

# The Evaluation about a Sense of Speed, Danger, and Being Disturbed for Road Marking on Expressway

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The risk of traffic accident is high in the curve section of Expressway. A road marking is used to arouse attention and deceleration to drivers. They were reported that a deceleration mark has an effect on a speed reduction, and a sense of speed changes in accordance with an installation interval. A colored pavement is used giving a sense of danger utilizing the effect of color. However, there are no case to verify the effect of combining road markings with "a sense of danger" and "a sense of being disturbed" of drivers. There, we clarified the relationship between the constituents of the road marking and the driver's senses. We selected three deceleration marks, as "Dot line", "Arrow" and "Optical dot", and three pavements, as "Standard", "Red colored" and "Red stripe". These are main road markings used on Japanese expressway. Experiment participants answered three senses, as "A sense of speed", "A sense of danger" and "A sense of being disturbed", after a driving simulator test. As the result of analysis, we got the following knowledge, such as 'There are no interaction for any sense in combination between deceleration marks and colored pavements', 'Arranging large deceleration marks in the center on a lane increases a sense of speed', 'Arranging small deceleration marks in the center on a lane increases a sense of being disturbed' and 'Red colored pavement and red stripe greatly affect an amplification of a sense of danger'. Finally, based on these knowledges, we designed a road marking pattern.

**Keywords:** *drive simulator; traffic safety; template; sensory evaluation experiment*

## 1 Introduction

On expressway, the occurrence probability of a traffic accident is high at the curve section. The main factor of it is "over speed". Many kinds of traffic safety measures are installed on expressway for drivers to slow down. For example, there are the direct messages to a driver, such as a draw attention sign and a letter sign on a road surface or on a guidepost. And also, a road marking, such as a colored pavement or a deceleration mark, is made indirectly use of urging safety driving. Table 1 shows major road markings made before the curve section on Japanese expressway. The road marking can be easily transmitted messages to the driver, because of occupying a large proportion of the driver's view. Furthermore, road markings without languages are important as a universal design because of appealing to the driver's senses and being able to climb over a language barrier.

The main role of the road marking is to give the driver a sense of speed and a sense of danger before the curve section. By this, drivers can reduce a speed in advance. "A sense of speed" means whether drivers got the faster sense or not for the actual speed. "A sense of danger" means whether drivers got the sense of danger or not by the road marking.

On the other hand, when a road marking gives a sense of being disturbed to a driver, it is concerned that the concentration of the driver will be inhibited. So, it has to be evaluated that whether a road marking gives "A sense of being disturbed" or not to a driver.

Several previous reports focused on "the relationship between deceleration marks and a sense of speed." However, there was no report that "a sense of being disturbed to road markings", "the relationship between elements of road markings and a sense of danger and a sense of being disturbed", and "the combination effect by elements of road markings such as the colored pavement and the deceleration mark".







It is essential to know these points in order to design a road marking that can urge the speed reduction safely and suitably, while the consideration of the psychological state of drivers.

Therefore, in this study, we clarified the relationship between elements of the road marking and a sense of speed, a sense of danger and a sense of being disturbed. The purpose of this study was to know the design method of road markings, which has not been clarified so far.

As elements of road marking in a research subject, we selected three colored pavements and three deceleration marks. These are major road markings on Japanese expressway as introduced in Table 1.

In each verification, we used a driving simulator. Furthermore, based on the experimental results, we designed the road marking as an application example.

Table 1. Traffic safety measures for speed control

	Direct message	Indirect message	
Road markings	 Text instruction	 Colored pavement	 Deceleration marks
Other	 Attention signboard	 Arrow marks on the wall	 Guide light

## 2 Review of previous studies

In this chapter, we describe the previous research about road markings to be the indirectly message and the position of this research.

On Japanese expressway, the deceleration mark, such as “Red colored pavement” and the “arrow” deceleration mark is frequently made use of expecting to slow down (Table 2).

There are some reports that the deceleration mark has an effect on the speed reduction. Studies on the effect of deceleration mark was started in the 1960 's. Denton (1966, 1971, 1976, 1977) reported that a deceleration mark has an effect on a speed reduction. Because, drivers are given the illusion of an excessive speed when they pass over the deceleration mark. In addition, he showed that a sense of speed of drivers was changed according to the installation interval of the deceleration mark by the indoor experiment using a driving simulator. HAN, TAMAKI, ONO, SASAKI, SUDA & IKEUCHI (2012) showed that oval dot marks (hereinafter referred to as “optical dot”) have an effect on the speed reduction by doing the enforcement on a real road. Kawata, Nagami, Kiyomiya & Nakagawa (2012) evaluated the effect on a speed reduction by the road markings using a driving simulator. Samples were composed “Red colored pavement” and deceleration marks of “Dot lines”. As the result, it was cleared that if easy-to-recognize figures were deployed at a short pitch, it was effective to control the speed.

“Dot line” is normally used to make keeping drivers in the center of a lane. However, a dot is recognized also as a figure by a driver. And “Dot line” also has an effect that a driver feels the lane to be narrowed. So, the “Dot line” is also expected to contribute to slow down, like the other road markings. For the above reasons, we treat also the “Dot lines” as a deceleration mark in this study.

Even the outside of Japan, deceleration marks are made use of slowing down. Andrew and Cherie (2010) introduced deceleration marks of various countries at the report of "Effectiveness of transverse road markings on reducing vehicle speeds". In this report, “Transverse road markings” are made use of increasing the driver's awareness of danger and reducing a speed. As for “Dragon teeth road markings”, the average of vehicle speed decreased by 8-14% in a result of the driving test. In Virginia, “Zig zag road (2015)” was installed to warn drivers’ approaching the intersection of walking and cycling trails. It had effect for drivers to reduce 5 miles per hour. However, these cases targeted not an expressway but a local road. Therefore, it is not clear the effect about them in driving with a high speed.

There are few reports about the colored pavement, but the colored pavement has some merits. The colored pavement increases the skid resistance of tires, give a sense of danger for drivers, and increase an attention to drivers. Aoki (2009) pointed out that the colored pavement had the effect of increasing the driver’s awareness to traffic safety. For giving a sense of danger and increasing driver's attention, the psychological effect of color is skillfully utilized in a traffic safety field. Especially, red color has the meaning of danger and the function of increasing attention. Shuto-kosoku (2019), Japanese metropolitan expressway, laid the red colored pavements to urge a driver’s attention at the curve section where cars run over-speed.

In the above, we introduced the cases of installation of deceleration marks and colored pavements, and reported about the decelerating effect. But there were very few reports that mentioned the psychological effects to the driver. YOTSUTSUJI, XING, YONEMURA, KAI, MATSUMOTO and KITA (2018) conducted experiments using the NASA-TLX evaluation

index developed by NASA, but they did not mention the detail such as mental demand or frustration.











Knowing the psychological effects is essential for identifying the factors of the effects and designing. For example, it needs to raise a sense of speed and a sense of danger to warn drivers that excessive speed may cause an accident. On the other hand, if road markings give for drivers a sense of being disturbed, it is concerned that the concentration will be inhibited. For drivers keep a safety driving, it must be able to concentrate driving without being disturbed.

However, there are no reports about a sense of being disturbed by road markings. In addition, there are no studies to examine the colored pavements increasing a sense of speed and a sense of danger while reducing a sense of being disturbed.

On actual roads, the colored pavements and the deceleration marks may be used at the same time. Nevertheless, no research has examined the combination effect of road marking patterns and colored pavements, too.

Therefore, in this study, we clarified the relationship between elements of a road marking and a sense of speed, a sense of danger and a sense of being disturbed. Elements of the road marking were three colored pavements and three deceleration marks. Furthermore, we designed a road marking pattern as an application example based on the experimental results.

Table 2. Examples of road marking

	Deceleration mark			Colored pavement	
Express-way	 Dot line	 Arrow mark	 Optical dot	 Red stripe	 Red colored
Local road	 Transverse road marking	 Dragon teeth	 Zig zag road marking (2015)	 Blue colored	 3D sign
	Andrew and Cherie (2010)				

### 3 Outline of experiment

#### 3.1 Experiment objects and simulation environments

As experiment objects, we selected three deceleration marks, as “Optical dot”, “Dot line”, and “Arrow”. And we decided three pavements, as “Standard pavement”, which is a common asphalt pavement, “Red colored pavement”, which is a completely covered red color on asphalt pavement and “Red stripe pavement”, which is on a red stripe marking on asphalt pavement. These are the typical road markings used in Japan.

Based on the road marking of a metropolitan expressway, we set the driving environment, such as section one was a standard section, section two was a deceleration introduction section (from 200 to 100 m in front of the curve), and section three was a deceleration

section (from 100 to 0 m in front of the curve). Road model had one way two lanes. This is the typical cross section on a metropolitan expressway. Experiment participants drove with 80km/h through the standard section. Then, they slowed down as needed at the curve section or before the curve section.

We arranged deceleration marks a wide pitch at the deceleration introduction section and at a narrow pitch in the deceleration section (Figure 1). We also arranged “Red stripe pavement” as same pitch as the deceleration mark and arranged “Red colored pavement” at the deceleration section. Table 3 shows the pitch and the size of three deceleration marks and three pavements in two sections. We selected the pitch referred to the case installed in Japan. We set that the 3 type deceleration marks times 3 type pavements equalled 9 types (Table 4) as the experiment objects. In addition, for the road space simulation, we used the software and hardware called UC-win / Road made by Forum 8 Co., Ltd. (Figure 2).

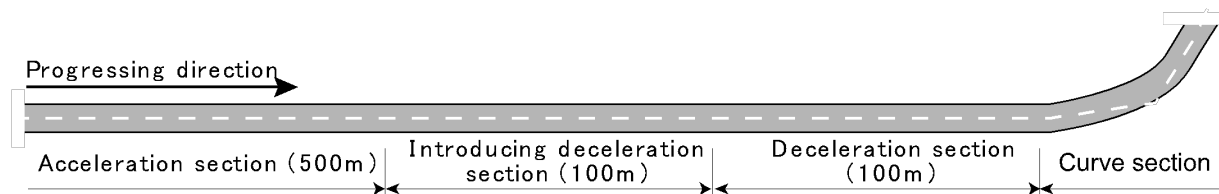


Figure 1. Road surface configuration in simulation space

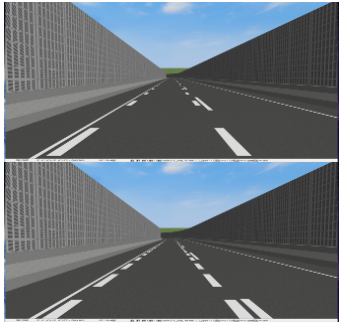
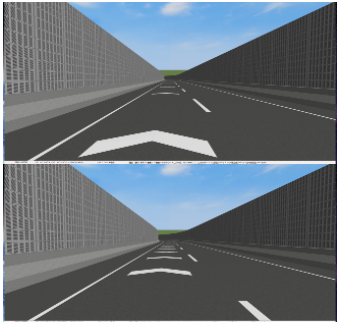
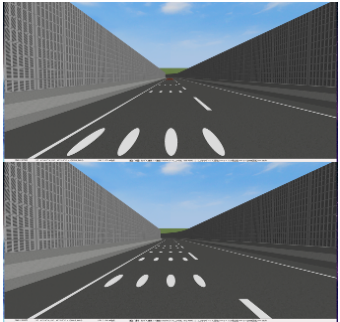
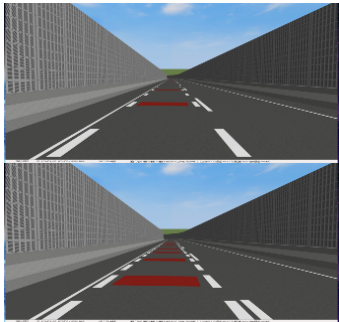
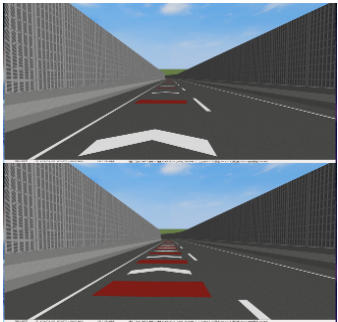
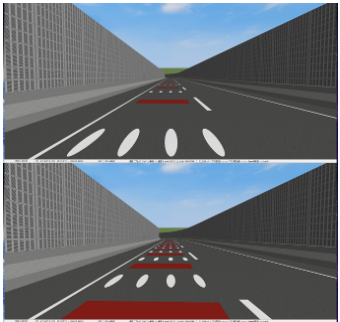
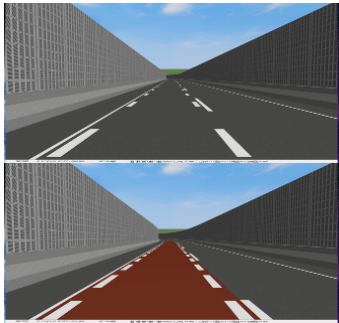

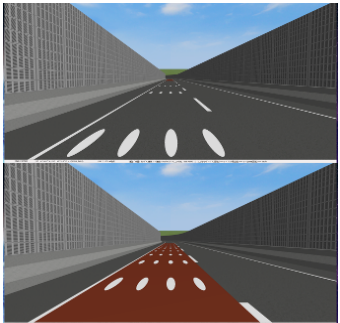
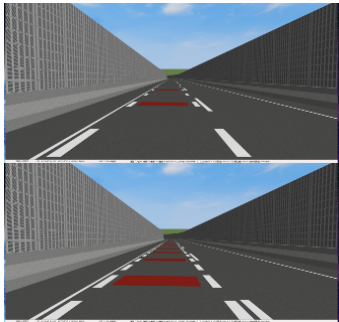
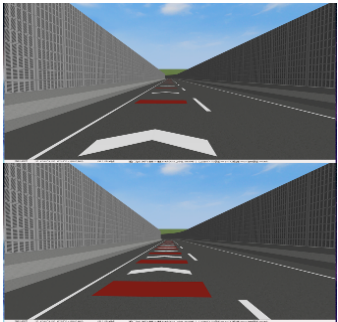
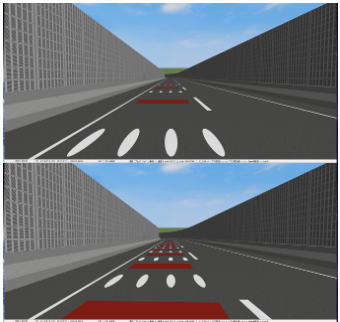
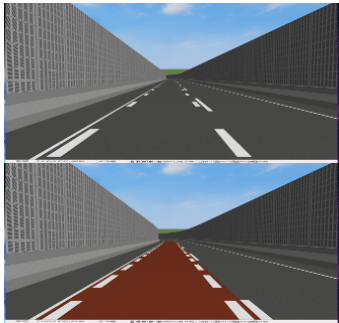

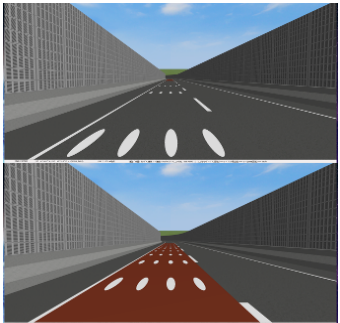
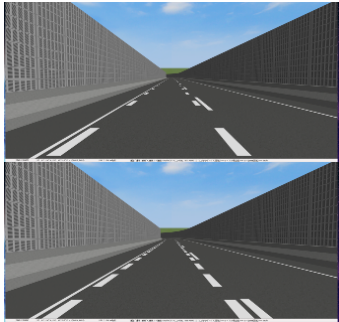
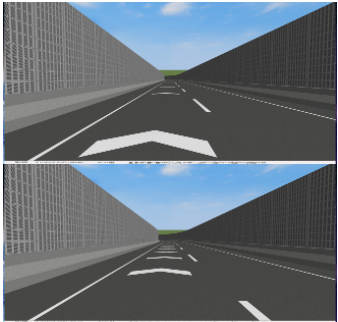
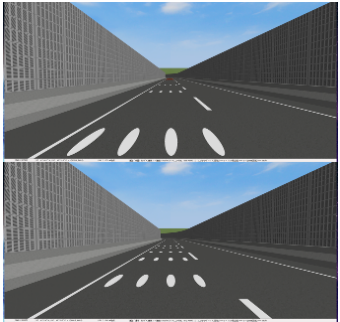
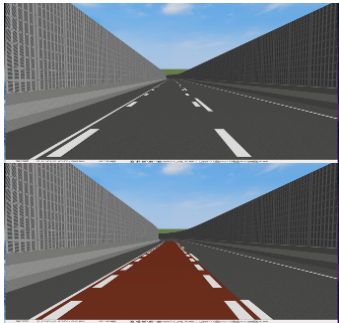

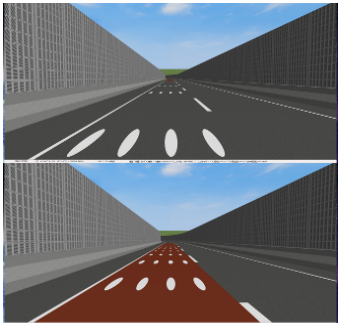
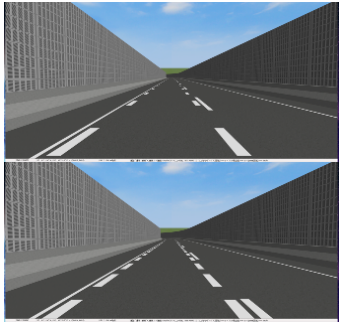
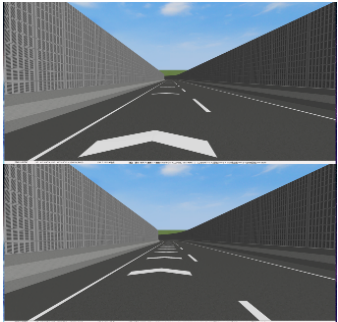
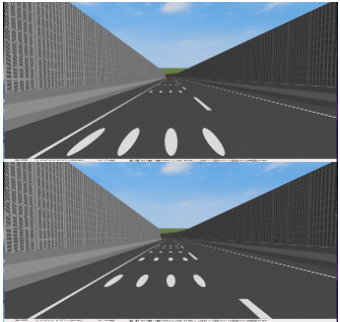
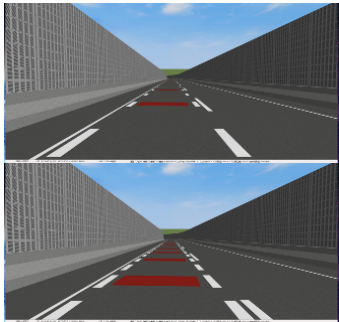
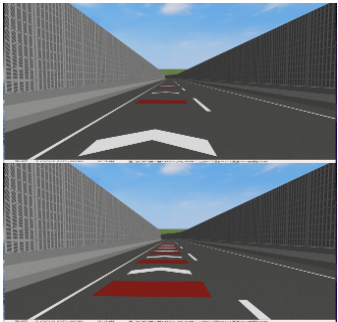
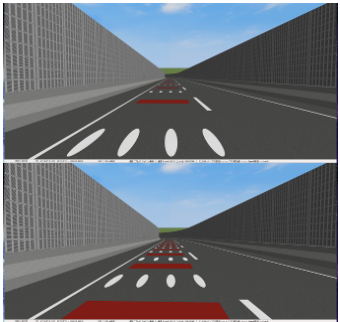
Table 3. Gap length and pattern size in each sample

		Introducing deceleration section	Decelerating section
Deceleration mark	Dot line		
	Arrow		
	Optical dot		
Road pavement	Standard		
	Red stripe		
	Red colored		



Figure 2. Experiment by driving simulator

Table 4. Experiment scene

		Deceleration mark		
		Dot line	Arrow	Optical dot
Road pavement	Standard	No.1 	No.2 	No.3 
		No.4 	No.5 	No.6 
		No.7 	No.8 	No.9 
	Red stripe	No.4 	No.5 	No.6 
		No.7 	No.8 	No.9 
		No.1 	No.2 	No.3 
	Red colored	No.7 	No.8 	No.9 
		No.1 	No.2 	No.3 
		No.4 	No.5 	No.6 

Upper image: Introducing deceleration section Lower image: Deceleration section

### 3.2 Method of experiment

The experiment participants were 20 students who were early 20's and held driver's licenses.

To nine objects, they operated the driving simulator, and after that they answered the interview-based inquiry. In other words, the trial number of operation and answer was 9 times per a participant. Before these experiments, they drove another course, in order to get used to the operation of the driving simulator. The sense evaluations in their answers were about 3 topics, such as "A sense of speed (Whether you got the faster sense or not.)", "A sense of danger (Whether you got the sense of danger or not.)" and "A sense of being disturbed (Whether you got the sense of being disturbed from road markings or not.)".

Participants answered in each of three senses by 5 levels SD method, like "I do not feel: 0 point", "I hardly feel: 1 point", "I feel a little: 2 points", "I feel: 3 points" and "I strongly feel: 4 points" (Figure 3). In addition, the experimental objects were randomly presented for each a participant.

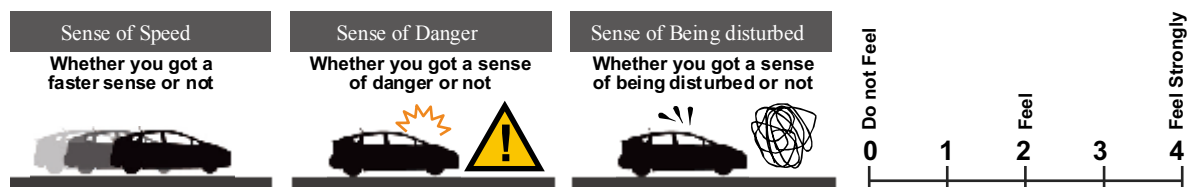


Figure 3. Evaluation items and evaluation criteria

## 4 Analysis of experiment results

We analyzed the experimental result by two-way analysis of variance (two-way ANOVA). Analysis targets are the evaluations of a sense of speed, danger and being disturbed to deceleration marks and pavements. By these analyses, we revealed the relationship between the evaluations and the elements of road marking.

### 4.1 Relationship between "a sense of speed" and elements of road marking

Table 5 shows an average and a standard deviation in 9 samples. Figure 4 shows an interaction diagram. The higher point shows that a driver feels faster. The highest score was 2.7 points, as the combination of "Red colored pavement" and "Arrow", and the lowest score was 1.5, as the combination of "Standard pavement" and "Dot line". From two-way ANOVA, we acknowledged a significantly different ( $p < .05$ ) at the main effectiveness of deceleration mark ( $F(2, 171) = 3.85$ ). We did not acknowledge a significantly different at the main effectiveness of pavement ( $F(2, 171) = .71$ ), ( $p = .50$ ) and the interaction effect between deceleration mark and pavement ( $F(4, 171) = 31.20$ ), ( $p = .31$ ). Based on a multiple comparison result (Tukey method) of main effectiveness for deceleration mark, we acknowledged a significantly different between "Arrow" and "Dot line" ( $p < .01$ ), and between "Arrow" and "Optical dot" ( $p < .1$ ), shown as Figure 5 a). Based on these results, we could indicate following points.

1. All participants similarly felt a sense of speed, because the point of a sense of speed was distributed the neighbourhood of 2.0.
2. A sense of speed with "Arrow" was larger than that with "Dot line" and "Optical dot".
3. The element of colored pavements did not affect the participant's sense of speed.

Table 5. Average and standard deviation of evaluated point about sense of speed

		Deceleration mark		
		Dot line	Arrow	Optical dot
Road pavement	Standard	1.5 (1.1)	2.3 (1.2)	2.1 (1.4)
	Red stripe	1.9 (1.0)	2.1 (1.3)	1.9 (1.1)
	Red colored	2.1 (1.4)	2.7 (1.0)	1.7 (1.2)

( ): standard deviation

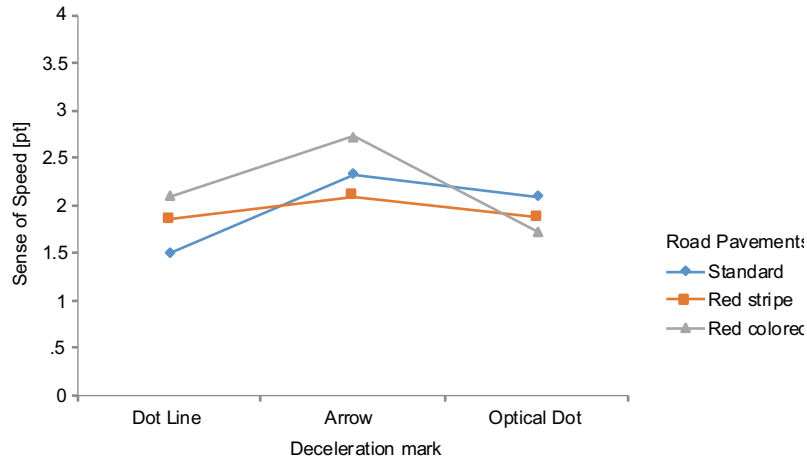


Figure 4. Interaction diagram about sense of speed

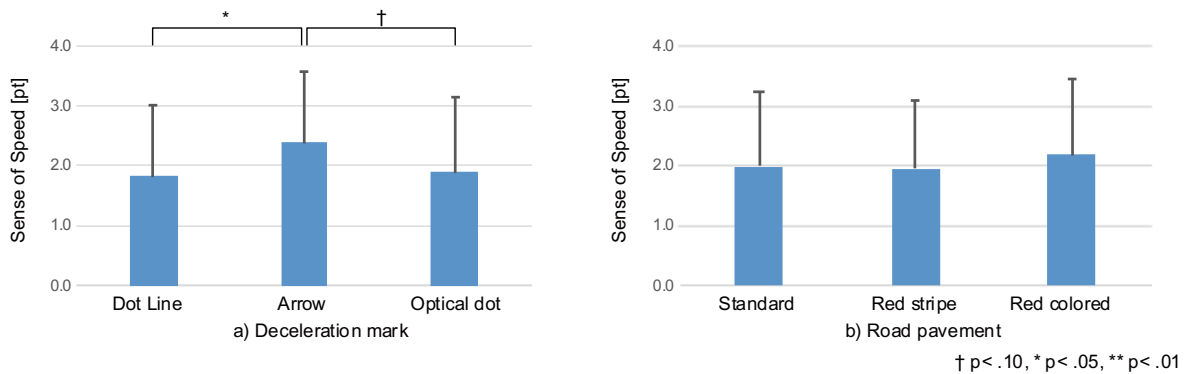


Figure 5. Main effect about sense of speed (Average and standard deviation of each level)

#### 4.2 Relationship between “a sense of danger” and elements of road marking

Table 6 shows an average and a standard deviation in 9 samples. Figure 6 shows an interaction diagram. The higher point shows that a driver feels more dangerous. The highest score was 2.4 points, as the all combination with “Red stripe pavement”, and the lowest was .3 points, as the combination of “Standard pavement” and “Dot line”. From two-way ANOVA, we did not acknowledge a significantly different ( $F(2,171) = 1.83, p = .17$ ) at the main effectiveness of pattern. We acknowledged a significantly different at the main effectiveness of pavement ( $F(2, 171) = 36.26, p < .01$ ). We did not acknowledge a significantly different at the interaction effect between deceleration marks and “Red colored pavement” ( $F(4, 171) = .43, p = .79$ ). Based on a multiple comparison result (Tukey method) of main effectiveness for deceleration mark, we acknowledged a significantly different between “Standard pavement” and “Red stripe pavement”, and between “Standard pavement” and “Red colored pavement”, shown as Table 6 and Figure 7 b). We acknowledged a significantly different between “Standard pavement” and “Red colored pavement” ( $p < .1$ ), and between “Standard pavement” and “Red stripe pavement” ( $p < .01$ ), shown as Figure 7 b). Based on these results, we could indicate following points.



1. The element of deceleration mark affected small to the sense of danger.
2. The sense of danger with “Standard pavement” was smaller than that with “Red colored pavement” and “Red stripe pavement”.
3. It could not be confirmed the combination effect of “Arrow” and colored pavements.

Table 6. Average and standard deviation evaluated point about sense of danger

		Deceleration mark		
		Dot line	Arrow	Optical dot
Road pavement	Standard	.3 (.5)	1.0 (1.2)	.6 (.9)
	Red stripe	2.4 (1.0)	2.4 (1.1)	2.4 (1.3)
	Red colored	1.7 (1.4)	2.2 (1.3)	2.1 (1.5)

( ): standard deviation

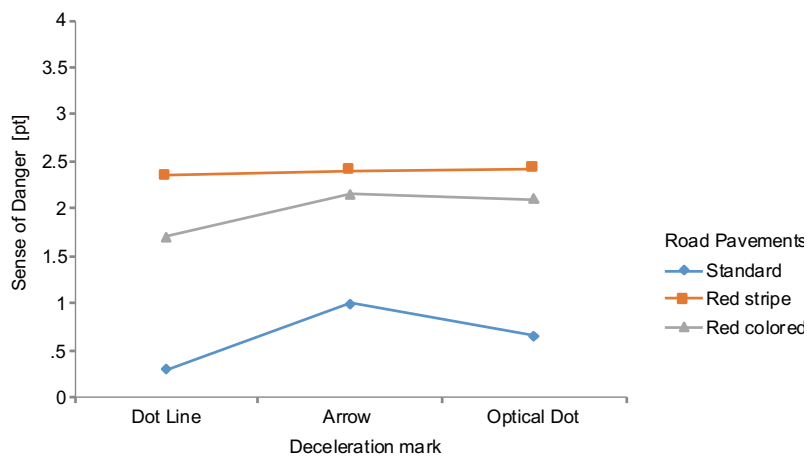


Figure 6. Interaction diagram about sense of danger

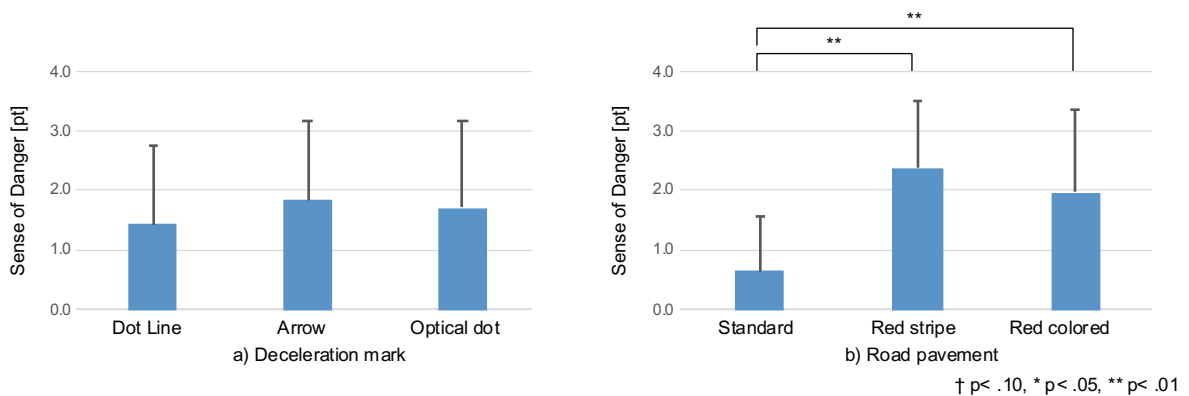


Figure 7. Main effect about sense of danger (Average and standard deviation of each level)

### 4.3 Relationship between “a sense of being disturbed” and elements of road marking

Table 7 shows an average and a standard deviation in 9 objects. Figure 8 shows an interaction diagram. The higher point shows for a driver to feel more being disturbed. The highest score was 3.3 points for the combination of “Red stripe pavement” and “Optical dot”, and the lowest was 0.5 points for the combination of “Standard pavement” and “Dot line”.

From two-way ANOVA, we acknowledged a significantly different at the main effectiveness of deceleration mark ( $F(2,171) = 18.62, p < .01$ ) and the main effectiveness of pavement ( $F(2,171) = 23.31, p < .01$ ). We did not acknowledge a significantly different at the interaction effect between deceleration marks and “Red colored pavement” ( $F(4,171) = .51, p = .73$ ). Based on a multiple comparison result (Tukey method) of main effectiveness for deceleration marks, we acknowledged a significantly different between “Dot line” and “Optical dot”, and between “Arrow” and “Optical dot”, shown as Figure 9 a). We acknowledged a significantly different between “Standard pavement” and “Red colored pavement” ( $p < .1$ ), and between “Standard pavement” and “Red stripe pavement” ( $p < .01$ ), shown as Figure 9 b). Based on these results, we could indicate following points.

1. The participant felt that “Optical dot” was more disturbed than “Arrow” and “Dot line”.
2. The participant felt that “Red stripe pavement” was most disturbed, and “Red colored pavement” was more disturbed than “Standard pavement”.

Table 7. Average and standard deviation of evaluated point about sense of being disturbed

		Deceleration mark		
		Dot line	Arrow	Optical dot
Road pavement	Standard	.5 (1.1)	.9 (1.2)	1.5 (1.2)
	Red stripe	1.9 (1.3)	2.2 (1.2)	3.3 (.9)
	Red colored	1.3 (1.4)	1.8 (1.3)	2.9 (1.2)

( ): standard deviation

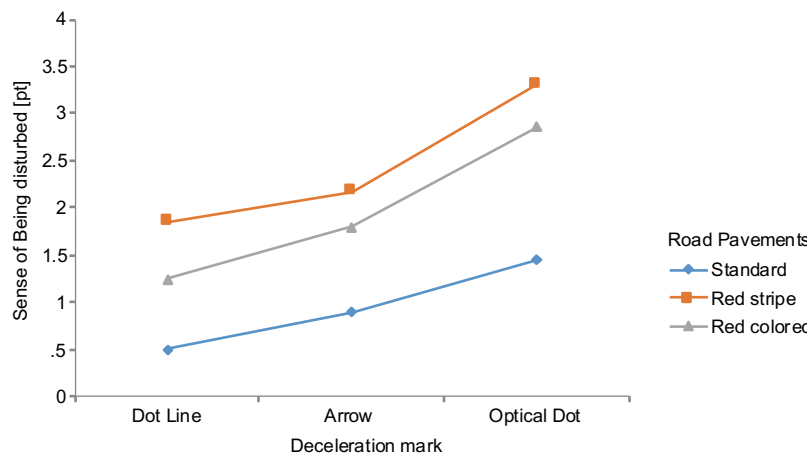
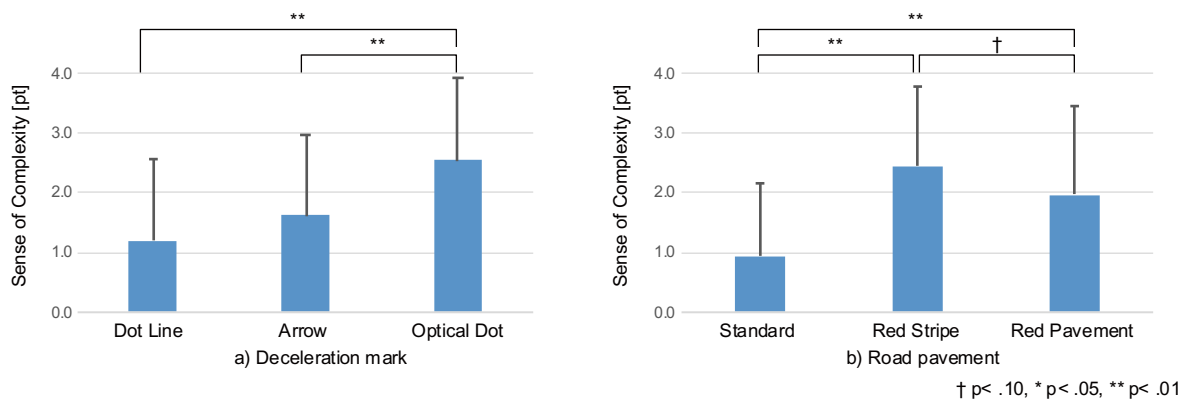


Figure 8. Interaction diagram about sense of being disturbed



†  $p < .10$ , \*  $p < .05$ , \*\*  $p < .01$

Figure 9. Main effect about sense of being disturbed (Average and standard deviation of each level)

## 5 Conclusions

In this study, we evaluated a sense of speed, a sense of danger and a sense of being disturbed given by the elements of road marking using the driving simulator, and we investigated the relationship between senses and elements. Its purpose was for us to accomplish the guideline of designing the road marking.

### 5.1 Conclusion and future issues

In below, we summarized the major knowledges about the road marking got in this study, divided into a deceleration mark and a pavement.

#### Deceleration mark

1. Similar to previous studies, a sense of speed became higher by the arrangement of deceleration mark. Especially, the center arrangement of a big pattern, like "Arrow", made a sense of speed higher.
2. Drivers evaluated that "Optical dot" made a noticeable sense of being disturbed, compared to "Arrow" and "Dot line".
3. It was small that the difference between senses of danger occurred by deceleration marks. We considered that it was caused by the center arrangement of many small marks on a lane.

Based on the mention above, we concluded as follows. In the case of being willing to increase a sense of speed of a driver, it is effective to arrange the big deceleration mark on a center of a lane. On the other hand, if aiming to reduce a sense of being disturbed of drivers, it is not better to arrange the many of small marks on a center of a lane.

#### Pavement

1. About a sense of speed, we did not confirm the significant difference between "Red stripe pavement" and "Standard pavement", and between "Red stripe pavement" and "Red colored pavement". So, we considered that a pitch of red stripes did not affect the change of a sense of speed in the case of being small contrast of brightness between the figure as a colored pavement and the ground as a standard pavement.
2. Participants felt the strongest disturbance by "Red stripe pavement".
3. About a sense of danger, "Red stripe pavement" and "Red colored pavement" were a significantly higher point than "Standard pavement". Based on this, we confirmed that the meaning of red color had an advantage in drawing attention for a danger, similar with knowledge so far. However, "Red stripe pavement" made a sense of being disturbed. So, on using the red color for pavement, it is important for the red color to carefully select only the appropriate locations.

#### Relationship between deceleration mark and pavement

It was cleared that the deceleration mark and the colored pavement gave an impression to the driver independently. Because, from the experiment results, we could not confirm the interaction, that is, a synergetic effect, between a sense of speed, a sense of danger and a sense of being disturbed.


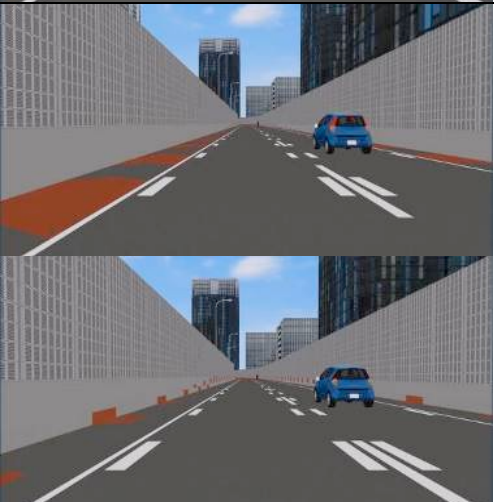
#### Task from now on




In this study, we evaluated only the road marking. However, Oguchi, Nigorisawa, Konuma & Shikata (2005) reported that the marking pattern on the wall surface affected a sense of speed. So, it also needs to verify the effects for other visual elements, like the traffic sign or the marking pattern on the wall surface, assuming the actual road space. In addition, in order to control a sense of speed by the deceleration mark, it is necessary to clarify other arrangement methods and the contrast value of brightness between the pavement at appropriate section and the figure. According to colored pavements, it is also necessary for us to evaluate a sense of danger and a sense of being disturbed by other colors. On the other hand, to make the verification results more credible, we consider (think) that above experiments will need (have to) target not only 20's experiment participants but also the other age.

## 5.2 Design example applied by this result

Finally, based on the experiment result and the discussion, Table 8 shows the design example of a road marking for the purpose of the speed reduction and the drawing attention at a curve section. The road marking pattern on a center of a lane raised not only an effective sense of speed but a sense of being disturbed. Then we propose the better design that the "Dot line" is arranged on a road surface at the introducing deceleration section, and moreover the "Red stripe pavement" is arranged from a road shoulder to a wall surface in former purpose. This proposal is used "Red colored pavement" during the curve section in order to raise a sense of danger. We expect this proposal to be able to improve a sense of speed and a sense of danger without a sense of being disturbed.

Table 8. An example of road marking design

Design point	Image
<p><b>Standard section</b></p>	
<p><b>Introducing deceleration section</b>            "Dot line" in the lane and "Red stripe pavement" at the road shoulder make a driver to raise a sense of speed.            To reduce a driver's sense of being disturbed not to arrange a pattern on a center of lane.            "Red stripes" at road shoulder move to a wall surface gradually.</p>	

<p><b>Deceleration section</b>  “Dot line” and “Red arrow” on the wall make a driver’s sense of speed raise more.</p>	
<p><b>Curve section</b>  “Red colored pavement” makes a driver’s sense of danger rise.</p>	
<p><b>Standard section</b></p>	

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