The influence of false and missing alarms of safety system on drivers' risk-taking behavior

Takayuki Masuda[1], Shigeru Haga[2], Azusa Aoyama[2], Hiroki Takahashi[2], Gaku Naito[2]

[1] Human Science Division, Railway Technical Research Institute,
2-8-38 Hikari-cho, Kokubunji-shi Tokyo, 185-8540, JAPAN
[2] School of Contemporary Psychology, Rikkyo University,
1-2-26 Kitano, Niiza-shi, Saitama, 352-8558, JAPAN
masuda@rtri.or.jp, haga@rikkyo.ac.jp, foreverkizamikakao@gmail.com,
spellmiss_hi6i@auone.jp, 10um007x@rikkyo.ac.jp

Abstract. This study investigates the influence of false and missing alarms of safety system on drivers' risk-taking behavior by laboratory experiments. The task is to move a vehicle from below to top through an intersection displayed on a PC monitor without colliding with crossing traffic. Participants performed the task under different experimental conditions with different types of system failure: (1) no failure, (2) false alarm, (3) missing alarm, and (4) no information. We conducted two experiments. The difference between Experiment 1 (E1) and Experiment 2 (E2) is the frequency of false or missing alarms: erroneous alarms occurred twice as many in E2 as E1. The differences of the result between E1 and E2 indicate that the different frequencies of missing alarm have a different effect on risk-taking behavior.

Keywords: negative adaptation, risk-taking, system failure

1 Introduction

To date, remarkable progress in vehicle technology has made it possible to introduce various driving support systems, such as ACC (adaptive cruise control), ISA (intelligent speed adaptation), AAP (active accelerator pedal) and VES (vision enhance system) to the market. These systems contribute to the safety improvements; however, negative adaptation may spoil the expected safety effect of these systems.

The negative adaptation means undesirable behavioral changes, which may occur following the introduction of safety measures such as driving support systems[1]. There are ample evidences of the occurrence of negative adaptation[2], [3], [4], though it does not always occur. What is important is to identify factors affecting negative adaptation and to find the way to mitigate the negative effect caused by the negative adaptation.

Various psychological factors relate to negative adaptation. Trust to the safety system is one of the most important psychological factors affecting the negative adaptation. Over-trust may lead to misuse and distrust may lead to disuse[5]. Both of them impair safety. Misuse refers to the problems that occur when people rely on the system and use it inappropriately. Disuse refers to the problem that occurs when people reject to use the system.

Trust is affected by false and missing alarms. Among the studies conducted on the trust and false and missing alarms, some studies have indicated false and missing alarms of safety systems lead delay of response to alarms due to over-trust[6]: however, there is few studies focused on the relation between false and missing alarms of safety systems and risk-taking behavior. This study investigates the influence of false and missing alarms of safety system on drivers' risk-taking behavior by laboratory experiments.

The purpose this study was to investigate the influence of false and missing alarms of safety system on drivers' risk-taking behavior. We conduct two experiments.

2 Experiment 1

2.1 Procedure

Participants Eleven people (six male, six female) participated in the study; they had the mean age of 20.64 years and the mean driving experience of 1.55 years. Ethical permission was granted by the Department of Psychology at the Rikkyo University. All participants were aware of their right to withdraw from the study at any time and had a full debriefing about the aims of the study.

Equipment We collected data using the experiment software (developed with Microsoft Visual Basic 2005). Experiment software was installed to the PC (Dell XPS720) and controlled with a USB device (Microsoft Side Winder Joystick) connected to the PC. Output was displayed on the monitor (Dell SE197FPS) at 1024 × 768 pix.

Task The task was to move a vehicle from below to top through an intersection displayed on the PC monitor without colliding with crossing traffic (Fig. 1). Participants moved the joystick to the left or right to “look” at approaching traffic, otherwise crossing traffic could not be visible. Participants performed the task under different experimental conditions with different types of system failure: (1) no failure, (2) false alarm, (3) missing alarm, and (4) no information.

The following illustrates the system providing information an approaching traffic. The system has four lights indicating the existence of traffic on four traffic lanes as shown on the monitor. If the system detects an approaching vehicle as far as two vehicle lights out of the visible range from the intersection.

The experimental task consisted of four "blocks". It took about one hour to go through one block per person. Intervals between blocks were more than two hours. One block consisted of four sessions. Participants go through "no information" condition in Block 1, them "no failure" condition. The order of "false alarm" and "missing alarm" condition was counter balanced (Table 1). One block consisted of four sessions. In each block, the first session was a pilot session. One session consisted of six sections. Participants took two minutes' rest between sessions. The speed of approaching vehicle and its number in one section is as shown in Table 2.

In each experimental condition, "events" occurred three times (Fig. 2). In "no information", "no failure" and "missing alarm" conditions, one vehicle approached the intersection on each traffic lane and its speed was selected from 16, 17 or 18 pix/100 msec. In missing alarm condition, light did not turn on during the event. In "false alarm" condition, the information was provided at the same timing as if a vehicle was approaching at the speed selected from the same range under other conditions as referred in Table 3.

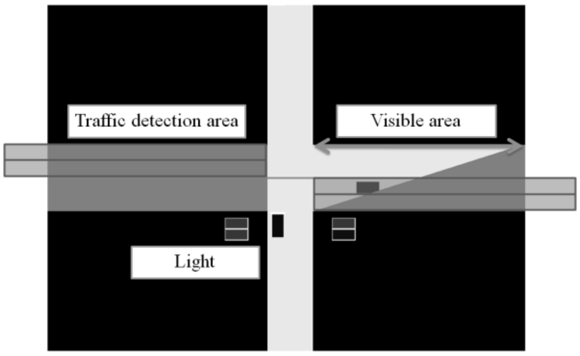

Fig. 1. Experimental task: Participants can "look" left or right with a joystick

Table 1. Experimental design.

Block 1				Block 2				Block 3				Block 4			
No information				No failure				False/missing alarm				False/missing alarm			
trial	S1	S2	S3	trial	S1	S2	S3	trial	S1	S2	S3	trial	S1	S2	S3

Table 2. Speed of approaching vehicle and its number on each traffic lane on one section.

Speed (pix/100msec)	Number
16	2
17	2
18	2
31	1
32	1

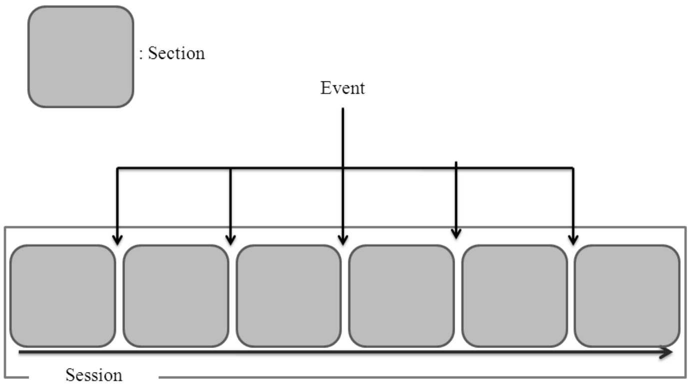

Fig. 2. Events occur in three out of five randomly selected intervals between sections.

Table 3. State of vehicle and information in event of:

	Vehicle	Information
No information	Approaching	None
No failure	Approaching	Provided
False alarm	No	Provided
Missing alarm	Approaching	Provided

2.2 Results

Effect of Types of System Failure Analysis of variance (ANOVA) was conducted to examine the effects of different types of system failure on risk-taking behavior. Dependent variables were number of intersection crossings in one block, number of looking left or right per crossing and number of collisions in one block. Number of intersection crossings "in one block" means the total number of intersection crossings in three sessions except the trial session in each experimental condition. Number of collisions in one block was calculated in the same way. The results indicated that the main effect of the types of system failure on the number of intersection crossings was significant ($F(3,30) = 8.10$, $p < 0.01$). The LSD multiple comparison indicated that the number of intersection crossings in no failure, missing alarm and false alarm conditions was significantly more than that in no information condition (Fig. 3). The results showed that the main effect of the types of system failure on the number of looking left or right was significant ($F(3,30) = 8.02$, $p < 0.01$). The LSD multiple comparison indicated that the number of looking left or right in no failure, missing alarm and false alarm conditions was significantly fewer than that in no information condition (Fig. 4). The results showed that the main effect of the types of system failure on the number of collision was significant ($F(3,30) = 26.80$, $p < 0.01$). The LSD multiple comparison indicated that the number of collision in no failure, missing alarm and false alarm conditions was less than that in no information condition. The number of collision in missing alarm was significantly more than that in no failure condition (Fig. 5).

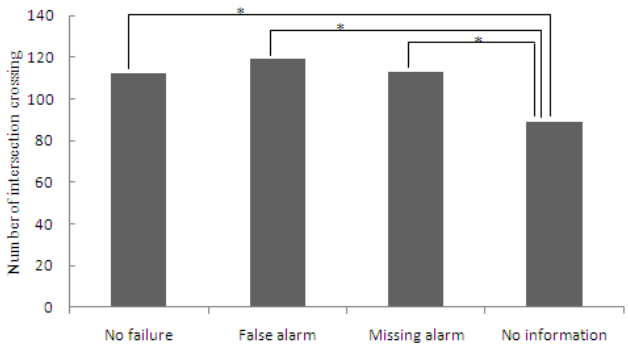

Fig. 3. Number of intersection crossings in one block (*: $p<.05$).

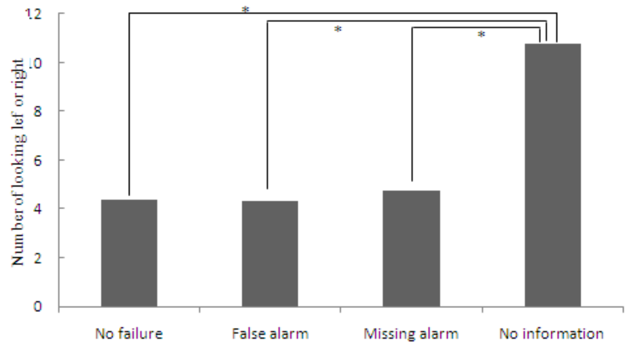

Fig. 4. Number of looking left or right per crossing (*: p<.05).

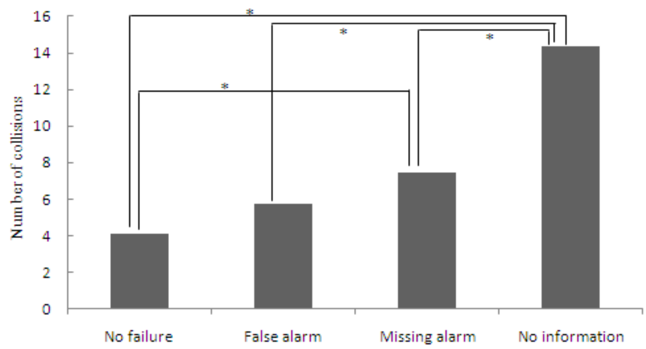

Fig. 5. Number of collisions in one block (*: p<.05).

2.3 Discussion

Effect of Types of System Failure The purpose of this experiment is to investigate the effect of the system failure on the risk taking behavior. As shown above, the effect of system failure on risk-taking behavior was not seen. There was a difference in the number of intersection crossings and looking left or right between no information condition and other conditions, but not false alarm and missing alarm conditions. This is because of the lack of the frequencies of false and missing alarms and could not affect on behaviors. Participants evaluated that the frequencies of system failure was low (false alarm: M = 1.73, missing alarm: M = 1.73, five-scale questions).

The result showed that participants collided more in the missing alarm condition than in the no-failure condition. However, the collisions occurred due to missing alarms was few (twice among all participants). In addition, there were no differences in the number of looking left or right and the number of intersection crossings among conditions. This result may indicate that participants were confused by missing alarm, and could not judge the timing to cross the intersection. The difference of the effect among types of system failures may be seen if relative frequency of missing or false alarms was higher.

We conducted Experiment 2. The difference between Experiment 1 (E1) and Experiment 2 (E2) was the frequency of false or missing alarms: erroneous alarms occurred twice as many in E2 as E1.

3 Experiment 2

3.1 Procedure

Participants. Sixteen people (three male, thirteen female) participated in the study; they had a mean age of 22.25 years and mean driving experience of 2.93 years. Ethical permission was granted by the Department of Psychology at the Rikkyo University. All participants were aware of their right to withdraw from the study at any time and had a full debriefing about the aims of the study.

Equipment and Task In E2, the same equipment and task was used. The difference between Experiment 1 (E1) and Experiment 2 (E2) was the frequency of false or missing alarms: erroneous alarms occurred twice as many in E2 as in E1. Events occur in 6-7 out of eleven randomly selected intervals between sections, with the first interval always having the event.

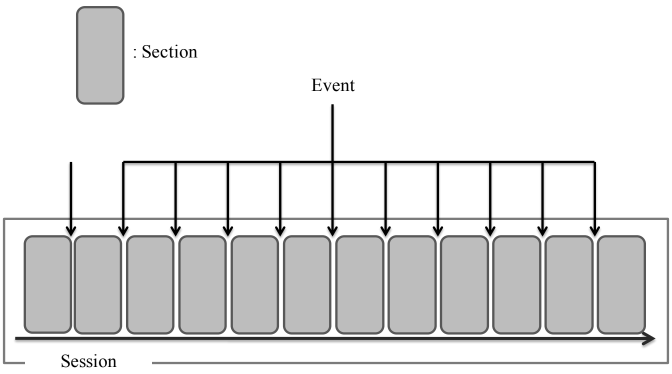

Fig. 6 Event occurs in 6-7 out of eleven randomly selected intervals between sections, with the first intervals always having the event.

Table 4. Speed of approaching vehicle and its number on each traffic lane in one section.

Speed (pix/100msec)	Number
16	2
17	2
18	2
31	1

3.2 Results

Effect of Types of System Failure Analysis of variance (ANOVA) was conducted to examine the effects of different types of system failure on risk-taking behavior. The results showed that the main effect of the types of system failure on the number of intersection crossings was significant ($F(3,45) = 12.09$, $p < 0.01$). The LSD multiple comparison indicated that the number of intersection crossings in no information condition was significantly fewer than that in no failure condition, missing alarm and false alarms conditions, and that the number of intersection crossings in missing alarm condition was significantly fewer than that in false alarm condition (Fig. 7). The results showed that the main effect of the types of system failure on the number of looking left or right was significant ($F(3,30) = 8.50$, $p < 0.01$). The LSD multiple comparison indicated that the number of looking left or right in no failure, missing alarm and false alarms conditions was significantly fewer than that in no information condition (Fig. 8). The results showed that the main effect of the types of system failure on the number of collision was significant ($F(3,30) = 28.49$, $p < 0.01$). The LSD multiple comparison indicates that the number of collision in no failure, missing alarm and false alarms conditions was significantly less than that in no information condition. The number of collision in missing alarm was more than that in no failure condition (Fig. 9).

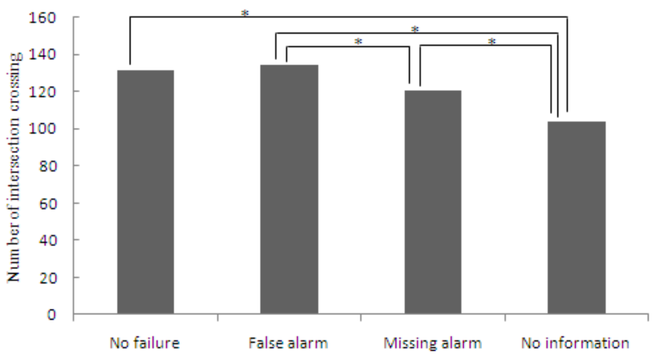

Fig. 7. The number of intersection crossings in one block (*: p<.05).

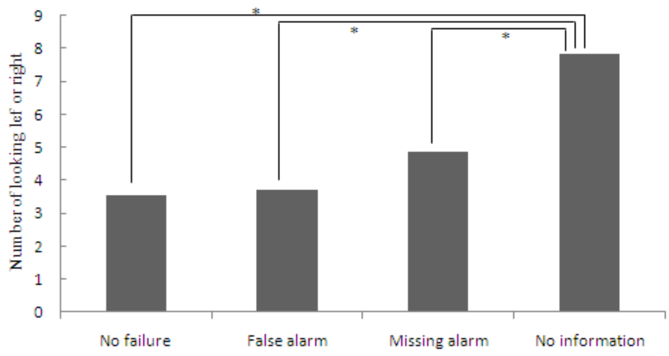

Fig. 8. The number of looking left or right per crossing (*: p<.05).

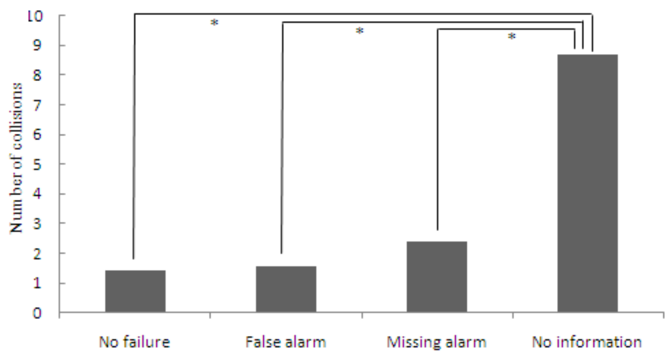

Fig. 9. The number of collisions in one block (*: p<.05).

3.3 Discussion

The result indicated that missing alarm affected risk-taking behavior. In the no-failure condition and false-alarm and missing-alarm conditions, drivers attempted to cross more than in no-information condition. In the missing-alarm condition, drivers attempted to cross more than in false condition. These results suggest that missing alarm possibly suppress the risk-taking behavior. However, there was no difference in the number of collisions between false alarm and missing alarm conditions. This result does not mean that missing alarm is safer than false alarm.

4 General discussion

We conducted two experiments to examine the effect of system failure on risk-taking behavior. The result of E1 did not show the difference under the effect of type of system failure on risk taking behavior. The result of E2 indicated that missing alarm affected risk-taking behavior. The differences of the result between E1 and E2 indicated that the different frequencies of missing and false alarms have a different effect on risk-taking behavior.

Although this study demonstrated the difference of effect of the type of system failure on risk-taking behavior, we need the following further researches.

We need to investigate a long-term effect of system failure. For examples, risk-taking behavior will increase longitudinally even if drivers use the systems effectively when system failures rarely occur. We need to conduct the experiment on conditions that missing and false alarms occur in various frequencies. We also need to investigate the case that has both missing and false alarms occur in one block. In reality, one driver may experience several types of system failures.

Understanding the relationship between types of system failure, its frequencies and behavioral changes may make it possible to help system design (e.g., the criteria for deciding tolerable frequencies of system failures).

References

1. OECD, Behavioural adaptations to changes in the road transport system: report / prepared by an OECD scientific expert group. Paris, Washington, D.C.: Organisation for Economic Co-Operation and Development, Paris (1990)
2. Stanton, N.A., Pinto M.: Behavioural compensation by drivers of a simulator when using a vision enhancement system. Ergonomics, 43, 1359--1370 (2000)
3. Hoedemaeker, M., Brookhuis, K.A.: Behavioral adaptation to driving with an adaptive cruise control (ACC). Transportation Research Part F: Traffic Psychology and Behaviour, 1, 95--106 (1998)
4. Rudin-Brown, C.M., Parker, H.A.: Behavioural adaptation to adaptive cruise control (ACC): Implications for preventive strategies. Transportation Research Part F: Traffic Psychology and Behaviour, 7, 59--76 (2004)
5. Lee, J.D., See, K.A.: Trust in Automation: Designing for Appropriate Reliance. Human Factors, 46, 50-80 (2004)
6. Abe, G., Richardson, J.: The influence of alarm timing on driver response to collision warning systems following system failure. Behaviour & Information Technology, 25, 443--452 (2006)