintenance (2),” The 33rd annual convention of the Japanese Association of Industrial/Organizational Psychology, pp. 33-36, 2017 (in Japanese).

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