Poles for Increasing the Sensibility of Vertical Gradient in a Downhill Road

Shunsuke Kakumori[1], Atsushi Osa[2], Ken Matsuda[3],Hidetoshi Miike[4]

[1] Graduate School of Science and Engineering, Yamaguchi University 2-16-1 Tokiwadai,Ube 755-8611, Japan r007vm@yamaguchi-u.ac.jp

[2] Graduate School of Science and Engineering, Yamaguchi University 2-16-1 Tokiwadai,Ube 755-8611, Japan osaa@yamaguchi-u.ac.jp

[3] Graduate School of Science and Engineering, Yamaguchi University 2-16-1 Tokiwadai,Ube 755-8611, Japan matsuken@yamaguchi-u.ac.jp

[4] Graduate School of Science and Engineering, Yamaguchi University 2-16-1 Tokiwadai,Ube 755-8611, Japan miike@yamaguchi-u.ac.jp

ABSTRACT

Excessive speed is one of major causes of traffic accidents, and it leads to traffic fatality with high probability. In a previous study, it has reported that drivers tend to perceive that the load they travel was horizontal, although they travel on a downhill road. If drivers perceive true vertical gradient more sensitively, we expect that the drivers reduce their car speed on the downhill road. The study also said that road poles on both sides of the road were useful to perceive vertical gradient of the road. The purpose of this study is to find the best way of the pole's form and formation. In experiments, we used a video simulator that can be rendered in real-time computer graphics (CG). Through three experiments, the pole tilted 60 deg to frontward direction, 1.7 or 2.0 m length, was the most effective for perception of vertical gradient of the downhill road.

Keywords

Road pole, Visual illusion, Excessive speed, Driving simulator

INTRODUCTION

Current Car Accidents

Have you experienced to misperceive a gradient in downhill roads? Have you experienced to drive a car faster speed than that you recognized on the downhill road?

According to a report about traffic accidents by the metropolitan police department in Japan, the number of traffic accidents in 2009 was 736,688, the number of the injured was 915,092, the number of the deaths was 4,914 [1] .

When cars are driven by high speed, the probability of fatal accident becomes very high. The rates of deaths in car accidents at vehicle speeds under 50 km/h, over 50km/h, over 80km/h were 0.4%, 5.1%, and 28.3% [2], respectively. The rate of deaths when cars were driven over 80 km/h speed becomes 49.7 times of the cases when cars were driven under 80 km/h speed. Reducing car speed leads to decrease fatal car accidents.

The *Obake-zaka*

Drivers tend to perceive that the load they travel was horizontal, although they travel on a downhill road. This phenomenon is well known as '*Obake-zaka*' in Japan. This is a kind of visual illusion. For example, a car is going a downward road like Figure 1. The gradient of road changes slightly at a location on the road. In this situation, drivers tend to see an illusionary upslope like Figure 2 [3].

If drivers perceive true vertical gradient more sensitively, we expect that the drivers reduce their car speed on the road. It is important that drivers can judge the gradient correctly.

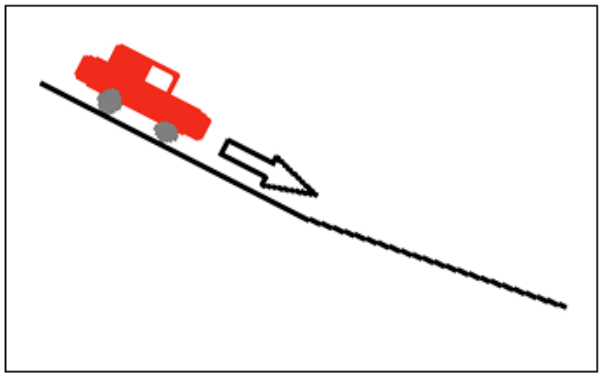


Figure1. Real gradient change in a road

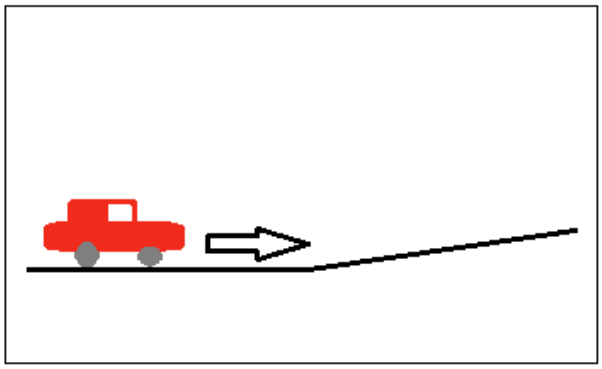


Figure2. Illusory perceived gradient change in a load

Previous Study and Our Purpose

In a previous research [4], our research group reported that road poles on both sides of the road were useful to perceive vertical gradient of the road. In the experiments,

we created a driving simulator that represented the *Obake-zaka* with road poles. We tried to install the poles in the following 4 patterns.

1. Nothing. (no-P.)
2. Poles with the same height. (same-P.)
3. Poles with gradually increasing height from near to far. (inc.-P)
4. Poles with gradually increasing height which has 2 cycles in the downhill road, which seems a staircase. (staircase-P)

14 participants observed the simulator, and judged whether the road is a horizontal road or a downhill. The gradient of the road was selected from 0 to 5%. The participants could judge downward gradient with high probability when the downward was high gradient. In the case of no-P, the 50% level of the probability was reported at 2.5% gradient. In the cases of same-P, inc.-P, and staircase-P, the 50% levels of the probability were 2.1, 2.0, and 1.5 % gradients, respectively.

The previous study is not enough to research the effect of road poles. The purpose of this study is to find the best way of the pole's form and formation.

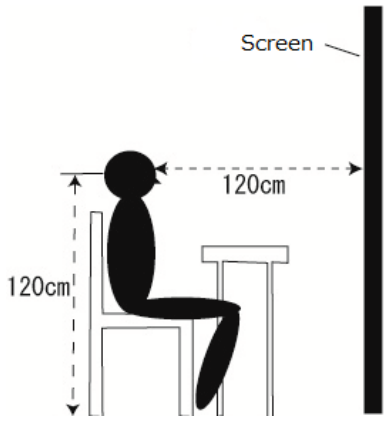
EXPERIMENT 1

Purpose of the Experiment

We conducted Experiment 1 for confirmation of the previous study [4], and for revealing effects of the order of observing stimuli.

Experimental Apparatus and Environment

An image sequence of driving simulator generated by a personal computer was projected on a screen. Figure 3 shows the experimental environment. The height of participant's eyes was adjusted to 120 cm which matches the center of the projected image. The participants were directed to gaze the center of the image. The image aspect ratio was 9:16. The projected size was 63 × 112 cm^2.



Fighre3. Experimental environment

Setting the Video Simulator

The simulation image was rendered by using open-GL (see Figure 4). The width of one road lane was 3.25m. The regulation speed was 60 km/h [5], however, the car speed of the simulator was adjusted to 80 km/h which was assumed an excessive speed. The total distance of the road was 290m. The simulator started a horizontal road for 35 m distance, and the road became a gentle downward gradient (7% gradient) to 80 m distance (see Figure 5). Then, the road from 115 m to 175 m was selected form 6 types of gradient (0~5%). We call this section as the test section. Two white lines were drawn at the start point and the end point of the test section. From 245 m to the finish, the road was horizontal. Therefore, the road from 80 m to 115 m, and the road from 175 m to 245 m were generated automatically in order to connect the gradient of the roads. Because the previous study showed that the probability to detect downward was almost 100% in 4~6% gradient downward, we used 0~5% as gradient variation. The sight around the road was a kind of hill in order to avoid information of road gradient.

Road poles were installed in the test section, from 85 m to 175 m distance. 10 poles lined up on each side of the road at intervals of 6 m. The pole diameter was 7cm, and the color was vivid yellow.

Figure4. Snapshot of the driving simulator

Patterns of Pole Installation

The patterns of pole installation were the following 6 types, of which 4 types were the same as the previous study [4], and two types were added in Experiment 1.

1. Nothing. (no-P.) (Figure 6)
2. Poles with the same height, 2 m. (same-P.) (Figure 7)
3. Poles with gradually increasing height from near to far. The shortest was 20 cm height; the longest was 2 m height. (inc.-P) (Figure 8)
4. Poles with gradually increasing height which has 2 cycles in the test section, which seems a staircase. The shortest was 20 cm height; the longest was 2 m height. (staircase-P) (Figure 9)
5. Poles with gradually decreasing height from near to far. The longest was 2 m height; the shortest was 20 cm height. (dec.-P) (Figure 10)
6. Poles tilted 60 degrees to frontward direction. The height was 2 m constant. (tilt-P) (Figure 11)

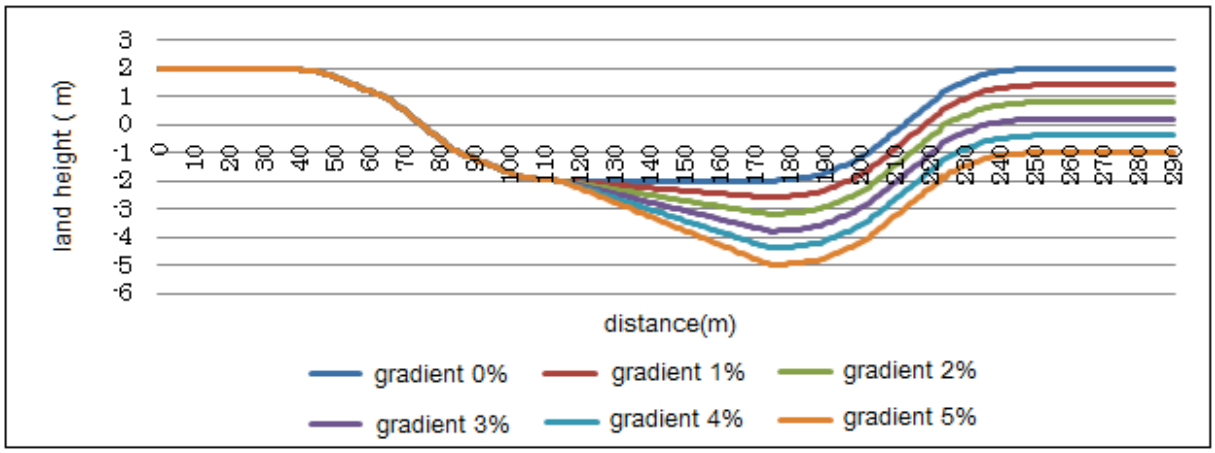


Figure5. Road alignment in the simulator

Participants

18 undergraduate and graduate students took part in this experiment as observers (aged 20-24 years). All participants used to drive a car, and had normal or corrected-to-normal vision.

Procedures

Poles installation conditions were 6 patterns as described before (Figure 6~11). Downward gradient conditions of the test section were 6 types, 0% (horizontal condition), 1, 2, 3, 4, and 5 %(gradient condition). We created 36 (6 x 6) video images totally for the driving simulator. One stimulus was shown for 13 seconds. 9 participants observed in the sequence of no-P, same-P, inc.-P, dec.-P, staircase-P, and tilt-P (Order 1). Remaining 9 participants observed in the sequence of tilt-P, staircase-P, dec.-P, inc.-P, same-P, no-P (Order 2). In each poles condition, participants observed a downhill road randomly selected from 6 types of gradient, and judged whether the road in the test section was downward or not. They answered the question verbally just after going through the second white line marked at the end of the test section (175 m distance). Breaks of the experiment were taken on demand of participants.

Figure6. no-P pattern of pole installation

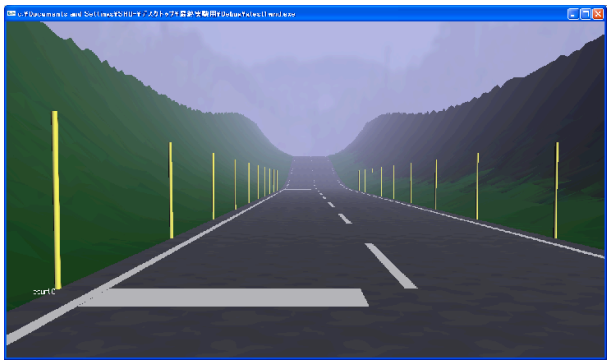


Figure7. same-P pattern of pole installation

Figure8. inc.-P pattern of pole installation

Figure9. staircase-P pattern of pole installation

Figure10. dec.-P pattern of pole installation

Figure11. tilt-P pattern of pole installation

Experimental Results and Discussion

Figures 12 and 13 show the results of the observing Orders 1 and 2, respectively. The vertical axis is probability of perceiving downward gradient, and the horizontal axis is actual gradient of the test section. The participant could judge downward gradient with high precision when the downward of the test section was high gradient. This result is the same as in the previous study, but different results are recognized by comparing between Figure 12 and Figure 13. The observing order effects to the perception of downward gradient.

Figure 14 shows the integrated result of Orders 1 and 2. In the case of no-P, the 50% chance level of the probability was about 4.5% gradient. In this simulation we also confirmed the phenomena of the *Obake-zaka*.

In the case of tilt-P, the 50% chance level of the probability was about 2% gradient, which was the lowest gradient in all pole patterns.

In the other cases, the differences were not clear. Because we found an effect of observing order, we have to take counter balance in the order of conditions among the participants.

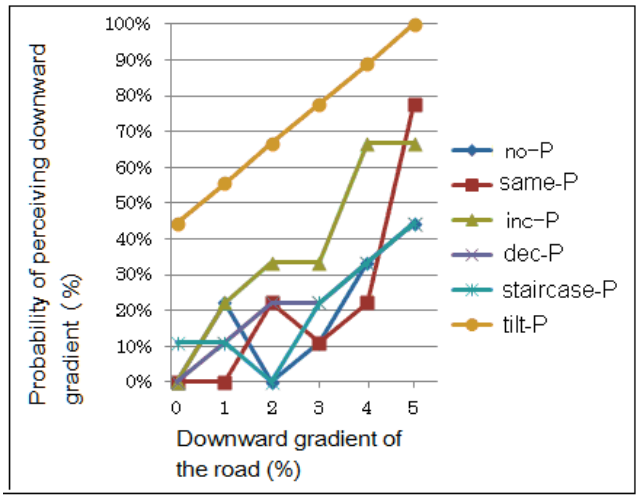


Figure12. Probability of perceiving downward gradient (Order 1 group)

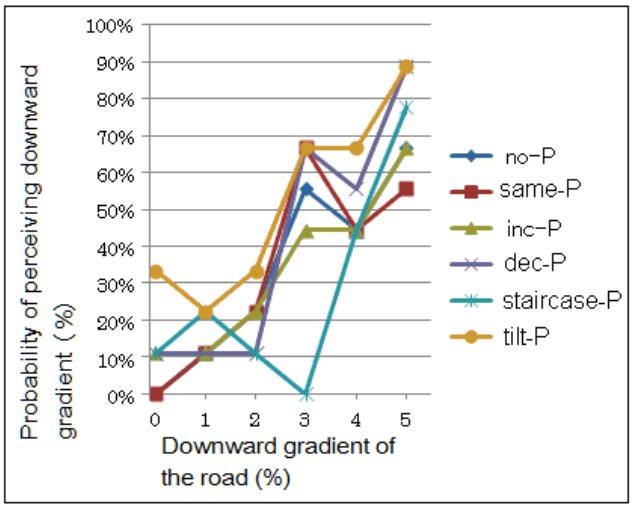


Figure13. Probability of perceiving downward gradient (Order 2 group)

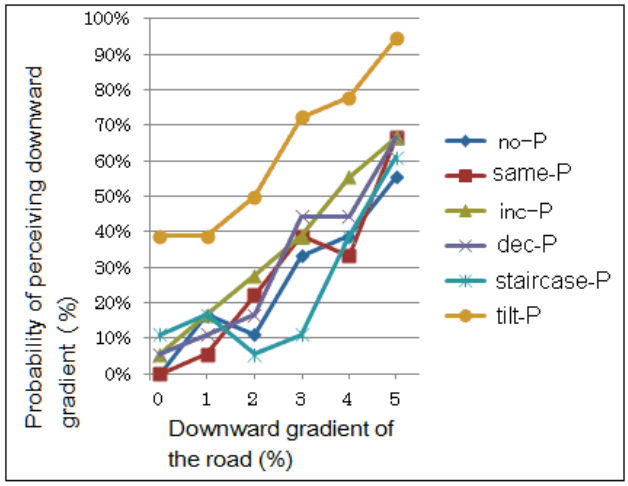


Figure14. Integrated result collected from the data in Order 1 group and in Order 2group.

EXPERIMENT 2

Purpose of the Experiment

In this experiment, the observing order of pole patterns was randomized in order to have counter balance among the participants. Then, we added variations of tilt pole pattern, because the tilt-P pattern brought the best sensitivity for downward gradient in Experiment 1. The purpose of this experiment was to find good pole pattern to perceive the true road gradient.

Patterns of Pole Installation and Experimental Purposes

The experimental environment and basic configuration of the simulator were the same as Experiment 1. Since the results of Experiment 1 show that the effect of poles in same-P and staircase-P patterns were not remarkable, we excluded those patterns. And we added new two patterns that were poles tilted 75 and 45 degrees to frontward direction. Thus, the patterns for the installation in Experiment 2 were the following six patterns.

1. Nothing. (no-P.)
2. Poles with gradually increasing height from near to far. The shortest was 20 cm height; the longest was 2 m height. (inc.-P)
3. Poles with gradually decreasing height from near to far. The longest was 2 m height; the shortest was 20 cm height. (dec.-P)
4. Poles tilted 75 degrees to frontward direction. The height was 2 m constant. (tilt75-P) (Figure 15)
5. Poles tilted 60 degrees to frontward direction. The height was 2 m constant. (tilt60-P) (Figure 16)
6. Poles tilted 45 degrees to frontward direction. The height was 2 m constant. (tilt45-P) (Figure 17)

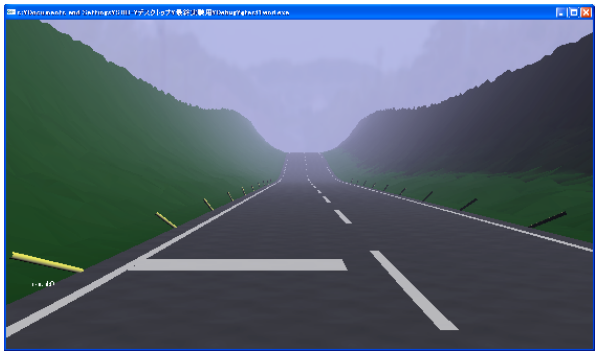


Figure15. tilt75-P pattern of pole installation

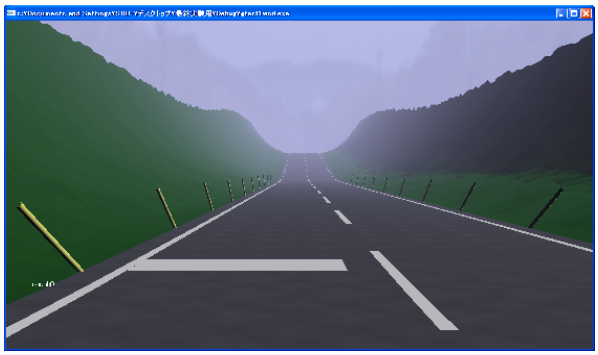


Figure16. tilt60-P pattern of pole installation

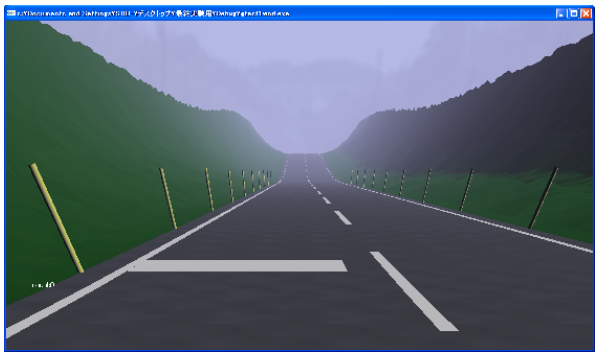


Figure17. tile45-P pattern of pole installation

Experiment Participants

20 undergraduate and graduate students took part in this experiment as observers (aged 19-25 years). All participants used to drive a car, and had normal or corrected-to-normal vision.

Experimental Results and Discussion

The results are shown in Figures 18, 19. As the gradient in the test section increased, the probability of perceiving the gradient in each pattern increased. We calculated each 50% chance level as a threshold to judge a downward gradient by using profit analysis. Table 1 shows the threshold in each pattern. Installing poles improved the sensitivity to perceive vertical gradient of the road. In the pole patterns, tilt poles brought good sensitivity, and the 60 deg tilt brought the best sensitivity.

We confirmed the effectiveness of tilted poles for increasing the sensitivity.

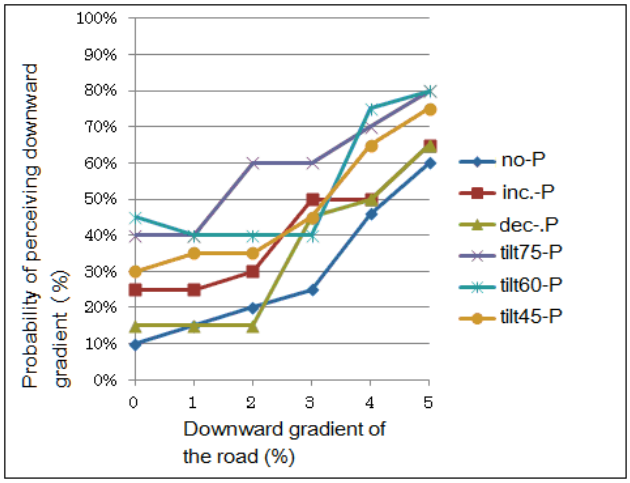


Figure18. Probability of perceiving downward gradient in Experiment 2.

Pole pattern	Threshold (gradient)
no-P	4.4%
inc.-P	3.6%
dec.-P	3.9%
tilt75-P	2.1%
tilt60-P	1.5%
tilt45-P	2.8%

Table1. Threshold to perccive the gradient in each pole pattern.

EXPERIMENT 3

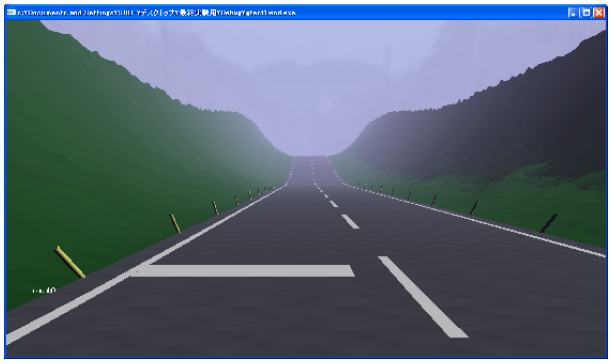
Purpose of the Experiment

In this experiment, we tried to find the best length of tilt pole for increasing the sensitivity.

Patterns of Pole Installation and Experimental Purposes

The experimental environment and basic configuration of the simulator were the same as Experiment 1. Because the results of Experiment 2 show that the effect of poles in tilt60-P pattern was the best for increasing of the sensitivity, we added new three patterns as follows;

1. Poles (1.0 m height) tilted 60 degrees to frontward direction. (Figure 20)
2. Poles (1.4 m height) tilted 60 degrees to frontward direction. (Figure 21)
3. Poles (1.7 m height) tilted 60 degrees to frontward direction. (Figure 22)
4. Poles (2.0 m height) tilted 60 degrees to frontward direction. (Figure 23)



Fighure 20. 1.0m tilt pole pattern of pole installation

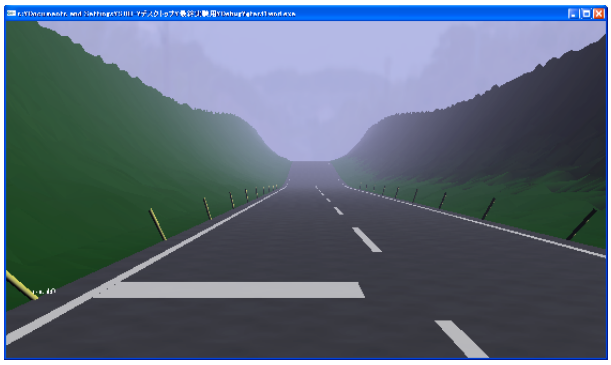


Figure 21. 1.4m tilt pole pattern of pole installation

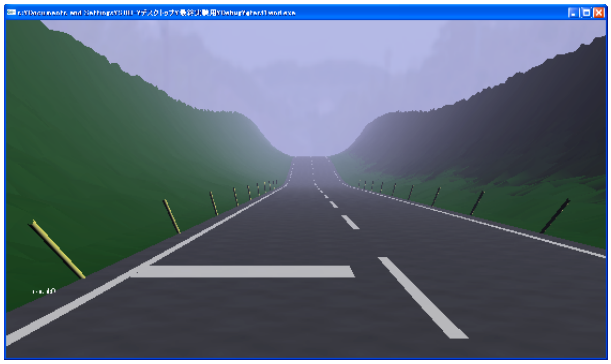


Figure 22. 1.7m tilt pole pattern of pole installation

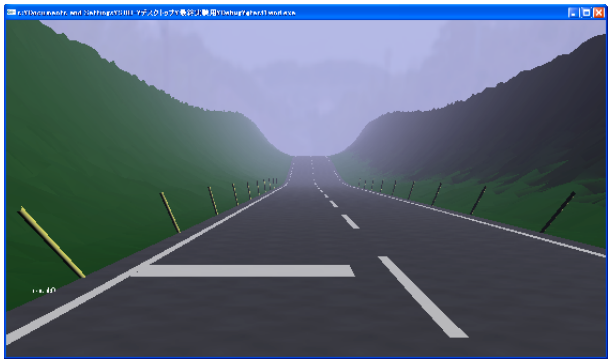


Figure 23. 2.0m tilt pole pattern of pole installation

Experiment Participants

11 undergraduate and graduate students took part in this experiment as observers (aged 21-23 years). All participants used to drive a car, and had normal or corrected-to-normal vision.

Experimental Results and Discussion

The results are shown in Figures 24, 25. We calculated each 50% chance level as a threshold to judge a downward slope by using profit analysis. Table 2 shows the threshold in each pattern.

As a result, the thresholds of 2.0 m, 1.7 m, and 1.4 m tilt pole were similar. 1.0m pole brought the sensitivity decreasing. This result indicates that tilt pole needs enough height for increasing the sensitivity.

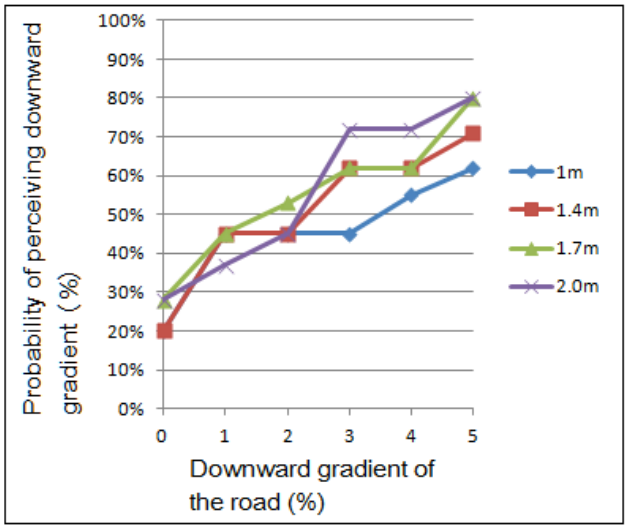


Figure24. Probability of perceiving downward gradient in Experiment 3.

Pole pattern	Threshold (gradient)
1.0m tilt pole	3.2%
1.4m tilt pole	2.3%
1.7m tilt pole	1.8%
2.0m tilt pole	1.9%

Table2. Threshold to perccive the gradient in each pole pattern.

CONCLUSION

In this study, we found the following results through three experiments;

1. Installing poles on the both sides of a downhill road, *Obake-zaka*, brought increasing sensitivity of vertical gradient of the road.
2. Poles tilting to frontward direction were more effective for increasing the sensitivity than the other installations.
3. The best angle of the tilt poles was 60 degree, and the best height of the tilt pole was 1.7 m.

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