International J. Highw. Engineering Vol. 15 No. 1 : 127-134 February 2013
http://dx.doi.org/10.7855/IJHE.2013.15.1.127

The Effects of Pavement Markings on High-risk Drivers' Speeds
사고위험성이 높은 운전자에 대한 노면표시 효과 연구

Lee, Jong Hak	이종학	Membership · Research Specialist · Korea Institute of Construction Technology · Completed the course of a doctorate in Traffic Engineering, the University of Seoul (E-mail : jonghak@kict.re.kr)
Noh, Kwan Sub	노관섭	Membership · Senior Research Fellow · Korea Institute of Construction Technology(E-mail : ksno@kict.re.kr)
Kim, Jong Min	김종민	Membership · Senior Researcher · Korea Institute of Construction Technology (E-mail : kimbellsky@kict.re.kr)
Choi, Jai-Sung	최재성	Membership · Professor · Dept. of Traffic Engineering, University of Seoul (E-mail : traffic@uos.ac.kr)

ABSTRACT

PURPOSES : Speeding is often the primary contributor to fatal crashes. Surprisingly, driving behaviors are indirectly affected by personal factors such as law-abidance, risk sensitivity, and situational adaptability. This research aims to verify the effectiveness of pavement markings at reducing the speeds of high-risk drivers. The purpose of this study is to establish how drivers (including law-abiding or law-breaking, high-risk or low-risk) react to different pavement markings in a driving simulator.

METHODS : The five different pavement markings were selected from markings used in other nations. The forty-two drivers were then surveyed, via questionnaires, and placed into the corresponding groups. Finally, statistical analysis was conducted to determine the extent of speed reduction for each pavement marking.

RESULTS : Higher speeds were linked to the high-risk drivers. Furthermore, after analysis of the mean difference of average speeds by pavement marking, it was determined that Dragon's Teeth had the greatest speed reducing effect on these drivers.

CONCLUSIONS : Perceptual countermeasures are unlikely to strongly affect high-risk drivers' perception of speed on the curves. This statistically demonstrates that Dragon's Teeth have a subtle effect on reducing speeds in the driving simulator. This study's significance lies in the improved understanding of high-risk drivers in terms of road facilities. It approaches the effects of various patterns of pavement markings for high-risk drivers.

Keywords
pavement marking, law-abidance, risk sensitivity, speed reduction, driving simulator

Corresponding Author : Lee, Jong Hak, Research Specialist
Korea Institute of Construction Technology, (Daehwa-Dong) 283,
Goyangdae-Ro, Ilsanseo-Gu, Goyang-Si, Gyeonggi-Do, 411-712, Korea
Tel : +82.31.9100.732
email : jonghak@kict.re.kr

International Journal of Highway Engineering
http://www. ijhe.or.kr/
ISSN 1738-7159 (Print)
ISSN 2287-3678 (Online)

1. INTRODUCTION

Speeding has long been recognized as a major factor in the severity of car accidents. Overseas studies have identified speed as a factor in fatal road crashes. Surprisingly, they reveal that both law-breaking and low-risk drivers cause speeding, drunken driving, road rage, etc. Generally, drivers that break laws tend to think that it is better to ignore rules for personal gain than respect them. This attitude is very dangerous and may correlate to a higher likelihood of

involvement in traffic accidents.

Engineering and enforcement methods as well as education have been used in an attempt to reduce speeding on roadways. Typically, high-risk drivers can be controlled through education and enforcement. But without enforcement and education it can be difficult to safeguard every possible high-risk location for high-risk drivers. There seems to be a lack of research on controlling drivers on various road facilities.

It is necessary to determine how high-risk drivers react to various road facilities. Therefore, this study was conducted to ascertain how each pavement marking will affect different groups' speeding tendencies on road facilities (including roundabouts, work zones, and curves). This study could also improve the understanding of high-risk drivers.

2. LITERATURE REVIEW

2.1. Review of Law-Breaking Dirvers and Driver Risk Sensitivity

Law-abidance and risk sensitivity have similar characteristics to each other. If drivers lack law-abidance and/or risk sensitivity, it can lead to dangerous driving behaviors. However, the intentions behind each of these dangerous driving characteristics are different. Risk sensitivity refers to the awareness of potential risks in traffic conditions. Therefore, it is the ability to cope with dangerous driving situations. Low-risk drivers sometimes enjoy driving dangerously for a brief thrill; however, they are unable to cope with the possible risks in different traffic situations compared to high-risk drivers. Law-abidance could be described as a psychological tendency of drivers to break rules despite the danger. For example, the car in front of a law-breaking driver runs a red light. The law-breaking driver follows closely despite the obvious danger. Law-breaking drivers also tend to speed in hazardous areas, such as sharp curves.

Iversen and Rundmo (2002) found that drivers' characteristics are related to dangerous driving behaviors and traffic accidents, and drivers with high risk-taking levels had relatively more traffic accident experiences.

In relationship to law-abidance, Laapottia, Keskinena, and Rajalin (2003) argued that a negative attitude towards traffic laws showed high correlations with traffic accident involvement, and these drivers reported more drunken driving experiences than others.

In the study of Han and Lee (2002) police officers stated, in their opinions, the major cause of traffic accidents is intentional traffic violations by drivers, including breaking safety rules, crossing central lines, speeding, and inappropriate passing.

According to Kim et al. (2006) drivers who don't abide by the law reported more experiences of drunken driving, speeding, and accidents than average drivers. It is likely that law-breaking drivers would drive faster under the influence to avoid temporary disadvantages.

Situational adaptability refers to a drivers' adaptability (ability to modify their driving technique) to various traffic environments. Some drivers are anxious when driving in bad visual conditions like rain, snow, or night. Others may try to avoid heavy traffic for the same reason. Elderly drivers' situational adaptability level is relatively low, so they try to drive safely and avoid driving in bad conditions.

Preusser, Williams, Fergusonb, Ulmera, and Weinstenia (1998) found that elderly drivers' high traffic accident rates were due to a lack of perception and attention in tangled traffic situations such as intersections. Hakamies-Blomqvist and Wahlström (1998) also showed that elderly drivers have a difficult time driving on slippery roads at night

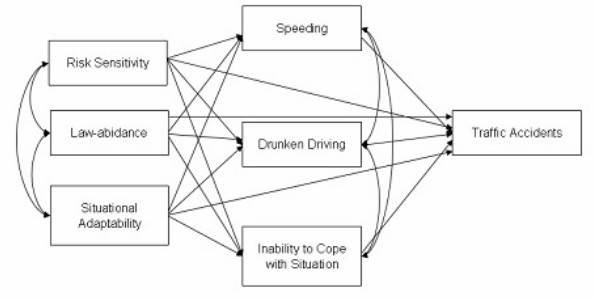


Fig. 1 Diagram for Driving Behavior Determination on Traffic Accidents

Fig. 1 explains the theoretical path that driving behaviors impact upon traffic accidents. In this path, driving behaviors consist of risk sensitivity, law-abidance and situational adaptability and these factors impact upon traffic accidents through drivers speeding, drunken driving and coping with situations.

2.2. Guideline of Perceptual Countermeasures for Speed Redution

The respective pavement markings used abroad are shown in Tables 1, 2, 3 and 4. The methods used in this study considered only techniques related to speed reduction and excluding techniques used at intersections. Tables 1, 2, 3 and 4. summarize the proposed perceptual techniques used in this study.

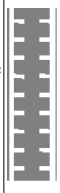
"Transverse Lines" are a series of lines which are perpendicular to the path of travel and are placed across the road like rumble strips, they are the most commonly used form of pavement markings in speed reduction. As seen in Table 1, this features a pattern with varying widths and varying distances to warn drivers of the upcoming zone.

Table 1. Summary of Transverse Lines for Speed Reduction

Type		Country	Summary
Transverse Lines		UK	□ Traffic Signs Manual (2003) • Markings are used in certain conditions on high speed approaches to roundabouts, or on the main carriageways. Not used in an attempt to reduce speeds at sharp bends or other hazards. • The marking consists of 90 yellow transverse bars on main carriageways, and 45 on slip roads. The bars are 600 mm wide, and are laid at right angles to the centre line of the carriageway.
		USA	□ Arnold.E.D., Lantz.K.E. (2007) • Markings are used on a major four-lane undivided highway. • The bars were 12 inches wide and were placed 1 foot off the edge line, skip centerline, and solid yellow centerline separating the east and westbound lanes. Lanes are approximately 10.5 feet through the section; thus, the bars are approximately 8.5 feet long.

"Peripheral Transverse Lines" are a series of bars (typically white) which are perpendicular to the path of travel. These techniques have several kinds of patterns. For example, a pattern with constant widths and constant spacing and a pattern with varying widths and varying spacing (as seen in Table 2).

Table 2. Summary of Peripheral Transverse Lines for Speed Reduction

Type		Country	Summary
Peripheral Transverse Lines		USA	□ Katz. B. J. (2004) • Markings are used on two lane rural roadways. • The treatment as installed used 12 inch (30.5 cm) wide pavement markings extending 18 inches (45.7 cm) into the roadway spaced increasingly closer together and placed perpendicular to the travel lane on both the left and right edges of the travel lane.
		Australia	□ Macaulay. J. (2004) • Markings are used in approaches to intersections on rural roadways. They're designed to encourage drivers to decelerate more rapidly. • Treatment starts approximately 435m from intersections, and goes over 400m (i.e., nothing over 35m immediately prior to intersections). Also, dimensions of peripheral transverse lines: 600mm wide, 600mm long, with a 4.5m gap between the parallel lines.
		USA	□ Virginia Department of Transportation (2002) • Local residential streets are eligible for traffic calming provided the posted speed limit does not exceed 25 mph; Two-lane roadways, Not a primary access to commercial or industrial sites. • Travel lanes not to be less than 9' in width.

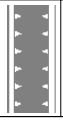
"Converging Chevron Markings" are a series of white chevrons which are painted on the road surface. The chevrons are placed increasingly close together as a driver moves into the pattern. The number of chevrons per set has to do with the speed within the pattern which usually ranged from 5 chevrons per set to 10.

Table 3. Summary of Converging Chevron Markings for Speed Reduction

Type		Country	Summary
Converging Chevron Markings		Japan, USA	□ Hancock. K. L., Riessman. R. (2004) □ Drakopoulos. A., Vergou. G. (2003) • Markings are used on high-speed ramps. • Sets of 4 to 10 chevrons per set, all sets have chevrons of 15cm each.
		UK	□ Traffic Signs Manual (2003) • The chevron markings are used on motorways only. • The marking is intended to remind drivers to keep a safe distance from the vehicle in front and has been shown to be beneficial in reducing accidents. • The start of a series of markings should be at least 1.6 km from the end of a previous entry slip road and should terminate at least 3.2km before the next slip road.

"Drenthe Province PCM" was formulated in the Netherlands by the TNO research organization and the University of Groningen. "Dragon's teeth" as the name implies, are shaped like dragon's teeth. These patterns are laid on the approaches to the gateways within villages. The gateways consisted of signing incorporating the 30mph speed limit, a speed camera warning sign, the village name and slogan 'Please drive carefully', on a yellow background.

Table 4. Summary of the Other Perceptual Techniques for Speed Reduction

Type		Country	Summary
Drenthe Province PCM		Nether lands	□ Godley. S. T. (1999) • Markings are used on rural 80km/h roads.
Dragon's Teeth		UK	□ Department for Transport (2005) • Markings are laid on the approaches to the gateways

2.3. Effectiveness of Perceptual Countermeasures for Speed Reduction

A report written by Katz, B.J. (2004) proved the effectiveness of the peripheral transverse lines treatment for speed reduction at several sites. Speed measurements were taken to evaluate the effectiveness of the markings during three phases: (1) before installation, (2) shortly after installation, and (3) six months after installation to examine the long-term effects at each site. The markings resulted in a decrease in overall vehicle speeds with total vehicles as well as with specific classifications of vehicles

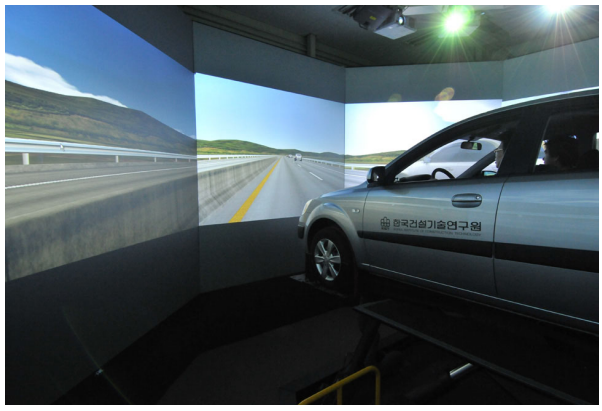
Drakopoulos, A., Vergou, G. (2003) demonstrated that the installation of chevron patterns on the test ramp appeared to result in large speed reductions. Speeds were lower in the "after" period despite the fact that the data for the after period was collected twenty months after the converging chevron pavement markings were installed.

Arnold, E.D., and Lantz, K.E. (2007) proved that the transverse lines treatment was an effective way to reduce speeds. Transverse lines were installed on a major, four-lane undivided highway in the town of Zuni,Virginia. Average speeds both decreased after installation. The decreases were statistically significant and ranged from 3 to 10mph.

3. METHODOLOGIES

3.1. Equipment

A Driving Simulator was used in this study. This piece of equipment allowed subjects to drive in a 3-D virtual reality environment for pavement markings.



Driving Simulator (K-ROAD)
Fig. 2 Experimental Equipment

3.2. Experimental Approaches

Every curve in the driving simulator consisted of a 300m radius. Total lengths of each treatment (pavement markings) were 280m long which include the straightway (tangent) to onset of curve (100m long) and curve (180m) on two lane roadways.

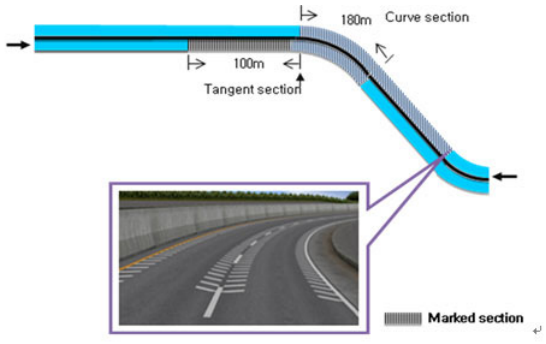


Fig. 3 Marked Section for Experiment

Detailed description of rod alignment is as follows.

○ Horizontal alignment

- Radius of Curve (R); 300m
- Transition Curve (L); 90m
- Curve Lengths (CL); 90m

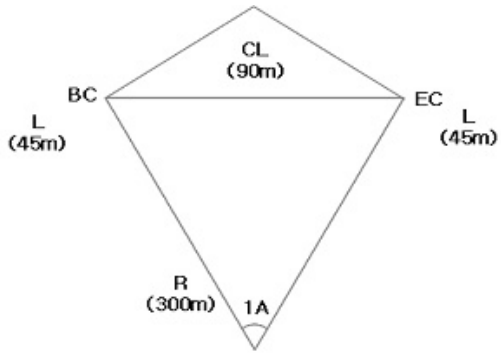


Fig. 4 Horizontal Alignments for Experiment

○ Cross Sectional Elements

- Divided Lanes (Four Lanes)
- Lane Widths; 3.5m
- Shoulder Width (on right side: 2m, on left side: 0.75m)
- Superelevation; 6%
- Medians

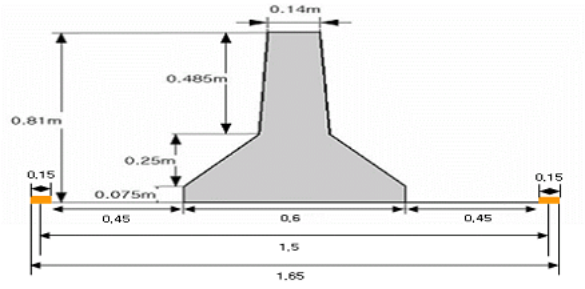


Fig. 5 Median's Design for Experiment

Pavement markings suggested throughout this literature review can be seen in Fig. 6. This study excludes speed reduction techniques used on intersections because these can be dangerous for reducing speeds on curves. A sequence of pavement markings along the alignment was randomly displayed by the simulator. Because it could play on important role that results could be affected by the sequence. Average speed was based on forty-two subjects along the sections with pavement markings

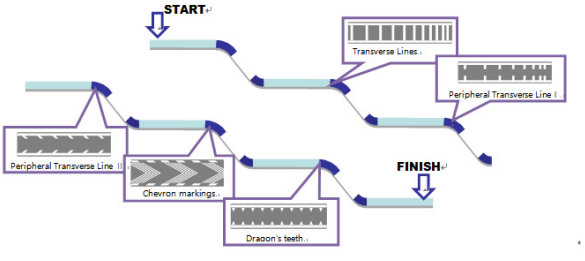


Fig. 6 Experimental Pavement Markings Design

3.3. Selection of High-Risk Drivers Through Questionnaire

After being tested in the driving simulator, the forty-two subjects participated in the questionnaire survey. The respondents' ages ranged from their twenties to their seventies. Surveys for the elderly drivers, those over sixty-five, were conducted by face to face interviews to aid them in understanding the questions. The respondents were asked to answer some questions about their driving experiences relating to law-abidance and risk sensitivity. The questions related to law-breaking and risk sensitivity were associated with the drivers' negative attitude.

The Questionnaire consisted of ten questions about respondents' personal behavior relating to risk sensitivity and law-abidance. These questions were collected from the "Questionnaire for Drivers' Character and Behavior" (Road Traffic Safety Authority, 1998) and the "Questionnaire for Moral Conception and Rules" (Park & Jo, 1998).

The survey divided the forty-two subjects into two groups for each factor (as seen in Table 5). Out of forty-two subjects, only those involved in the top 25th percentile and the bottom

Table 5. Sample of Questionnaire for Law-Abidance and Risk sensitivity

Factors	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Law-Abidance	- It is OK to break rules when those rules inflict a loss on me - If I get an advantage by breaking a rule, it is OK to do so. - If they are not detected, some minor illegalities are OK - Getting an advantage by breaking rules is better than being disadvantaged by respecting rules	①	②	③	④	⑤
Risk Sensitivity	- I get rid of my stress by speeding - I feel good when I'm speeding - I take risks just for fun - Speeding makes me look good - I often take risks just to feel thrills - I like the challenge of taking risks	①	②	③	④	⑤

25th percentile were selected to classify as subjects using "Interquartile Range" (IQR). The median 50th percentile was excluded because of the lack of statistical significance. In Table 5, higher numbers mean lower law-abidance.

4. DATA ANALYSIS

4.1. Basic Information on Subjects

Forty-two people between the ages of twenty and seventy took part in this experiment by using the driving simulator. The average age of the subjects was forty-two years old. Out of the forty-two subjects, thirteen of them were in their twenties while nineteen of them were over sixty.

4.2. Aanalysis of Law-abidance and Driver's Risk Sensitivity

"The Independent Samples T-Test" was carried out to attain the mean difference between law-abiding drivers and law-breaking drivers. The results demonstrate that law-breaking behaviors correlate with speeding in the driving simulator. The average speed for law-abiding drivers was 39.6mph (63.1km/h), but the average speed for law-breaking drivers was 48.4mph (77.42km/h). The results are statistically significant (t=-2.23, p<0.05).

Table 6. Average Speeds for Law-Abiding Drivers and Law-Breaking Drivers

Dependent Variable	Independent Variable	N	Mean (mph)	Std. Error	t
Average Speeds	Law-Abiding Group	10	39.6 (63.31 km/h)	17.88	-2.23*
	Law-Breaking Group	14	48.4 (77.42 km/h)	13.22	

*p <.05

As mentioned above, low-risk drivers sometimes enjoy driving dangerously for a brief thrill; however, they are unable to cope with the possible risks in different traffic situations compared to high-risk drivers. As seen in Table 7, the results reveal that high-risk drivers showed relatively higher speeding compared to the low-risk group. The average speed for low-risk drivers was 36.5mph (58.34km/h), but the average speed for high-risk drivers was 49.0mph (78.42km/h). The results are statistically significant (t=-4.26, p<0.001).

Table 7. Average Speeds for Low-Risk Drivers and High-Risk Drivers

Dependent Variable	Independent Variable	N	Mean (mph)	Std. Error	t
Average Speeds	Low-Risk Group	10	36.5 (58.3 km/h)	10.11	-4.26***
	High-Risk Group	14	49.0 (78.4 km/h)	11.70	

***p <.001

4.3. Average Speeds Between Groups by Pavement Markings

"The Independent Samples T-Test" was carried out to attain the mean difference of average speeds between the two groups (law-abiding and law-breaking) by pavement marking. Statistically, the effectiveness of speed reduction of several sections was different at a 95 percent confidence level. Speeds on "Transverse Lines," "Peripheral Transverse

Table 8. Average Speeds between Law-Abiding Drivers and Law-Breaking

Pavement Markings	Groups	N	Mean (mph)	Std. Error	t
Transverse Line 	Law-Abiding Group	10	39.2 62.7 (km/h)	18.82	-2.71*
	Low-Breaking Group	14	50.2 80.2 (km/h)	12.92	
Peripheral Transverse Line | 	Law-Abiding Group	10	39.4 63.1 (km/h)	19.71	-2.04
	Low-Breaking Group	14	47.9 76.7 (km/h)	13.06	
Peripheral Transverse Line || 	Law-Abiding Group	10	37.5 60.1 (km/h)	17.00	-2.52*
	Low-Breaking Group	14	47.1 75.4 (km/h)	12.83	
Chevron Marking 	Law-Abiding Group	10	41.1 65.7 (km/h)	20.58	-1.56
	Low-Breaking Group	14	48.0 76.8 (km/h)	14.67	
Dragon's teeth 	Law-Abiding Group	10	40.8 65.2 (km/h)	18.10	-1.40
	Low-Breaking Group	14	47.0 75.2(km/h)	16.56	
Unmarked Section	Law-Abiding Group	10	39.4 63.1 (km/h)	17.79	-2.52*
	Low-Breaking Group	14	50.1 80.2 (km/h)	15.42	

Drivers by Pavement Markings *p <.05

Lines II," and the "Unmarked Section" showed differences between the two groups. Only "Peripheral Chevron Markings" and "Dragon's Teeth" were not significant at the 95 percent confidence level (as seen in Table 8). This indicates the mean difference of the average speeds between the two groups differed slightly. However, "Dragon's Teeth" and "Peripheral Transverse Lines II" proved the most effective perceptual technique at reducing law-breaking drivers' speeds. Following these was the "Peripheral Transverse Lines I." The speed for law-breaking drivers on "Dragon's Teeth" was 3mph (5km/h) lower than their speed on the "Unmarked Section," which was regarded as the highest speed, except for "Transverse Lines."

Overall, the effectiveness of speed reduction on every section between the two groups (high-risk and low-risk) was different at a 95 percent confidence level. These results indicate the mean difference of average speeds between the two groups by pavement marking was different. "Dragon's Teeth" proved the most effective perceptual technique for reducing speeds for the low-risk group. Following "Dragon's Teeth" was "Peripheral Transverse Lines II" and "Chevron Markings" (as seen in Table 9).

Table 9. Average Speeds between Law-Risk Drivers and High-Risk Drivers by Pavement Markings

Pavement Markings	Groups	N	Mean (mph)	Std. Error	t
Transverse Line 	Low-Risk Group	10	34.8 55.8 (km/h)	11.29	-5.63***
	High-Risk Group	12	50 80. (km/h)	8.93	
Peripheral Transverse Line I 	Low-Risk Group	10	36.1 57.8 (km/h)	11.97	-4.10**
	High-Risk Group	12	49.4 78.9 (km/h)	12.17	
Peripheral Transverse Line II 	Low-Risk Group	10	37.2 59.5 (km/h)	12.90	-3.50**
	High-Risk Group	12	48.2 77.1 (km/h)	10.76	
Chevron Marking 	Low-Risk Group	10	35.5 56.9 (km/h)	10.58	-3.63**
	High-Risk Group	12	48.6 77.7 (km/h)	15.35	
Dragon's teeth 	Low-Risk Group	10	37.1 59.4 (km/h)	9.69	-3.01**
	High-Risk Group	12	47.8 76.5 (km/h)	15.64	
Unmarked Section	Low-Risk Group	10	38.0 60.8 (km/h)	9.02	-3.83**
	High-Risk Group	12	50.1 80.1 (km/h)	13.66	

**p <.01. ***p <.001

5. DISCUSSIONS and CONCLUSION

Drivers' improper behavior can lead to fatal crashes; therefore, this study focused on how drivers' risk sensitivity and law-abidance affect speeding. In this study, drivers with deficiencies in risk sensitivity and drivers that violate traffic regulations tended to drive faster than other drivers. One problem is that low-risk sensitivity drivers seem apt to act emotionally, so they cannot correctly judge whether their behavior is dangerous. Also, law-breaking drivers displayed relatively higher speeds. This suggests that they could potentially lead to more serious car accidents than other groups.

Statistical analysis was conducted in order to verify how the subjects react to pavement markings in relation to speed. Looking at the mean difference of average speeds between the two groups of law-abidance (law-abiding and law-breaking) by pavement markings reveals that "Dragon's Teeth" and "Peripheral Transverse Lines II" were the most effective treatments for reducing driving speeds in the driving simulator. Following these was "Peripheral Transverse Lines I." The difference between "Dragon's Teeth" and the "Unmarked Section" (which had the highest speeds other than "Transverse Lines"), was 3mph (5km/h).

In analysis of the mean difference of average speeds between the two groups of risk sensitivity (high-risk and low-risk) by pavement markings, the overall results indicated the mean difference of average speeds between the two groups by pavement marking was different at a 95 percent confidence level. "Dragon's Teeth" proved the most effective perceptual technique for low-risk drivers. The speed difference between "Dragon's Teeth" and the "Unmarked Section," (which had the highest speeds other than "Transverse Lines"), was 2.3mph (3.6km/h). This study differs from previous studies in that it approaches the benefit to pavement markings on roadway facilities in regard to high-risk drivers. However, it was concluded that perceptual countermeasures are unlikely to strongly affect high-risk drivers' perception of speed on curves. Statistically, the mean difference of average speeds by pavement marking showed a

subtle impact on speed reduction.

This research will require more subjects to provide statistical significance to verify the results. In addition, studies into the psychological effects of the various patterns on high-risk drivers could provide more information. Further research will be required to determine the long term effectiveness of these countermeasures due to concerns over high-risk drivers becoming too accustomed to implemented markings. Lastly, the color contrasts (for example, dark asphalt with white markings) should be considered in further study.

References

MUTCD, *Application of the Manual on Uniform Traffic Control Devices for Streets and Traffic Control Devices for Streets and Highways*, 2001.

Department for Transport Traffic Signs Manual Chapter 5: *Road Markings*, 2003.

Virginia Department of Transportation, *Traffic Calming Guide for Local Residential Streets*, 2002.

Department for Transport, *Traffic calming on major roads - A49, Craven Arms, Shropshire*. Traffic Advisory Leaflet 02/97, 2005.

Iversen, H., & Rundmo, T. Personality, risk driving and accident involvement, *Personality and Individual Differences*, 33, 1251-1263., 2002.

Laapotti, S., Keskinen, E., & Rajalin, S. Comparison of young male and female drivers' attitude and self-reported traffic behaviour in Finland in 1978 and 2001, *Journal of Safety Research*, 34, 579-587., 2003.

Han, D. W., & Lee, K. S. Attributions of traffic accidents: the differences between the drivers and the traffic police, Korean *Journal of Psychological and Social Issues*, Vol. 8, No 1, 41-59., 2002.

Kim, J. H., Oh, J. S., & Lee, S .C. The influences of driving behavior determinants on traffic violations and accidents, *Korean Journal of Industrial and Organizational Psychology*, Vol. 19, No 3, 349-369., 2006.

Preusser, D. F., Williams, A. F., Fergusonb, S. A., Ulmera, R. G., & Weinstenia, H. B. Fatal crash risk for older drivers at intersections, *Accident Analysis and Prevention*, 30, 151-159., 1998.

Hakamies-Blomqvist, L., & Wahlström, A. Why do older drivers give up driving? *Accident Analysis and Prevention, 30, 305-312*., 1998.

Arnold, E. D., & Lantz. K. E., Evalution of Best Practices in Traffic Operation and Safety: Phase 1: Flasing LED Stop Sign and Optical Speed bars. Report Number FHWA/VTRC 07_R34. *Virginia Transportation Research Council*. pp.12-14, 37, 2007.

Katz. B.J. Pavement Markings for Speed Reduction: TPF-5(065). *Traffic Control Devices Pooled Fund Study*, 2004.

Macaulay, J., Gunatillake. T., Tziotis. M., Fildes. B., Corben. B., & Newstead. S. On-road Evaluation of Perceptual Countermeasures. Report Number CR 219. *Australian Transport Safety Bureau*., 2004.

Hancock. K. L., & Riessman. R. Report on Passive Speed Control Devices. Report Number 04-G020-001. *Massachusetts Traffic Safety Research Program*, 2004.

Drakopoulos, A.,& Vergou, G. Evaluation of The Converging Chevron Pavement Marking Pattern at one Wisconsin Location. *AAA Foundation for Traffic Safety*, 2003.

Godley, S. T., Triggs, T. J., Fildes, B. N., & Brown, L., Perceptual Countermeasures: Experimental Research. Road Safety Research Report CR 182, *Australian Transport Safety Bureau*, 1999.

Road Traffic Safety Authority. *Developing research for the improvement of drivers' aptitude test*., 1998.

Park, K. B., & Jo, E.. Influencing factors for citizens' voluntary conformity of the law, *Korean Journal of Psychological and Social Issues*, Vol. 4, 95-13, 1998.

(접수일 : 2012. 9. 3 / 심사일 : 2012. 9. 21 / 심사완료일 : 2013. 1. 10)