

Optical Illusion Effect on Traffic Safety

Liuxiao CHEN

College of Civil & Architectural Engineering, Chongqing Jiaotong University, Chongqing, CHINA

Abstract: When driving, there are some optical illusion phenomena in the road alignment and the driving environment which will affect the driver's visual effect. Driver may realize that the perception is wrong but still cannot make a correct respond promptly, which finally causes some operational errors, or even leads to a serious accident. By analyzing the reasons and the phenomena of optical illusion, the study intended to seek the measures to overcome as well as take advantage of optical illusion, then improve the road traffic safety and provide some references to the design of road landscape.

Keywords: Optical illusion; Road traffic safety; Road alignment; Application

1. Introduction

As the rapid development of economic construction, the road transportation plays a more important role in national economic development. At the same time, it also causes a massive number of traffic problems. Road traffic safety has become one of the important factors that influence the safety of public life. And there are 80%~90% of all traffic accidents are caused by human factors, of which, 70%~80% are due to the driver's own mistakes [1]. There is no doubt that driver is the certain factor that causes traffic accidents, but it is ought to further analyze the determining factors which lead to the driver's perception, judgment and operation mistakes.

Domestic and international researches indicate that the accident rate that is caused by optical illusion accounted for 36.8% of total traffic accident rate [2]. About 70% of information which driver obtained in the driving process is coming from vision. Driver uses his eyes to observe the appearance shapes of some objects, while forming a judgment in the brain. Sometimes the eyes may have not observed the object clearly, but the brain has reacted already. Such react often generate some errors. So it is necessary to understand the characteristics of optical illusion and grasp the rule of some different kinds of illusion in the process of driving. Such study may be able to help improve the road traffic safety.

2. Cause of Optical illusion

Optical illusion refers to one wrong judgment or perception which is produced in a moment when a person looking at objects but choosing an improper frame of reference or depending on the past experience. This is a kind of wrong judgment due to the disturbance of physiological and psychological factors as well as the interference of the shape, light and color. Physiologically, optical illusion is related to the structure of eyes. Driver is vulnerable to the interference of the form, light and color of one object when observing, then resulting in a visual er-

ror which is not tally with the actual. Psychologically, it is related to the current driving environment and the past life experiences [3]. This perceptual property is hard to fade and induces the behavior of driver directly insensibly.

The cause of optical illusion mainly includes: physical illusion (or physiological illusion) from an external stimulus or objects; sensorial illusion from the sensory organs; psychological illusion from the sense-center [4]. In general, the optical illusion tends to contain the combination of many factors.

3. Optical Illusion in the Road Environment

In the process of driving, natural environment and ancillary facilities along the road will evoke many visual effects on the driver's brain. Many accidents appear to be caused by the driver's oversight or errors superficially but finally proved to be attributed to the bad road surroundings. An abominable driving environment leads driver to make wrong judgments which generate accidents eventually. So it is ought to reduce the possibility of driver to make wrong judgments by the way of renovating and modifying the road surroundings.

Lighting, weather and landscape in the road environment as well as the choice of reference are likely to cause some optical illusions. There are mainly seven optical illusions in the driving process: distance illusion, speed illusion, bending illusion, slope illusion, width illusion, time illusion and color illusion [5].

3.1. Distance illusion

Driver may generates illusion on the basis of varies types of the opposite vehicles. He can't make a correct judgment to the length of vehicles or the distance between two cars. When the passing distance or the following distance is not enough it will lead to an accident. The characteristic of distance illusion is shown as follows: it looks more closer in the daytime but further at night or dark environment in the same distance; it looks more

closer when there is a cart driving in the front but further a small car driving in the front; it looks more closer when there is much reference along the road but feels distance when there is little reference; when two cars meeting, no matter how much different the two cars' speed is, it will always give an illusion that the meeting point is located in the halfway point of the distance between the two cars.

3.2. Speed illusion

Driver always operates the car on the basis of the judgment of speed. Most of drivers prefer to depend on the moving objects which they observed to estimate the speed rather than the speed table. In this way, different dynamic scenery will lead driver to produce different judgment of speed. For instance, it is easy to overestimate the speed on urban road but underestimate the speed on wild road; during acceleration, it is easy to overestimate the speed at a low speed, thus leading to extend the distance when overtaking other cars on the road; during deceleration, driver underestimates the speed easily which may trigger a dangerous situation due to the high speed when the driver making a turn or meeting the opposite car; driver will adapt to a speed after a long time running so that to underestimate the speed easily, especially the most dangerous situation of underestimating a high-speed.

3.3. Bending illusion

According to the requirements for science, there is no completely straight road. The natural curves and artificial curves of highway make roads extending in all directions. Driver controls the speed often according to the changing of the road camber. However, the extent of change also can cause some illusions. Tests have shown that when a circular arc's length is less than the semicircle, driver will tend to feel the radius of the curvature is so smaller than the actual. The shorter the arc length is, the smaller the curvature radius is. When driving in the consecutive turns of mountain road, even if the radius of curvatures are same, the driver will also feel it is more easier to turn on a mountain road but harder to turn on a plain road. Such illusion may lead to a very dangerous high-speed when during a continuous turning. It is necessary to pay attention to set enough space for turning so that to make sure the rear wheels will not out of the road and the deceleration is effective.

3.4. Slope illusion

When driving on a downhill for a long distance, the driver will produce an illusion of driving on a flat road. When close to the bottom of the long and steep downgrade sections or the slope becomes smaller, driver will often think the downhill has become to an uphill. At this time, the driver may step on the gas which leads to a faster speed. When the slope of an uphill be-

comes moderated, driver also tends to think the uphill has changed to a downhill. If he presses on the brake at this moment, it will be easy to make the vehicle occurring landslip.

3.5. Width illusion

When driving in a tree-lined road at night, the reflection from both sides of trees makes driver to cause a feeling of driving in a narrow channel. After the trees disappearing or becoming shorter, the driver will generate an illusion that he has driven out of the narrow way then become driving fast. What's more, when overtaking in a high-speed, driver will feel the road is narrow. When driver making a turning, he will generate an illusion that the road has become narrow which may lead to taking an operation in a muddle.

3.6. Time illusion

Driver often feels time flies when driving in a good mood. On the contrary, he will feel time drags when driving in a flutter. In addition, he will feel time passes quickly when driving in an urgent circumstance because of being eager to reach the destination quickly. At this moment, the driver is easy to cut in or drive too fast and such psychological state of advanced will cause illusion. In this case, driver should avoid impatience and adjust the state of mind then be more patient to drive as well as control the speed so that to ensure the safety.

3.7. Color illusion

Color penetrates into every corner of the road traffic environment. For the driver, at least 80% of the information is obtained by vision, and the color of an object is the easiest information to be perceived. Due to the complexity of color, it is easy to cause color optical illusion. This is a psychological and physiological phenomenon. Color illusion is essentially based on the visual characteristics of color, and these features as shown below: the cold-hot sensation, the swell-shrink sensation, the advance-retreat sensation, the vivacious sensation, the fatigue sensation, the light-heavy sensation and the hard-soft sensation.

Different sensations of color will produce different visual effects. Red, orange, yellow belong to the warm color department which gives people an impassioned feeling. But the simulating effect of the warm color is big. When using a strong warm color or watching a warm color for a long time, the driver will feel tired, irritable and uncomfortable. So it should use the warm color reasonably, especially in the color design of slope. The cool color such as blue or green tends to evoke placid and peaceful feeling. It can be used to ease the driver's mood. Generally speaking, the warm color will evoke a fatigue feeling for its strong simulation to people when compared with the cool color. The reason why it remains such difference is that a high brightness and hue color will be more easily

to make a person's optic nerve tired. For the same area, an expansive color and a contractile color will give a person different feelings. The expansive color makes a graphic's area seemed larger than the actual, and the contraction color comes to the opposite. In general, a high brightness color brings a forward, expand and vivacious feeling, on the contrary, a low brightness color has a regressive, shrunken and gloomy sense. Sense of lightness determines the feeling of color's weight. The color with high lightness will make people producing a feeling that the object is light, and the color with low lightness will make people producing a feeling that the object is heavy. For the aspect of hue, a warm color gives people a feeling that the object is light and a cool color gives a feeling that the object is heavy. At the same time, a light feeling color gives people a sense of soft and expansion, and a heavy feeling color gives a sense of hard and contraction.

4. Optical Illusion Caused by Road Alignment

The design of road alignment is always finished on the basis of two-dimensional space which divides the design of three-dimensional road alignment into horizontal alignment design, profile alignment design and cross-sectional design. However, a road surrounding always shows its unique three dimensional features in the practical application [6]. As a result, the following situations will be happened in road alignment design: road designers design the road according with the properties of automobile driving, at the same time, they conform to the standard of road design. But it still remains some illusions due to the improper road alignment design which causes the traffic accidents. Some optical illusions caused by the improper alignment design are described as follows.

4.1. Optical illusion in straight road alignment

People generally believe that the safest state is driving on the straight line. But if the length of a straight road is too long or too short will make the driver generating some driving illusions which may evoke the potential security risks.

When driving in a long straight road, after a long time driving, the driver will become depressive and impatient due to the lack of changing of the line. He will be eager to pass through the boring long straight line quickly, thus accelerating in the subconscious. In general, with the increasing of the driving speed, the driver's field of vision gradually narrowed then he will hard to make a rapid and effective judgment to the road environment. As a result, he cannot adopt the right approach to deal with a sudden emergency.

When driving in a short straight road, especially when the short line is inserted into the synthetic circular curves, which is called "broken back curve", the driver will gen-

erate an illusion of inflection because of the short straight line and circle curve. The "broken back curve" causes driver to change direction before entering the straight line which may lead to traffic accidents.

4.2. Optical illusion in curve road alignment

When driving in a curve road, driver generates curve illusion easily. When the location of an object is different, the size of image obtained by visual perception is different. So the less visible part of the curve, the curvature more likely to be underestimated [7]. For example, the radius of an s-shaped curve road will be seemed smaller in the distance than near on the visual effect. For the length of an arc line which is no more than the length of a semi-circle, its radius will be seemed smaller than the actual on the vision. For the continuous curve, due to the constantly changing of the gazing direction of driver, the driver will generate an illusion that the curve is more tortuous than actual [8]. Such kinds of optical illusions from the curve road alignment will make driver turning steering wheel more or less, and it is disadvantageous for driving safety.

Road alignment is a combination of plane curve and vertical curve. So a good combination is the key for driving safety. The bending optical illusion is the biggest illusion influenced by the combination of road horizontal alignment design and vertical alignment design. A combination of the plane curve and concave vertical curve can make the line shape relatively flat on the vision. When driving on the curve, driver will be too late to realize the existence of plane curve, and still speeding up. The combination of plane curve and vertical curve makes the effect of plane curve more crooked than the actual on the vision. Sometimes, even if the longitudinal slopes front and back the vertical curve have meet the maximum longitudinal grade vertical curve, but if the slopes front and back is too much different it also will be easy to make driver generate cliffs illusion. Such illusion causes the error of driving and traffic accidents.

5. Correction and Application of Optical Illusion

5.1. Correction of optical illusion

Although the optical illusion may be inevitable, at least it can be corrected and avoided by reducing the visual errors in the road alignment design. The roads which had not fully considered the visual factors before being designed can be corrected only by amending the elements which are easily modified in road environment. For a new road, the corrective methods can be summarized as follows:

(1) Improve the unreasonable linear factors in the road. The length of the straight line between two adjacent curve lines should not be too short; The difference of

slope front and back the vertical curve should not be too big so that to prevent to produce slope illusion; The combination of plane curve and vertical curve should be integrated with the natural environment; It should be avoided the combination of a long horizontal curve with a steep slope as well as a minor radius with a short vertical curve; A long horizontal curve should not contain too many vertical curves; A minor radius curve should not be set in a long vertical curve; It should be avoided the superposition of the top of a convex vertical curve or the bottom of a concave vertical curve with the inflexion point of a reverse plane curve [9].

(2) Use landscape elements along the road to avoid optical illusion. When there is a cross exists in the bending part of a road, the planar and discrete plant landscape or structure can induce a good visual effect. When the intersection is on the left side of the road in the forward direction, the structures should be set on the right side of the main road and secondary main road and vice versa.

(3) A reasonable use of vision features of color can also play a positive role in traffic safety. Driver produces different emotions by the perception of different colors unconsciously. Red has the most visual impact, orange gives people a feeling of warm, yellow has the highest brightness, green is the highest fitness color to human's eyes, purple has the minimum lightness, white reflects all light and black absorbs all light. Thus color will affect traffic safety in some way. It can make use of the synaesthesia of color including changes in temperature, light or heavy, strong or punt, advance or retreat, soft and hard unites function esthetics and art esthetics to weaken hidden troubles in road traffic safety. When people observe one object initially, 80% of the attention is paid to its color [10]. At present most road surface appears as gray or black, and such colors have a calming effect on driver's nervous system. But a long time watching can make driver's attention become dull, feel fatigue and become sleepy, then increase the risk of traffic accidents. Color to the proper position on the road can improve the driver's visual environment, remind the driver to pay more attention to the special section, simulate his nervous system, then help the driver keep awake. For example, the steep slope, curve and speed limit area are coated with yellow can improve the driver's vigilance; the acoustic area are coated with blue means the driver should press the horn softly or not press the horn; some particularly dangerous sections on the Alps in the Sweden has been painted with red which leads to the result of traffic accidents decreasing by 85%~90%. Practices prove that the coloring highway has the advantages that the pure black coloring asphalt road and the white coloring cement road not have. Its outstanding aspect is the rich colors can simulate the driver's brain, relieve his fatigue, keep him a good mood then reduce accidents.

It can also through matching the design of affiliated facilities with the color landscape on both sides of road to achieve the alleviating fatigue effect. For instance, in Turban and Urumqi a blue highway waveform guardrail will be adopted. This color can make a stark contrast to the yellow Gobi Desert. Such guardrail makes driver constantly be received the outside stimulation so as to keep a clear driving condition. However, in a green mountains place or a good planting road it should avoid painting a blue and green road fence.

On the choice of road landscape plants, besides attaching great importance to the engineering properties of plants, the color of plants should be targeted selected according to the highway area. In hot areas it should adopt cool color which can make driver feel relaxed. While in cold areas it should use a warm color department. But the hue should not be too strong, or it will cause a feeling of fatigue, irritability and discomfort by a long time watching. It can adopt a change of color types of plants at a regular interval. Such change can not only make the bright-colored flower to foil a warm feeling and simulate driver's nervous system to make the driver stay awake driving condition, but also can avoid a too bright-color to make driver fatigue.

It can adopt a contrast color of traffic signs line in a dangerous road to simulate the nervous system of driver so that to enhance the effect of visual perception [11]. In addition, it can also use the forward and withdraw sense of color to convey some information to the driver [12]. As shown in Figure 1, it presents a highway toll station. B and C represent the warning sign boards or advertising boards. The upper end of A, B and C painted with maize-yellow, and the lower end color of B and C gradually translated to the celadon. Such coloring mode produces an illusion that as if reducing the distance between the toll station and B and C. The information of "the toll station has been arrived already" can be passed to the driver early so that the driver will have more time to adopt measures to slow down.

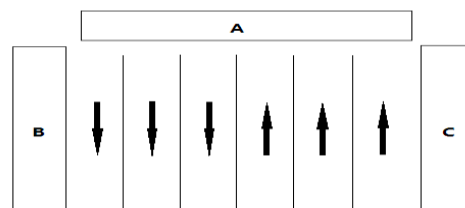


Figure 1. The forward and backward phenomenon of color

(4) Use the sense of distance to correct the poor road alignment. When the spatial location of an object is different, the visual perception of people is different. For the same object, the one in distance always appears smaller than the one in the vicinity on the vision. The vision of people are often influenced by the surrounding environment, when the size of the landscape element outside the

road line is 50% larger than size inside the road line, the inside one will be larger than the actual on the vision. So as far as possible, it should keep an appropriate distance with a large area or a big volume element in design of landscape.

5.2. Application of optical illusion

If the optical illusion can be used effectively and be targeted to ameliorate road signs or traffic marking, it can take part in helping people to observe the road order and control the speed so that to improve road traffic safety [13]. The comparative mature of optical illusion in road traffic safety is a variety of optical illusion speed humps such as the longitudinal speed hump, the transverse speed hump, the shark fin shape speed hump and three-dimensional color stereo speed hump.

The longitudinal speed hump makes an illusion of the front driveway gradually narrowed by a reasonable design of the additional lane edge's form, so that to increase the driver's tension in the driving process and induce driver braking to slow down. This kind of performance is based on the theory of traffic engineering and traffic psychology. It seems to compress the width of the driveway physically, and make drive thinking the lane in front has been narrowed. Such speed hump can improve the driver's attention, remind driver to slow down and drive carefully. By using the illusion of the road width or the driving speed to change the visual intersection point of driver can make the drivers feel the edges of the road are intersected in a closer point.

The transverse speed hump is perpendicular to the centerline. It can make driver to reduce speed by influencing the driver's perception of the actual speed. As the distance between two adjacent lines decreasing along the vehicle movement direction, this speed hump can effectively reduce the speed. This way of marking layout causes a feeling that the driving speed has been increased while the speed did not change actually. Thus such illusion will induce the driver to decelerate. The reduction mechanism is that when the driver drive through the line section but not slow down, more marking line will come into his view, the line blinking rate will become more quickly, just like the speed becomes faster and faster. Nevertheless, if the driving speed has been reduced gradually, the marking will flash at a constant frequency. The shark fin speed hump is another horizontal speed hump which is used to reduce the driving speed. It is by means of retracting the distance of two adjacent marking lines so that to give the driver the illusion mentioned above [14].

The three-dimensional color stereo speed hump is designed according to the law of human vision and psychology, and combines the three dimensional principle with the mechanism of visual illusion. Such pattern of marking can produce a stereo effect. When in the process

of driving, it can make driver thinking there are some obstructions existing on the road, thus taking brake actively. This marking pattern can not only achieve the slowing effect, but also avoid causing damages to vehicles. But there are also some limitations to use this kind of speed hump. Such speed hump should be painted on the proper location. It cannot be drawn in curve or other area where driver can't be agreed to see. Otherwise, it may cause the driver to make an emergency braking or take a sudden turning which may give rise to a collision or a vehicle scratching [15].

The advantages of optical illusion speed hump are shown as follows: it will not damage the pavement structure; it is affordable and convenient for construction; driver does not take a braking to slow down forcefully. The driver will decelerate spontaneously so as not to cause errors.

But the defects of such measures also should not be ignored: When the driver has been familiar with the reduction measures of a certain road, he will respond in advance and even no longer slow down so that the slowing effect will be weakened; The marking line will be wear and tear when it is used for a long time; If the marking line set unreasonable, the driver will take braking compulsorily when he found the speed hump which is more likely to cause traffic accidents. What's more, for the pattern of the speed hump, the ground mark can also be used which is based on clairvoyant principle. In our country, currently USES of the ground mark is one pattern of the traditional vertical arrangement which is on the basis of two-dimension. But in actual, a road shows its characteristics to driver is in a 3D way. The visual perception theory shows a perspective phenomenon that a closer object in space always seemed bigger than the further one. So we can design a road sign which is used a bigger word in the distance and use a smaller word in the near.

6. Conclusion

Good road alignment can not only induce the driver's line of sight, but also can reduce the traffic accident rate. Although the visual illusion is inevitable, we can reduce the number of traffic accidents by correcting and optimizing the alignment line as well as using a reasonable optical illusion. The conclusion of this article is mainly from the following three aspects:

In terms of driver: The illusion would produce some hidden troubles on the traffic safety, so that the driver must understand the factors which are easy to cause visual illusion. Driver must be in accordance with the car dashboard and observe carefully while driving in order to avoiding the negative effects of the visual illusion.

In terms of road alignment design: Diver will take the driving operation according to the road alignment. An unreasonable design of the road alignment may produce some bad visual illusions. In order to avoid the bad opti-

cal illusions, it is necessary to adopt a good visual effect alignment.

In the terms of applications of optical illusion in the road environment: The application of visual illusion in landscape design is not universal, and the visual feature has been used limited. It is just simply used in symbol. But the visual feature has more significance and functions to the road. It is confined to the plane speed hump. In addition, it is lack of unified standard and requirements to restrain the visual illusion.

In the terms of the application of color illusion: Color has a strong influence on human vision. The modern practice of color shows that a reasonable application of color can benefit mankind, society and environment. However, it also will bring many negative effects in the opposite side. Therefore, it should use and analyze color data scientifically, and according to the corresponding theoretical guidance system to realize the combination of color design of highway landscape and road traffic safety.

If the visual illusion can be used more reasonable, it will be more conducive to prevent traffic accidents.

References

- [1] Mohamed A, Abdel Aty A, Essam Radwan. Modeling traffic accident occurrence and involvement[J]. Accident Analysis and Prevention, 2000, 32(5): 633-635.
- [2] CHEN Le-jun. Simply analyze illusion and prevention countermeasures caused by highway geometric and roadside environments[J]. Science & Technology Information, 2008, 25.
- [3] ZHOU Dong-mei. Researches of Optical Illusion in Environmental Space Designs and Its Application[D]. Shanghai: East China University, 2006.
- [4] MA Xian-bing, SUN Shui-fa, XIA Ping, GONG Guo-qiang. Visual illusion and its application[J]. Computer and Information Technology, 2012, 20(3): 1-3.
- [5] WANF Nan, SHAO Yi-ming, YAN Hong-tao, ZHOU Na-na. Analysis of Optical Illusion in Road Traffic Safety[J]. Highways & Automotive Applications, 2010, 4.
- [6] LI Duo-qi, FU Xin-sha. Visual illusion and correction in road alignment design[J]. Central South Highway Engineering, 2004, 29(2): 86-89.
- [7] YUAN Guo-lin, CHEN Jian-chuan. Application of the illusion in the design of highway route[J]. China Journal of Highway and Transport, 2002, 2.
- [8] GUO Qian, WU Guo-xiong, WANG Fu-jian. Cartoon simulation analysis of illusion caused by highway alignment and roadside environments[J]. Journal of Chongqing Jiaotong University, 2006.5.
- [9] SUN Bao-yun, DONG Lei. Prevention and application of optical illusion in the design of highway Route[J]. Highway Traffic Technology (Application Technology Education), 2014.6.
- [10] LI Duo-qi. FU Xin-sha. Visual illusion and correction in road alignment design[J]. Central South Highway Engineering, 2004.2.
- [11] [Japan]DAITI Hiroshi. The knowledge of color design[M]. YIN Wusong, tmsl. Beijing: Popular Science Press, 1986.
- [12] XU Xin. Color and traffic safety[J]. China Science and Technology Investment. 2013(23): 291.
- [13] WEI Zhonghua, WANG Shan. Highway landscape color effect[J]. Journal of Beijing University of Technology.
- [14] LIU Hao-xue, LIU Jia, ZHAO Wei-hua, YAN Xian-hua, YAN Ying. Parameter optimization of highway optical illusion deceleration markings[J]. Journal of Chang'an University (Natural Science Edition), 2011, 31(6): 77-81.
- [15] ZHOU Jian-ping, CHEN Fei, CHENG Yin-yin, CHEN Li-li. Study of speed hump technology based on the principle of optical illusion[J]. Highway Traffic Technology (Application Technology Education), 2013.4.