EFFECTS OF CURVE DESIGNS AND ROAD CONDITIONS ON DRIVER’S CURVE SHARPNESS JUDGMENT AND DRIVING BEHAVIOR

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Abstract: In order to explore function of curve design, road information and driving conditions (season, and time of day), this study investigates driver’s judgment on curve sharpness and driving behavior. The field study with an experimental group of 105 drivers has been conducted at 16 curves on a mountain highway, with employing 3 types of road information; non-treatment (actual roadway setting), advance curve-warning sign placed on the roadway, and roadway signing combined with curve-guidance through an in-car navigation system. The study then finds that information provision has a positive effect on driver’s judgment on pre-curve sharpness under any road conditions, especially when the curve radiuses are less than 100 meters. On the other hand, however, several negative effects are found on driving performance of summer-daytime, particularly with roadway signing combined with curve-guidance through the in-car navigation system.

Keywords: Road Safety, Curve Design, Road Information, and Human Factors

1. INTRODUCTION

As the fatal accident rate at curves has been significantly high on national highways running through Hokkaido, Japan, communicating the necessary information on curve, such as turning...
direction and sharpness, to the drivers before entering the curve is important in preventing curve-related accidents. Indeed various studies have been conducted on information needs for driving tasks on curves.

Suzuki et al. (2001) have investigated the qualitative relationships between information provisions and assessment of curve sharpness at daytime and nighttime. They find that traffic control devices significantly affect the pre-judgment score but that these alone cannot provide complete information on the curve alignment. It should be considered how to inform drivers of the curve depth between back and forward tangents. However, the current warning curve signs do not provide accurate information on curve depth. Otherwise, drivers can only expect the sharpness subjectively using other traffic control devices, roadscape, experiences on the route and so on. Besides, unfortunately there are only few studies to conduct exploring for the effects of information on sharpness judgment.

Japan Society of Traffic Engineers (1998) have considered how road signs change with the progress of ITS in the future. Then, as the use of in-car navigation system has become quickly and widely popular, the Society expects that the importance of curve information provided by car navigation is increasing significantly.

Tokunaga et al. (2002) have conducted a simulative experiment to investigate the effects of information on the driver's judgment of curve sharpness. As a result of their experiment, they find that the accurate information contributes positively on sharpness expectation. Moreover, the study shows that road scene is the most influencing factor for sharpness expectation. Tokunaga et al. have also determined that the positive effects of an arranged traffic sign are more significant than that of voice guidance system.

Hayashi et al. (2003) have conducted a field experiment to investigate the effects of information on driver’s judgment of curve sharpness through different information provision types and difference between daytime and nighttime, to determine what types of information provisions are most effective. Four kinds of information have been considered in this study: non specific information (actual condition), paper map, electronic map by in-car navigation system, and advance curve warning sign displayed on in-car LCD monitor. Then, Hayashi et al. find that the information provision has positive effect on driver’s curve sharpness judgment, but in some cases, risky driving performance is identified at sharp curves with downhill gradient, especially when the driver use the in-car navigation system. The information applied in this study is in-vehicle information, so it does not provide how the driver’s performance and subjective assessment would be affected by roadside information.

In this study, we take a further approach than these previous studies with focusing on investigating the effects of curve design, road information and driving condition on driver’s judgment of curve sharpness and their driving behavior. Three types of road information have been applied for this study, and these are non-treatment (actual roadway setting without specific information), advance curve-warning sign placed on the roadway, and roadway signing combined with curve-guidance through an in-car navigation system.
2. METHODS

2.1 EXPERIMENTAL SITE AND SIXTEEN CURVES

The experiment was conducted on a hilly 5-km section (round trip) on the two-lane rural highway in Hokkaido, Japan (National Route 393) from October 27th to November 3rd and from December 8th to December 28th of 2003. Figure 1 shows the test section, including a rehearsal section. This route has low traffic volume on business days (2500 veh. per day). As shown in Figure 1, the study defines as the section from starting to turning point as “outward” and the section from turning to starting point as “homeward.” In the outward section, the study selects 9 curves with downhill gradients where the average gradient is around -5.4% while 7 uphill curves with average gradients of 4.8% are selected in the homeward. Figure 2 shows the plane view and basic design data of the selected curves (C1 to C16).

![Figure 1. Experimental Site (Route-393)](image)

2.2 EXPERIMENTAL GROUP

An experimental group in this study includes 120 drivers. However, the study has excluded driver who could not become familiar to the tasks or not satisfied a minimum condition of safety during the rehearsal run, as well as professional and novice drivers. Consequently, 105 drivers are selected as the subjects for this study. All the subjects have valid Japanese driver licenses with normal visual acuity, and none of them are familiar with Route 393 selected as the test field. Table 1 shows the characteristic of subjects who participated in this experiment.

<table>
<thead>
<tr>
<th>(A) Gender of the Subjects</th>
<th>Total</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>105</td>
<td>61</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>100.0%</td>
<td>58.0%</td>
<td>42.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(B) Age Composition of the Subjects</th>
<th>Total</th>
<th>20s</th>
<th>30s</th>
<th>40s</th>
<th>50s</th>
<th>60s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>105</td>
<td>31</td>
<td>31</td>
<td>29</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>100.0%</td>
<td>29.5%</td>
<td>29.5%</td>
<td>27.6%</td>
<td>9.5%</td>
<td>3.8%</td>
</tr>
</tbody>
</table>
Drivers generally communicate information related to curve sharpness through traffic control devices, such as chevron signs and warning signs. However, these devices controlling traffic or transmitting information to drivers do not convey clear meaning of the forward curve’s sharpness to drivers. Then, the study employs three types of road information to explore the effects on driver’s judgment of curve sharpness and driving behavior.

Figure 2 Plane Views and Design Characteristics of the Selected Curves

2.3 ROAD INFORMATION AND DRIVING CONDITION
a) Non-Treatment (Non Specific Information: NSI): the subject evaluates the sharpness of each curve with using only roadway scene and traffic facilities placed on the actual roadway setting.

b) In-Place Warning Sign (PWS): the subject evaluates the sharpness of each curve communicating with an in-place advance warning sign proposed by the Civil Engineering Research Institute of Hokkaido (CERI). As shown in Figure 3, this easy-readable bent arrow sign characteristically indicates the curve radius and depth, and it has been placed only on curve zone which has a radius of less than 100 meters (C1, C3, C5, C6, C12, C13, C15 and 16); the other uses the present-posted curve warning sign. Furthermore, on a downhill curve gradient information has been provided as general aid to drivers.

c) In-Place Warning Sign with Virtual Curve-Guidance (VCG): the subject evaluates the curves sharpness using an advance warning sign placed on the roadway and virtual curve-guidance through an in-car navigation system (electronic map) mounted on the dashboard of an experimental vehicle (see Figure 4).

In addition to road information, driving condition is clearly defined in terms of season (summer and winter condition) and time of day (daytime and nighttime) for this study. Here summer condition means a roadway without snow while the winter means a road background with snow but the pavement condition is bare at all the time even in wintertime.

![Figure 3. Design of In-Place Warning Signs (PWS) Proposed by CERI](image)

**Figure 3. Design of In-Place Warning Signs (PWS) Proposed by CERI**

![Figure 4. In-Car Navigation System](image)  ![Figure 5. Experimental Vehicle](image)

**2.4 EXPERIMENTAL VEHICLE**

The study adopts a four-door sedan (Nissan Primera UA-TP12) for the experimental vehicle (see Figure 5). In order to obtain driving behavior data, an on-board system (including a computer machine for record, high-performance DGPS, etc.) is installed on the vehicle, as well as a series of digital video cameras with a multiple video displayer system, a microphone
and a steering button system for recording the driver behavior. The instruments have recorded
the speed variation, longitudinal and transversal acceleration, brake operation and curve
sharpness recognition point, and the video images have recorded any other driver behavior,
including curve sharpness judgment performance.

2.5 CURVE SHARPNESS JUDGMENT TASK

One subjective assessment value in this study is the driver’s curve sharpness judgment before
entering the target curve, and the pre-judgment is classified into 3 sharpness levels: very sharp,
sharp and gentle. A second value is post-curve sharpness judgment with 3 accuracy levels:
underestimation, accurate estimation and overestimation. The criteria used for evaluating the
curves are as follows.

a) Pre-Curve Sharpness Judgment (PRE-CSJ): The subject is asked to estimate the curve
sharpness on the tangent before the target curve. “Very sharp” means small radius and
sharp angle (i.e., hairpin). “Sharp” means small radius and somewhat sharp angle.
“Gentle” means gentler than the aforementioned categories.

b) Post-Curve Self-Evaluation: The subject evaluates his or her pre-curve sharpness
judgment as soon as passing each curve. “Underestimation” means that the passed curve is
sharper than predicted while "Accurate Estimation" means that it is about as sharp as
predicted. "Overestimation" means that the passed one is gentler than predicted.

2.6 EXPERIMENTAL DESIGN

The independent variables for this study are curve design (curve radius, curve length and
gradient), road information and the driving conditions (season, and time of day). The
dependent variables are the driver’s curve sharpness judgment (pre and post) and their driving
behaviors (speed variation and acceleration in curve zones). The study employs a completely
randomized design in which 54 subjects drive under “summer road condition” and 51 subjects
are under “winter road condition,” and each subject drives only a round trip in order to avoid
the feedback effect.

2.7 EXPERIMENTAL PROCEDURE

All the subjects are first given time to be familiar with operating the experimental vehicle in
order to obtain a certain uniformity of driver’s aptitude, and then the experimental staff
explains and instructs the experimental tasks to them (see Figure 4). Besides, the subjects are
instructed to drive safely with keeping the driving speed under the posted speed limits.
Avoiding the presence of a leading vehicle at all times, each subject drives the experimental
vehicle on the rehearsal section first (see Figure 1), and any drivers who can not satisfy the
above conditions are excluded from this experiment at time. After rehearsal driving, the
subject drives on the test section, and the driving performance of each subject is recoded on
data and video recording system. During the experimental run, the subject pushes a switch
button installed on the steering wheel as soon as recognizing a target curve, and then the
subject calls his or her curve sharpness judgment before and after the target curve. After
finishing the run, all the digital data is saved, and each subject is asked several questions
concerning the curve sharpness assessment.
3. RESULTS

3.1 EFFECTS OF CURVE DESIGN, ROAD INFORMATION AND DRIVING CONDITION ON DRIVING BEHAVIOR

The study analyzes driving speeds at the time when the subjects have performed their pre-curve sharpness judgment (PRE-CSJ Speed). Figure 6 shows the average and standard deviation of the speed before entering the target curve as a function of curve design, road information and driving condition: the curves are reordered from the left to right according to curve radius ascendant order. Averages and standard deviations for the pre-curve speed in outward (downhill) and homeward (uphill) sections are not varied widely and these are ranged approximately from 50 km/h to 60 km/h. However, the average driving speed decreases (approx. 10 km/h) as driving conditions became worsened.

Table 2 shows the number of samples of driving behaviors and T-test results (NSI vs. PWS and VCG). Providing road information to the subject tends to increase the speed on “summer daytime (SD)” significantly while decreasing it on “summer nighttime (SN).” This tendency has not been recognized in winter daytime (WD) and winter nighttime (WN).

Figure 7 shows the average and standard deviation of a maximum longitudinal acceleration (MaxLong-G) on each curve section. On the outward section, a change in accelerations by road information and driving conditions are not varied widely. The average of the MaxLong-G ranges approximately from -0.15G to 0.00G with a little decreasing of The MaxLong-G while increasing the curve radius. The MaxLong-G on the homeward section shows a similar tendency. Meanwhile, no significant difference has been identified from T-test of MaxLong-G as a function of road information except on C6 and C16 in summer conditions.

Figure 8 shows the average and standard deviation of a maximum lateral acceleration (MaxLat-G) on each curve section. The Average of MaxLat-G ranges approximately from 0.35G to 0.10G in which its value decreases with increasing curve radius and worsening road conditions. Providing road information tends to increase significantly the MaxLat-G on SD while the average of MaxLat-G on SN shows a decreasing tendency (see Table 2).

3.2 EFFECTS OF CURVE DESIGN, ROAD INFORMATION AND DRIVING CONDITION ON DRIVER’S CURVE SHARPNESS JUDGMENT

Figure 9 shows a ratio of 3-level pre-curve sharpness judgment (“Very sharp”, “Sharp” and “Gentle”) on each curve section as a function of curve design, road information and driving condition. Based on 1680 data points recorded from this study, it calculates each ratio of sharpness level. When the curve radius is small, a ratio of “Very sharp” and “Sharp” is extremely high, but it decreases with increasing curve radius. Then, the provision of road information tends to increase the “Very sharp” ratio on a curve with the radius of less than 100 m (C1, C3, C6, C5, C8, C12, C15, C16 and C13) and with the length of greater than 100 m (C7, C4, C9, C2, C10, C11 and C14) in any driving conditions.

Figure 10 shows “Accurate Estimation” ratio of post-curve self-evaluation for each curve with using the recorded 1680 data points. Road information tends not to improve the “Accurate Estimation” on SD while on SN, WD and WN road information tend to increase the “Accurate Estimation” of many curves independently of their design.
NOTE:  
NSI (Non Specific Information)  
PWS (In-Place Warning Sign)  
VCG (PWS + Virtual Curve-Guidance through In-Car Navigation System)  

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C3</th>
<th>C6</th>
<th>C5</th>
<th>C8</th>
<th>C7</th>
<th>C4</th>
<th>C9</th>
<th>C2</th>
<th>C12</th>
<th>C15</th>
<th>C16</th>
<th>C13</th>
<th>C10</th>
<th>C11</th>
<th>C14</th>
</tr>
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<tbody>
<tr>
<td>Radius (m)</td>
<td>50</td>
<td>50</td>
<td>65</td>
<td>80</td>
<td>150</td>
<td>200</td>
<td>300</td>
<td>500</td>
<td>530</td>
<td>50</td>
<td>50</td>
<td>80</td>
<td>150</td>
<td>200</td>
<td>300</td>
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</table>

Figure 6.  Pre-Curve Driving Speeds on Target Curves
Figure 7. Maximum Longitudinal Acceleration (MaxLong-G) of Target Curves

<table>
<thead>
<tr>
<th>NOTE:</th>
<th>NSI (Non Specific Information)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>PWS (In-Place Warning Sign)</td>
</tr>
<tr>
<td></td>
<td>VCG (PWS + Virtual Curve-Guidance through In-Car Navigation System)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C3</th>
<th>C6</th>
<th>C8</th>
<th>C10</th>
<th>C12</th>
<th>C14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius (m)</td>
<td>50</td>
<td>50</td>
<td>65</td>
<td>80</td>
<td>150</td>
<td>200</td>
<td>300</td>
</tr>
</tbody>
</table>
NOTE: NSI (Non Specific Information)  
PWS (In-Place Warning Sign)  
VCG (PWS + Virtual Curve-Guidance through In-Car Navigation System)

<table>
<thead>
<tr>
<th>Radius (m)</th>
<th>C1</th>
<th>C3</th>
<th>C6</th>
<th>C5</th>
<th>C8</th>
<th>C7</th>
<th>C4</th>
<th>C9</th>
<th>C2</th>
<th>C12</th>
<th>C15</th>
<th>C16</th>
<th>C13</th>
<th>C10</th>
<th>C11</th>
<th>C14</th>
</tr>
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<tbody>
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<td>50</td>
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<td>80</td>
<td>150</td>
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<td>300</td>
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<td>50</td>
<td>80</td>
<td>150</td>
<td>200</td>
<td>300</td>
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</tr>
</tbody>
</table>

Figure 8. Maximum Lateral Acceleration (MaxLat-G) of Target Curves
Table 2. Number of Samples and T-Test Results (NSI vs. PWS and VCG)

<table>
<thead>
<tr>
<th>Selected Curves</th>
<th>Road Information</th>
<th>Number of samples and T-test results (NSI vs PWS &amp; VCG)</th>
<th>PRE-CSJ Speed Significance</th>
<th>MaxLong-G Significance</th>
<th>MaxLat-G Significance</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>SN</td>
<td>WD</td>
<td>WN</td>
</tr>
<tr>
<td>C1</td>
<td>NSI</td>
<td>9</td>
<td>9</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>PWS</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>VCG</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>C3</td>
<td>NSI</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>PWS</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>VCG</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>
| C6              | NSI              | 9  | 9  | 7  | 10 | 9  | 9  | 7  | 10 | 9  | 9  | 7  | 10 *
|                 | PWS              | 7  | 10 | 8  | 10 | 7  | 10 | 8  | 10 | 7  | 10 | 8  | 10 *
|                 | VCG              | 8  | 9  | 8  | 8  | 8  | 9  | 8  | 8  | 8  | 9  | 8  | 8  |
| C5              | NSI              | 9  | 8  | 7  | 10 | 9  | 8  | 7  | 10 | 9  | 8  | 7  | 10 |
|                 | PWS              | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  |
|                 | VCG              | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  |
| C8              | NSI              | 10 | 9  | 7  | 10 | 10 | 9  | 7  | 10 | 10 | 9  | 7  | 10 |
|                 | PWS              | 8  | 10 | 8  | 10 | 8  | 10 | 8  | 10 | 8  | 10 | 8  | 10 |
|                 | VCG              | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  |
| C7              | NSI              | 9  | 8  | 7  | 10 | 9  | 8  | 7  | 10 | 9  | 8  | 7  | 10 *
|                 | PWS              | 7  | 9  | 8  | 10 | 7  | 9  | 8  | 10 | 7  | 9  | 8  | 10 *
|                 | VCG              | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  |
| C4              | NSI              | 9  | 9  | 7  | 10 | 9  | 9  | 7  | 10 | 9  | 9  | 7  | 10 *
|                 | PWS              | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  |
|                 | VCG              | 9  | 9  | 8  | 7  | 9  | 9  | 8  | 7  | 9  | 9  | 8  | 7  |
| C9              | NSI              | 10 | 9  | 8  | 10 | 10 | 9  | 8  | 10 | 10 | 9  | 8  | 10 *
|                 | PWS              | 8  | 10 | 8  | 10 | 8  | 10 | 8  | 10 | 8  | 10 | 8  | 10 *
|                 | VCG              | 8  | 10 | 8  | 10 | 8  | 10 | 8  | 10 | 8  | 10 | 8  | 10 *
| C2              | NSI              | 9  | 8  | 7  | 10 | 9  | 8  | 7  | 10 | 9  | 8  | 7  | 10 *
|                 | PWS              | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  | 8  | 9  | 8  | 7  *
|                 | VCG              | 8  | 8  | 8  | 7  | 8  | 8  | 8  | 7  | 8  | 8  | 8  | 7  |

**NOTE:**
*5% significance SD: Summer Daytime
** 1% significance SN: Summer Nighttime
NSI: No Special Information
PWS: Proposed Warning Sign
WD: Winter Daytime
VCG: PWS + Car Navigation System

| Radius (m) | 50  | 50  | 65  | 80  | 150 | 200 | 300 | 500 | 530 | 50  | 50  | 80  | 150 | 200 | 300 |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| C1         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C3         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C6         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C5         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C8         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C7         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C4         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C9         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C2         |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C12        |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C15        |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C16        |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C13        |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C10        |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C11        |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| C14        |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

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Figure 9. Driver’s Pre-curve Sharpness Judgment (PRE-CSJ) Ratio
Figure 10. Driver’s Post-Curve Self Evaluation Ratio (Accurate Evaluation)
A multiple categorical analysis has been applied to identify the effect curve design and road information on driver’s curve sharpness judgment. Table 3 shows standard partial regression coefficients and multiple correlation coefficients. Curve radius shows large positive effect on pre-curve sharpness judgment. Curve length, longitudinal gradient and road information have not very large effects on pre-curve sharpness judgment. Also, there are not clear relation between post-curve self-evaluation and combination of curve design and road information.

Table 3. Categorical Analysis Results:
Effect of Combining Curve Design and Road Information on Driver’s Sharpness Judgment

<table>
<thead>
<tr>
<th></th>
<th>Curve Radius (m)</th>
<th>Curve Length (m)</th>
<th>Long. Gradient (%)</th>
<th>Road Information</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Curve Sharpness Judgment (n=1680)</td>
<td>0.539</td>
<td>0.06</td>
<td>0.038</td>
<td>-0.036</td>
<td>0.302</td>
</tr>
<tr>
<td>Post-Curve Self Evaluation (n=1680)</td>
<td>0.278</td>
<td>-0.038</td>
<td>0.029</td>
<td>0.07</td>
<td>0.071</td>
</tr>
</tbody>
</table>

4. DISCUSSION AND CONCLUSIONS

In this field study, we have investigated the effects of information on driver’s behavior and their judgment on curve sharpness as a function of curve design, road information and driving conditions. Even though the study shows that curve design and driving condition do not have a profound effect on the driving speed and maximum longitudinal acceleration (MaxLong-G), we find that the maximum lateral acceleration (MaxLat-G) decreases as curve radius increases. On the other hand, however, the study finds significant negative effects toward driving performance (speed and MaxLat-G) at several curves during summer-daytime, particularly when the driver relies on In-Place Warning Sign with Virtual Curve-Guidance (VCG).

On one hand, the study finds that speed and MaxLat-G tend to decrease at several curves by providing information on curves during summer-nighttime. It is likely that depending on visibility condition of roadway (daytime or nighttime), information provision affects positively or negatively driver’s behavior. This tendency can be only seen in summer, not in winter. This might be due to the lower values of driver’s behavior on the whole at almost all of curves in winter, comparing those in summer.

As for driver’s judgment on curve sharpness depending on curve design and under driving conditions, the study finds that curve radius has a marked effect on pre-curve sharpness judgment. Besides, even though it is not significant, the multiple categorical analysis shows that the expected result on curve sharpness can be obtained from the experimental group of drivers at curves under difficult driving conditions or with small radius by providing information about sharpness in addition to noticing curve ahead and curving way throughout in-place advance warning sign with virtual curve-guidance through in-car navigation system: the drivers see these curves “very sharp,” as we expected. This analyzing result however is not to show the specific tendency, and there are indeed some situations without the intended effect from providing information even at curves under almost same severe setting. The post-curve self-evaluation also does not lead to obtain the meaningful result showing the specific tendency: at some curve points we have not received the intended effect from information provision even if more drivers see the expected curve sharpness by receiving
information. Consequently, it is expected that there are other factors affecting curve sharpness judgment than those employed in this study (curve design, road information and driving conditions), and a full understanding of those factors awaits future studies.

REFERENCES


Japan Society of Traffic Engineers (1998); Study on Traffic Sign in ITS Society, Tokyo-Japan.
