Prospective Calling Method to Prevent Excessive Train Speed

Ayanori SATO
Safety Psychology Laboratory, Human Science Division

Noriko ONOMA
Safety Psychology Laboratory, Human Science Division (Former)

Takayuki MASUDA
Safety Psychology Laboratory, Human Science Division

This article proposes the use of calling as a method to help train drivers avoid exceeding speed limits. The prospective calling consists of mental-imagery calling and repetition calling. ‘Mental-imagery calling’ refers to an action where a driver voices out loud the mental image they have of their driving in restricted speed sections. Repeated calling involves a driver repeating reminders to themselves as they operate the train. The effects of these two types of calling to improve prospective memory recall were confirmed experimentally. In addition, the effect of prospective calling on preventing excessive train speeds was confirmed in an experiment involving train drivers, using a train driving simulator.

Keywords: prospective calling, excessive speed, prospective memory, train driving simulator

1. Introduction

Excessive train speed can cause fatal train accidents, such as derailments or overturning. In this context, methods to develop train safety, including prevention of excessive speeding, are essential. Driver error and excessive train speed prevention require not only hardware measures, such as ATS (Automatic Train Stop), but also complementary software: by taking measures from both sides, it is possible to achieve greater levels of safety.

The authors therefore propose prospective calling as a measure to prevent excessive speed, which can be carried out by individual drivers. First, this article mentions the cause of excessive speed, explains the outline of prospective calling, and then reports on 3 experiments conducted to verify the effect of prospective calling.

2. The cause of excessive speed

Speed limits are specified according to track layout such as straight lines and curves, and drivers must ensure that their train runs within this speed limit. Excessive speed refers to a train running at higher speed than the speed limit.

Sections with temporary speed restrictions are considered to be areas where excessive train speed is likely to occur. Sections with speed restrictions are sections where temporary restrictions have been imposed for safety reasons, for example, when construction is being carried out along that section of track or when there is heavy rain or wind.

In order to investigate the causes of excessive train speed, we investigated speeding incidents that occurred between 2009 and 2016 in a railway company in Japan. Of the 18 cases collected, the rate of occurrence in sections with speed restrictions accounted for 72% (Fig. 1).

Also, a common cause of excessive speed was that although the driver knew that there was a section with a speed restriction ahead, they had forgotten this by the time they approached it. In this way, it is possible to say that excessive train speed is related to memory failure. Recalling a plan such as “I will reduce my speed before arriving at the section with a speed restriction” is called prospective memory. The percentage of excessive speed incidents in sections with speed restrictions due to an error in prospective memory is 69%, which is a large proportion (Fig. 2). Consequently, finding a way to prevent prospective memory failure is an important issue.

3. Prospective calling

To prevent this forgetfulness, firstly, it is necessary to recall prospective memory at the appropriate time, when the scheduled plan can be executed. After recall, it is neces-
sary to maintain attention on the plan until it is executed. Two respects of this prospective memory, “recollection at the appropriate time” and “retaining attention on the planned action,” are necessary to appropriately execute the plan.

Prospective calling is a method to support “recollection at the appropriate time” and “retaining the planned action” by pre-calling an action to be remembered and related information. The term prospective calling because it requires voicing out loud the prospective event before the event actually happens. There are two types of prospective calling: mental-imagery prospective calling and repetition prospective calling (Figs. 3 and 4). In the rest of this paper, these are referred to as mental-imagery calling and repetition calling, respectively.

Mental-imagery calling recall of the action at the appropriate time. The process works by remembering the existence of a section with a speed restriction when approaching one, by imagining the behavior of and context in which a train driver operates their train within a speed limit. Mental imaging can enhance memory trace, and therefore mental-imagery calling has the potential to be a tool to prevent excessive train speed.

Mental-imagery calling may however have a negative impact on driving because the driver has to make the effort of creating a mental image of the planned action. Therefore, it should be used, when in a depot, or when at a platform, waiting for their train to arrive; it should be used when train drivers are not driving the train.

Repetition calling on the other hand, helps remain conscious of the action to be performed. This is based on commentary driving methods used in railway companies in the UK [1]. It is a method to prevent forgetfulness by continuously calling out the content of what should not be forgotten, and there is no specific rule about what to call when. However, the repetition calling proposed in this article is to call in sections with speed restrictions and call the speed limit, when attention may be focused elsewhere, such as immediately after checking a signal by point and call or after accelerating or decelerating. It is reported that forgetfulness occurs easily, even if the plan to be executed was in the conscious mind, when attention is turned to something else for some reason and the plan temporarily disappears from the conscious mind [2]. During train operation, it is necessary to pay attention to various things such as traveling speed, operating time, signal aspects, and track conditions, and it is difficult to remain conscious of sections with speed restrictions at all times. However, if a driver calls out sections with speed restrictions and the speed limit continuously immediately after having turned their attention to something else, such as checking a signal, etc., can help retain consciousness of the speed limitation.

The following sections report three experiments conducted to verify the effect of prospective calling. The first experiment was to verify the effect of promoting recall of prospective memory at the appropriate time by mental-imagery calling. The second experiment was to verifies the effect of maintaining recall content by repetition calling. In addition to each of the above-mentioned experiments, the interference effect of prospective calling was also verified. In an actual driving situation, if too much attention is paid to performing prospective calling, it may
negatively affect the driving task. Therefore, investigations were conducted to determine whether mental-imagery calling and repetition calling reduced the performance of tasks other than the target task of calling itself.

4. Verification of the effect of mental-imagery calling

4.1 Purpose

The purpose of this verification was to determine whether mental-imagery calling promoted recall of prospective memory at the appropriate moment. Since this effect is not considered to be limited to driving situations, as a trial, experimental verification was performed with participants who were not train drivers but university students.

In this experiment, participants were instructed to press a specific key when a specific word appeared on the screen during performance of another computer task. In this article, the task of pressing a particular key at the appropriate time is called “prospective memory task”, and the other task is referred to as the “ongoing task”.

The performances of prospective memory tasks with and without mental-imagery calling were compared. If the mental-imagery calling helps recall of prospective memory at the appropriate time, the performance of the prospective memory task should improve when mental-imagery calling is performed.

The interference effect of mental-imagery calling on performance of an ongoing task was also examined. It was predicted that if mental-imagery calling made participants focus only on the prospective memory task, they would pay little attention to ongoing tasks. If the mental-imagery calling reduces attention to ongoing tasks, then performance of the ongoing task should decline when mental-imagery calling is performed.

4.2 Method

4.2.1 Experimental design

The experiment was designed to be a single factor experiment with two levels, between subjects. There were two conditions (mental-imagery calling condition vs. no-mental-imagery calling condition).

4.2.2 Participants

42 university students participated in this experiment (22 males and 20 females) with a mean age of 21.50 and standard deviation of 1.93. They were allocated randomly to one of the two conditions (22 in mental-imagery calling condition, 20 in no-mental-imagery calling condition).

4.2.3 Material

The ongoing task was a lexical decision task. The task involved deciding as quickly as possible whether the character string continuously presented on the personal computer screen was a word (e.g., watermelon) or a non-word (e.g., yusate). Subjects had to press the “J” key for a Japanese word and the “F” key for non-Japanese, as quickly as possible.

The prospective memory task was a task of pressing the numerical key “5” when seeing a specific word specified in advance (e.g., pencil, sakura) during the lexical decision task. The number of questions (the number of trials) in the lexical decision task was 204, and each set of 102 trials included a real word or a non-word. Of the 102 trials in which a word was presented, the above-mentioned specific word was presented in only 4 trials. The presentation order was random.

4.2.4 Procedure

The experiment was conducted with every participant alone in the laboratory. The participant was seated in front of a computer screen and received an explanation from the person conducting the experiment, about how to do the task.

After explaining the task, the person conducting the experiment gave the participant two specific words as the prospective memory task. In addition, the participants for mental-imagery calling were required to say three times, “When either pencil or sakura are presented on the screen, press the numerical key 5.” The participants were also required to imagine pressing this key for 30 seconds.

After this, participants were required to carry out another task for about 15 minutes, unrelated to both the ongoing task and the prospective memory task. Then they performed the ongoing task and the prospective memory task. The purpose of doing another task was to make them less aware of the prospective memory.

4.3 Results and discussion

After the experiment, it was found that 9 out of 42 participants did not correctly remember specific words in the prospective memory task. They were excluded from the analysis. Therefore, 33 participants were analyzed (19 in mental-imagery calling condition and 14 in no-mental-imagery calling condition). In this article, significance probability was set to 10% in all subsequent analyses.

4.3.1 Prospective memory task

Responses where participants pressed the numerical key “5” to a specific word presented during the ongoing task were defined as correct reactions. The results are shown in Fig. 5. A $t$ test was conducted with the number of correct responses between mental-imagery calling and no-mental-imagery calling condition. Results showed that performance on the prospective memory task in mental-imagery calling condition was significantly higher than with no-mental-imagery calling condition ($t(31) = 2.09, p < .10$). These results demonstrate that mental-imagery calling promotes recall of prospective memory at the appropriate time.

4.3.2 Ongoing task

Table 1 shows the mean number of correct responses and reaction times per participant in the lexical decision task performed as an ongoing task. A $t$ test was conducted
between the number of correct responses and reaction time with mental-imagery calling condition and no-mental-imagery calling condition. The result showed no significant difference (the number of correct responses: $t(31) = 0.87$, n.s., reaction time: $t(31) = 0.76$, n.s.). From this, interference of mental-imagery calling with the ongoing task was not confirmed in this experiment.

5. Verification of the effect of repetition calling

5.1 Purpose

The purpose of this experiment was to verify the effect of repetition calling on retaining attention on the planned action in prospective memory. Since this effect is not considered to be limited to train driving situations, as a trial, experimental verification was performed with participants who were not train drivers but university students.

As in the previous section, this experiment comprised an ongoing task and a prospective memory task. In the experiment in section 4, when the cue of the prospective memory task such as a specific word was presented, the participants were requested to respond immediately after seeing it. However, in this experiment, the participants were required to respond after a certain time lag. In other words, the participants had to consciously keep the response unanswered for a certain amount of time. In this experiment, the cues for this prospective memory task were given prominence, so that participants could notice them easily.

The performance of this prospective memory task with repetition calling was compared to the experiment without repetition calling. If repetition calling helps consciously maintaining planned action in mind, the performance of the prospective memory task should be better when repetition calling is performed.

Repetition calling may however, interfere with other tasks aside from the prospective memory task and the ongoing task. This was also examined: it was predicted that if repetition calling was focused on the prospective memory task, participants’ attention would be distracted from the other task. Therefore, the performances of the other task with and without repetition calling were compared. If repetition calling reduces attention to other tasks, the performance of this other task should be lower than when repetition calling is not used.

5.2 Method

5.2.1 Experimental design

The experiment was designed to be a single factor experiment with two levels, between subjects. There were two conditions (repetition calling condition vs. no-repetition calling condition).

5.2.2 Participants

A different cohort of 41 university students participated in this experiment (20 males and 21 females). The mean age was 21.00 and the standard deviation was 1.80. They were allocated randomly to one of the two conditions (21 to repetition calling, 20 to no-repetition calling).

5.2.3 Material

As an ongoing task, a series of subtasks were presented on a personal computer screen. The ongoing task had 8 simple subtasks, such as rating the likeability of words. Questions in each subtask were presented in succession, and subtasks were switched every two minutes. This constituted one set, and a total of 16 sets were performed. Each subtask was asked twice. The order of subtasks was random for each participant, but two or more consecutive sets of same subtasks were avoided.

The prospective memory task was to press the slash key on the keyboard at the time when subtask was switched, following the question of the ongoing task (all subtasks) that was written in red letters. The question of the ongoing task in red letters was the cue of the prospective memory task. Participants who noticed this cue had to wait before pressing the slash key until the subtask was switched. All questions in an ongoing task other than this cue were presented in black letters. Therefore, it was considered that the participants could easily notice the cue of this prospective memory task. The cue of the prospective memory task was presented to each participant four times.

In addition, the participants were required to perform another task (the number monitoring task) while performing the ongoing task and the prospective memory task. In this task, numbers from 1 to 10 appeared in the upper right corner of the personal computer screen during the ongoing task: when the number reached 10, participants were required to press the space key. After reaching 10, the number would return to 1, before climbing back to 10. The numbers did not climb uniformly, but fluctuated between 2 seconds and 12 seconds. Therefore, it was difficult for the participants to predict when exactly the numbers would
change. However, the number 10 was always displayed for 3 seconds. “10” was presented 51 times to each participant.

5.2.4 Procedure

The experiment was conducted with every participant alone in the laboratory. The participants were seated in front of the computer and were given an explanation of how to do each task. When the cue of the prospective memory task appeared, the participants performing repetition calling were instructed to continue saying out loud, “Press the slash key when the subtask was switched”, until the subtask was switched. The speed at which the calling should be done was not specified. The participants who were not asked to perform repetition calling were not given an explanation of repetition calling, and the task simply started.

5.3 Results and discussion

There were 5 participants who misunderstood the task itself, so they were excluded from this analysis. This left 36 participants to be analyzed (18 in repetition calling and 18 in no repetition calling).

5.3.1 Prospective memory task

After the cue of the prospective memory task was presented, the responses which participants pressed the slash key after the subtask in the ongoing task was switched were defined as correct responses in the prospective memory task. The results are shown in Fig. 6. T test was conducted in the number of correct responses between repetition calling condition and no-repetition calling condition. As result, performance on prospective memory task was significantly higher in repetition calling condition than that in no-repetition calling condition ($t(34) = 2.01, p < .10$). From this result, the effect of repetition calling for retaining the planned action was confirmed.

![Fig. 6 Performance of prospective memory task](image)

5.3.2 Number monitoring task

Table 2 shows the mean of number of correct responses per participant able to press the space key when the number in the number monitoring task was 10.

A $T$ test was conducted to compare the number of correct responses with repetition calling and without repetition calling. As result, there was no significant difference ($t(34) = 1.40, n.s.$).

Since no difference between two conditions was observed, the interference of repetition calling on the task was not confirmed in this experiment.

6. Verification of prospective calling

6.1 Purpose

The experiments conducted with university students confirmed that mental-imagery calling and repetition calling helped “recollection at the appropriate time” and “retaining the planned action” in prospective memory. These results therefore suggest that prospective calling may help prevent excessive train speed due to failure to recall or maintain prospective memory.

In order to verify whether prospective calling is effective in preventing excessive speed, an experiment with train drivers was conducted under conditions similar to actual train driving, using a train driving simulator. If prospective calling has the effect of preventing excessive speed, the rate of excessive speed incidents should be lower when participants perform prospective calling.

This experiment also examined whether prospective calling induces oversight of other tasks. If prospective calling is performed excessively, participants’ attention focuses only on the action subject to prospective calling, not on other tasks, which may lead to forgetfulness. Therefore, it was examined whether or not divers forget to do other tasks, when the driver was given the freedom to adjust the frequency of prospective calling.

6.2 Method

6.2.1 Experiment design

The experiment was designed to be a single factor experiment with two levels, between subjects. There were two conditions (prospective calling condition vs. no-prospective calling condition).

6.2.2 Participants

Thirty train drivers (24 men and 6 women) participated in this experiment. The mean age was 34.40 years. The standard deviation was 8.30 years. The thirty participants were split randomly into two groups and assigned to one of the two conditions (prospective calling condition vs. no-prospective calling).

6.2.3 Material

Participants were required to drive a train on a simulator on a route where the train journey lasts about 20 minutes if there are no incidents. This simulator route imi-
tated an actual route that participants were accustomed to driving on a daily basis.

In this experiment, in order to create a situation where it was easy to induce excessive speed, various incidents were triggered by one of the researchers conducting the experiment, while the driver was running through the section with a speed restriction. Participants who stopped at the station were informed about sections which had speed restrictions by the dispatcher (person conducting the experiment) and that they had to operate their train within the speed limit. After the experiment finished from station A to station C, two stations further on. As drivers arrived at the platform in station A, the person conducting the experiment reduced train’s braking power and caused a stop position failure, making the train go beyond the platform. In addition, at the next station B, when leaving the station, the aspect of the departure signal was changed to a closed signal from an open signal, causing a SPAD (signal passed at danger). Subsequently, it was verified whether participants were able to continue driving within the speed limited in the section with the speed restriction, while resolving the incidents described above.

In addition, in order to verify whether prospective calling induces forgetfulness of another work, the participants were asked to confirm the safety of a level crossing in the section with a speed restriction. During the stop at station B, the participants were instructed by the dispatcher (person conducting the experiment) to stop before the level crossing and contact the dispatcher by radio to check the safety of the level crossing between Stations B and C. While traveling from Station B to C, it was verified whether participants were possible to stop their train before the level crossing.

After the participants had checked the safety of the level crossing, they received instructions from the dispatcher to restart the operation. This experiment ended when they arrived at station C.

Prior to the start of the experiment, participants in the prospective calling group received an explanation about how to perform prospective calling. In the section with a speed restriction, the participants were instructed to use repetition calling while they were running between stations and use mental-imagery calling when they were stopped at a station. The participants in the other group were instructed to drive as usual.

### 6.3 Results and discussion

One participant misunderstood the section with the speed restriction in the prospective calling group, and two participants in the other group who actually used prospective calling during the exercise were excluded from this analysis. As a result, the number of participants analyzed was 27 (14 in prospective calling group, 13 in the no-prospective calling group).

#### 6.3.1 Excessive speed

Table 3 shows the number of participants who exceeded the speed limit because they forgot the existence of the section with a speed restriction. Fisher’s exact test was conducted. According to result, the number of participants who exceeded the speed limit was significantly lower in the prospective calling group than in the group with no-prospective calling ($p < .10$). These results demonstrate that prospective calling is effective for preventing excessive speed.

### 6.3.2 Oversight of other tasks (level crossing check)

Table 4 shows the number of participants who forgot to check the safety of the level crossing in each group. Fisher’s exact test revealed no significant difference (n.s.). This result, did not confirm therefore, that prospective calling increased oversight of other tasks.

#### Table 3 Number and ratio (%) of participants exceeding speed limit

|          | Excess speed | No excess speed |
|----------|--------------|-----------------|
| Prospective | 0 [0.00 %]   | 14 [100.00 %]   |
| No-prospective | 4 [30.77 %] | 9 [69.23 %]     |

#### Table 4 Number and ratio (%) of participants forgetting to check level crossing

|          | Forgot | Remembered |
|----------|--------|------------|
| Prospective | 0 [0.00 %] | 14 [100.00 %] |
| No-prospective | 2 [15.38 %] | 11 [84.62 %] |

### 7. Conclusion

In this article, we proposed prospective calling as a method to prevent excessive speed. Mental-imagery calling supports recall of prospective memory at the appropriate time, and repetition calling supports consciously maintaining planned action in mind, until it is executed.

Experiments with university students confirmed that prospective calling helps recall of prospective memory and maintains planned action in mind. Another experiment conducted with train drivers confirmed that prospective calling is effective for preventing excessive speed. These results therefore indicate that prospective calling is an effective measure for preventing excessive speed due to prospective memory errors.

In addition, experiments could not confirm that prospective calling interfered with the performance of other tasks. Results from each of the experiments conducted demonstrated that there was no significant difference in the performance of other tasks, with or without prospective calling. One of the reasons for this was that the participants were able to adjust the frequency of the prospective calling, especially for repetition calling. However, it cannot be concluded from these results that prospective calling does not interfere at all with the performance of other tasks (work). Previous research has shown that if participants repeat the same wording continuously while driving a simulator train, it was difficult for participants to understand what they were actually saying or would become monotonous [3] [4]. Therefore, excessive repetition of the same words over a long period of time can affect other tasks.

Proper use of prospective calling should help to prevent prospective memory errors. In this article, the focus was on excessive speed prevention, but it is possible that it could be applied to prevent other accidents caused by prospective
memory errors. However, in order to be applied, the user needs to understand the error prevention mechanism underlying prospective calling. Currently, we are developing teaching materials to teach users how to apply it, such as the time and frequency of prospective calling and the underlying mechanisms.

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Authors

Ayanori SATO
Assistant Senior Researcher, Safety Psychology Laboratory, Human Science Division
Research Areas: Cognitive Psychology

Noriko ONOMA
Researcher, Safety Psychology Laboratory, Human Science Division (Former)
Research Areas: Applied Psychology

Takayuki MASUDA, Dr. Psychology
Assistant Senior Researcher, Safety Psychology Laboratory, Human Science Division
Research Areas: Traffic Psychology