Optical Illusions on Roads and Measures for Their Reduction

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Introduction

An optical illusion is an illusionary phenomenon where what we see differs from what exists in reality. In the sense that anyone can fall prey to them, optical illusions are universal. By causing errors in judgment, optical illusions can cause accidents. This is particularly true in the case of a moving vehicle. What the driver sees from the perspective of the driver's seat is constantly moving. This means the driver must make instant judgments without enough time to really examine what he is seeing. For this reason, the driver is particularly susceptible to optical illusions. From this, it can be deduced that a close relation exists between optical illusions and traffic accidents. While many accidents are blamed on driver carelessness, it is possible that in a significant number of such cases, driver carelessness has actually been induced by some form of optical illusion. Considering the seriousness of this possibility, there is an urgent need to identify the relation between optical illusions and traffic accidents and to develop guidelines for effectively reducing or eliminating such optical illusions. It is for this purpose that this booklet has been prepared by members of the Japan Science and Technology Agency CREST Project for "Computational Illusion" in consultation with other experts.

It should be noted at the outset that this booklet is not without its shortcomings. In the normal course of research, research results are published only after sufficient experimental data have been collected and closely examined within an appropriate theoretical framework. Researchers finally publish their works when they are sufficiently confident that their conclusions are correct and viable. However, the daily occurrence of tragic traffic accidents prompts us to question whether we can afford to wait until that level of confidence has been achieved. Although perhaps insufficient for academic purposes, we feel that if the sharing of this knowledge can contribute to reducing traffic accidents, we would be justified in publishing our findings as soon as possible. This booklet reflects such an outlook, and may thus be faulted for containing materials that are not fully supported by theoretical foundations as normally required in academic publications. What we have done is to hypothesize (and in places to bolster our hypotheses with bold assumptions) that certain conditions can give rise to an optical illusion that may in turn become the cause of an accident. We are aware that such sections of the booklet may invite criticism, and look forward to supplementing those sections in the future.

Thus, this booklet is being published with the earnest hope to improve our understanding of traffic accidents and to contribute however modestly to their reduction.

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1. Optical Illusions Related to Sloping Roads

Phenomenon

When driving through a series of slopes, an ascending slope can appear to be a descending slope from the perspective of the driver. Conversely, a descending slope may appear to be an ascending slope. Under these conditions, it is very easy for the driver to misjudge the incline of the road. Mistaking a descending slope for an ascending one can result in speeding, while mistaking an ascending slope for a descending one can result in unnecessary loss of speed. This slight tendency for drivers to slow down is a cause of serious traffic congestion. For example, in Figure 1.1, the slope seen in the distance is actually a descending slope. But many drivers mistake it for an ascending slope. As shown in Figure 1.2, it is often difficult to accurately judge the incline of the road when driving through a tunnel.

Figure 1.1. Example of a descending slope that appears to be an ascending slope. The distant slope appears to be ascending but is actually descending. (Yashima Driveway, Kagawa Prefecture; photo by Akiyasu Tomoeda)

Cause

Mistaking the incline of the road can be caused by various factors. For instance, an optical illusion may occur on a portion of a road with two differing inclines. In the case of Figure 1.1, a trough appears where two descending slopes converge (referred to as a "sag"). Wherever there is a sag in the road, there is a very strong tendency for drivers to misjudge the incline. Both slopes may be ascending or both may be descending. In both

cases, the nearer incline appears to be descending and the farther incline appears to be ascending.

Countermeasures

Drivers can be helped to correctly judge the incline by adding patterns to the side of the road to indicate horizontal direction. An example of such a pattern is shown in Figure 1.3. Patterns can be easily added inside tunnels or on roads equipped with sound walls because appropriate structures already exist. The addition of such patterns should be helpful in reducing this type of optical illusion.

Figure 1.2. View inside a tunnel.
The patterns on the wall are registered as an indication of horizontal direction, creating an illusion that the road surface has no incline. Actually, this is an ascending slope. (Hanwa Expressway; photo by Akiyasu Tomoeda)

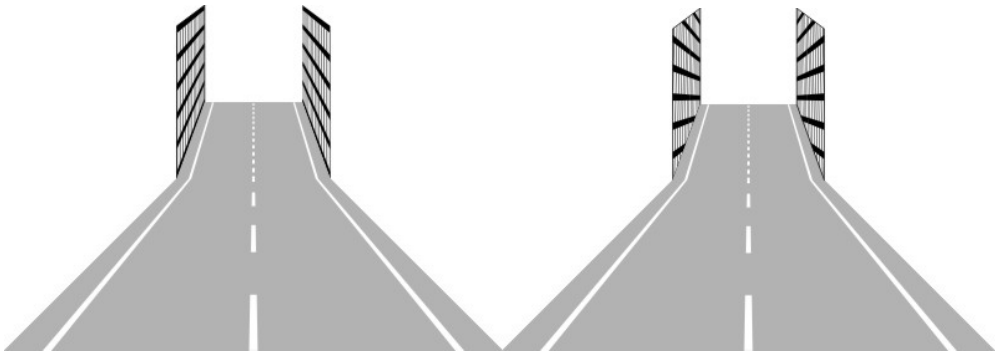

Figure 1.3. Striped pattern and impact on recognition of incline.
With the pattern shown on the left, 80 percent of respondents (sample of 162 drivers) judged the farther incline to be horizontal. With the pattern on the right, 90 percent judged the farther incline to be ascending. (Image by Seiichi Tsuinashi)

2. Optical Illusions Related to Car Lanes

Phenomenon

When driving on an ascending slope, an approaching vehicle slightly beyond the top of the slope appears to be running in the same lane as the driver, although in reality it is running in the opposing lane. (A driver trying to avoid a head-on collision by moving into the opposite lane can end up causing a head-on collision.)

Cause

When there is a curve beyond the top of the slope, the driver is unable to see the surface of the road. Because the driver sees only the top half of the approaching vehicle, he is unable to determine which lane the approaching vehicle is running in. In Figure 2.1(a), the road curves to the left beyond the top of an ascending slope. Assume that both Vehicle A and Vehicle B are running in their respective correct lanes. As shown in Figure 2.1(b), there is a moment when it appears to the driver of Vehicle A that Vehicle B is approaching in the same lane.

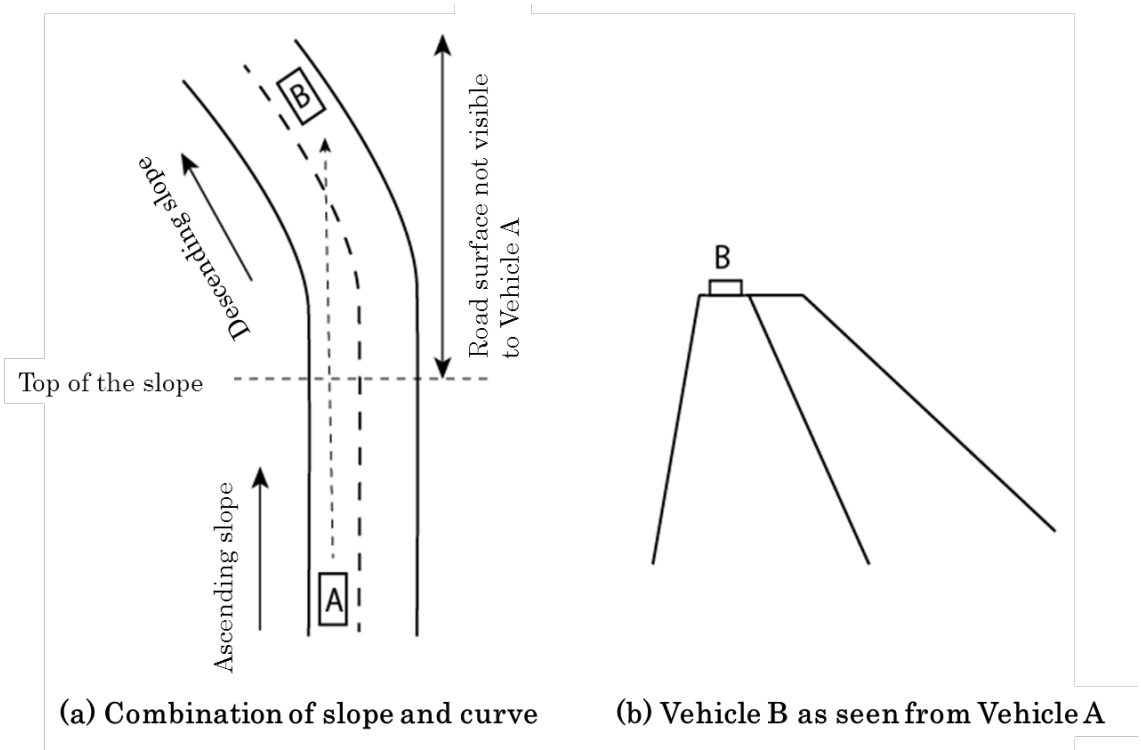

Figure 2.1. Road curves beyond the top of the slope

An even more dangerous example is shown in Figure 2.2 where the road follows a crank-shaped curve beyond the top of the slope. When the approaching vehicle lines up with the left lane of the ascending slope, the illusion is sustained and it appears to the driver of Vehicle A that Vehicle B is maintaining a course that will end in a head-on collision.

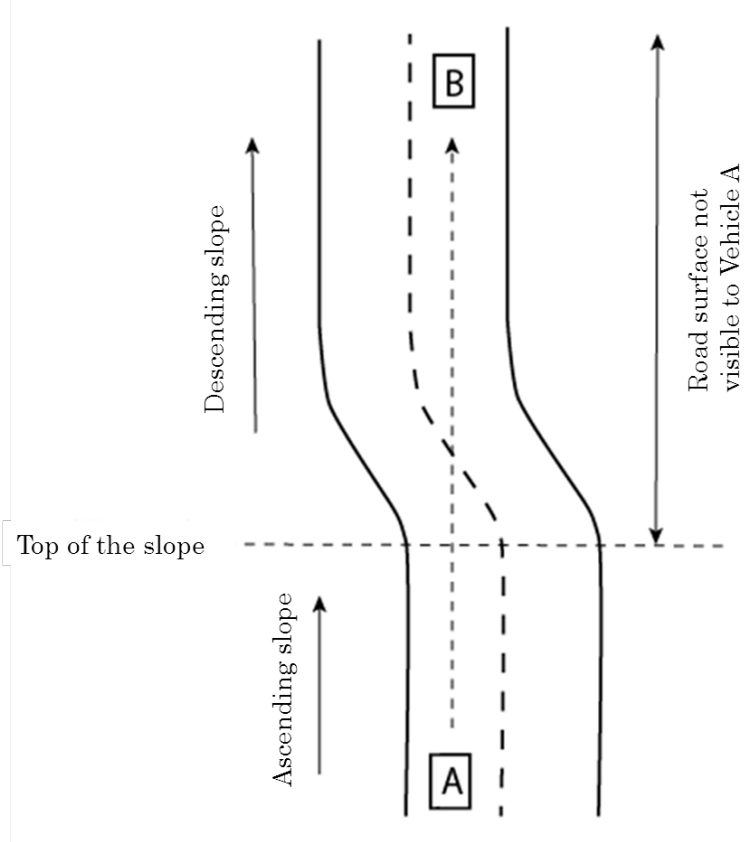

Figure 2.2. Crank-shaped curve beyond the top of the slope

Countermeasures

1. The most important thing is to avoid building roads shaped like this.
2. In the case of existing roads, an effective countermeasure would be to install a centerline separator wall that is tall enough to be seen from the ascending vehicle. The optical illusion is avoided by the separator wall, which hides the approaching vehicle that is running in its correct lane.

Another example is shown in Figure 2.3 where railway tracks intersect a curving street. Furthermore, the street is sloping and the railway tracks are located at the top of the slope. Figure 2.4 shows the street as seen in the direction of Arrow A. Figure 2.5 shows the view from immediately before the railway tracksand Figure 2.6 shows the view as seen in the direction of Arrow C. A pedestrian standing at Position D on the edge of the street suddenly appears before a driver moving in the direction of Arrow A, and appears to be standing in the middle of the street.

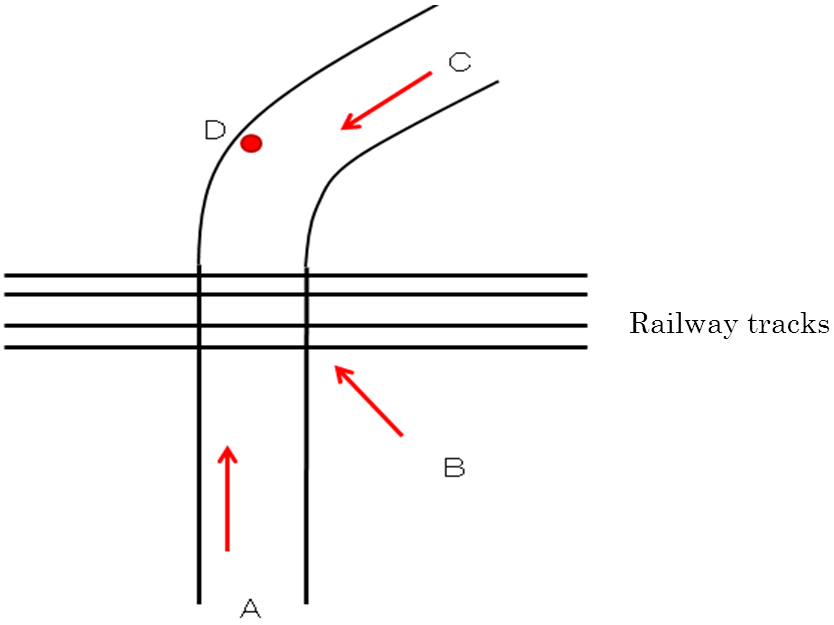

Figure 2.3. Railway tracks intersect the street at the top of the slope

Figure 2.4. Street as seen from the direction of Arrow A in Figure 2.3
(Photos in Figures 2.4, 2.5, and 2.6 by Kokichi Sugihara)

Figure 2.5. Pedestrian standing on the edge of the street suddenly appears before the driver as the driver approaches the railway tracks

Figure 2.6. Street as seen from the direction of Arrow C in Figure 2.3

3. Optical Illusions Related to Traffic Lights

Phenomenon

A traffic light standing on a flat portion of a road appears to be farther away than the next traffic light, which stands on an ascending slope. (A driver may ignore a traffic light by mistakenly obeying a traffic light that appears to be nearer.)

Cause

Normally, traffic lights are the same height. Due to the impact of linear perspective, the closer traffic light appears to be taller from the perspective of the driver, as shown in Figure 3.1. However, an optical illusion occurs when the nearer portion of the road is flat, and is followed by an ascending slope, as shown in Figure 3.2(a). With two traffic lights standing in each portion of the road, the traffic light positioned on the slope appears to be taller. As a result, the driver judges that the second traffic light is nearer. This risk is particularly high at night when the supporting pole is not visible and only the traffic light can be seen. Truck drivers seated at an elevated position are especially prone to this illusion.

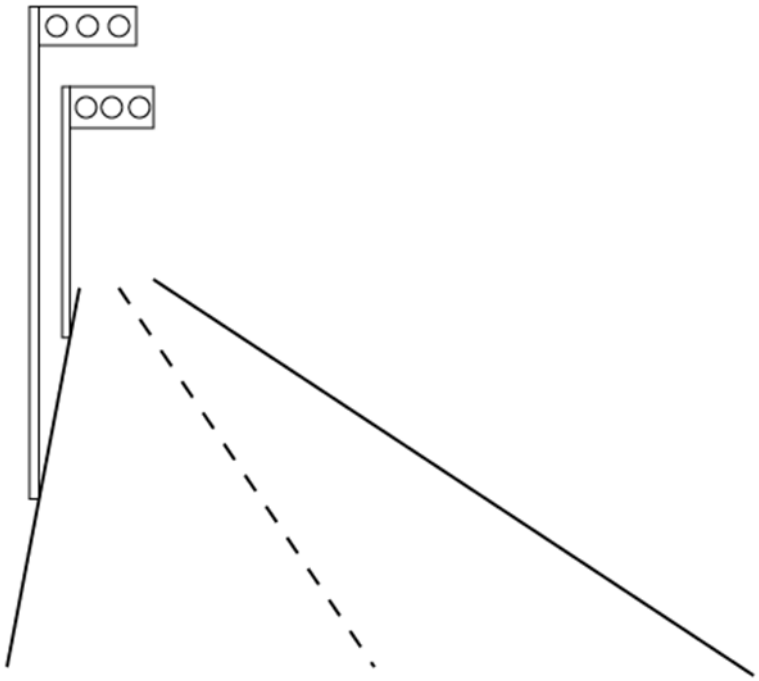

Figure 3.1. Two traffic lights standing on a flat road

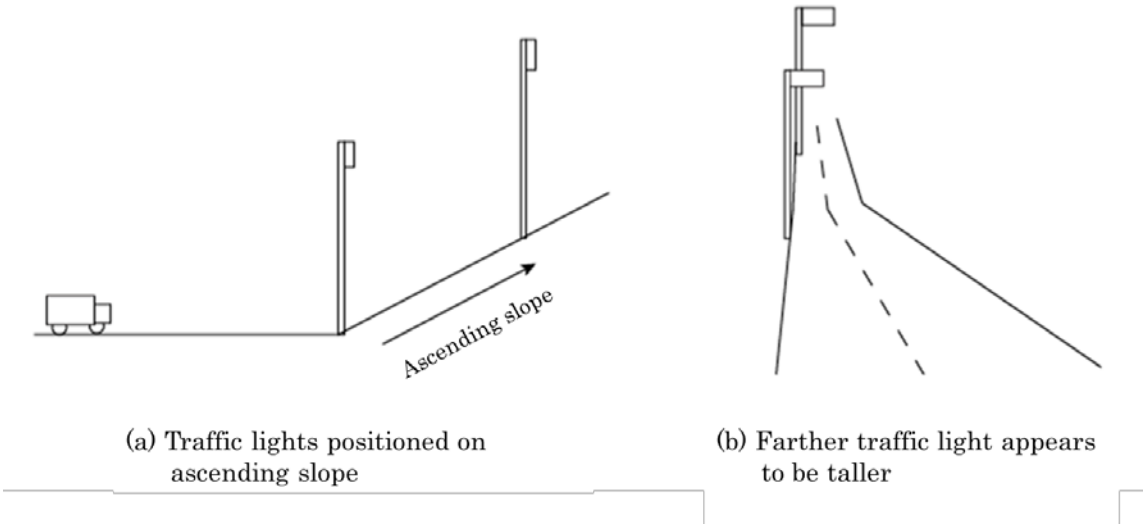

Figure 3.2. Driver's perspective of traffic lights positioned on an ascending slope

Countermeasures

1. Synchronize the two traffic lights. If the two are simultaneously red, the driver's misjudgment that the farther light is nearer will not result in the driver running a light.

4. Optical Illusions Related to Vehicles Approaching at Equal Speeds

Phenomenon

A vehicle approaching on an unobstructed perpendicular road may go unnoticed. The danger is compounded on country roads where the driver does not expect other vehicles. (The risk is particularly high at a T-shaped intersection because, even when the driver of a vehicle approaching along the top of the T has noticed the vehicle that is coming from the bottom of the T, it is highly probable that he will drive through the intersection on the expectation that the other vehicle will stop.)

Cause

As shown in Figure 4.1, assume that two vehicles are approaching a T-shaped intersection. Both vehicles are driving at the same speed and are positioned at the same distance from the intersection. From the perspective of Vehicle A, the other vehicle is constantly positioned at the same 45° angle. This creates an optical illusion that leads the driver of Vehicle A to think that Vehicle B is not moving. Alternatively, because the driver does not see the movement of Vehicle B, it is more likely for him not to notice Vehicle B. As shown in Figure 4.2, the risk is compounded when Vehicle B is hidden behind the frame between the windshield and door window. In this case, Vehicle B remains hidden throughout the entire approach to the intersection and goes unnoticed by the driver of Vehicle A.

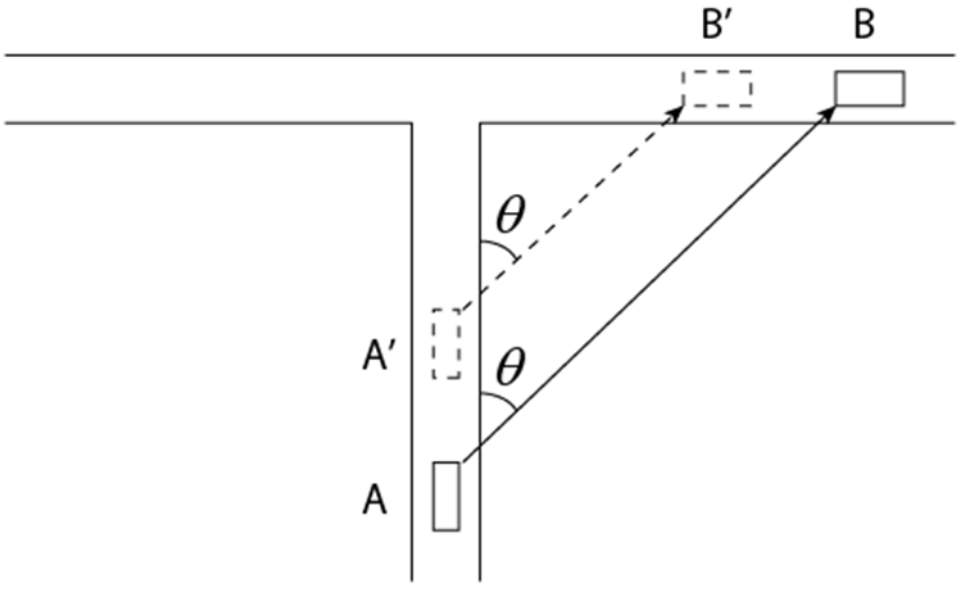

Figure 4.1. Two vehicles approaching at a constant angle ($\theta = 45^{\circ}$)

Figure 4.2. Vehicle approaching on a perpendicular road
hidden by the frame between the windshield and door window
(Photo by Kokichi Sugihara)

Countermeasures

1. The ideal countermeasure would be to manufacture vehicles with no frame between the windshield and door window.
2. In existing vehicles, the only available measure is for drivers to be more careful.

5. Height of Headlights and Sense of Distance

Phenomenon

At nighttime, approaching buses, trucks, and other large vehicles may appear to be farther away than they actually are.

Cause

At nighttime, a pedestrian primarily relies on the height of headlights to judge the distance of an approaching vehicle. As shown in Figure 5.1, because vehicle lights are lower than the height of the eye and due to the resulting impact of linear perspective, the pedestrian judges that lights appearing lower in his field of vision are nearer. However, headlights are positioned higher in large vehicles and appear higher in the field of vision. As shown in Figure 5.2, by mistaking this for the headlights of a smaller vehicle, a pedestrian may judge a large vehicle to be farther away than it actually is.

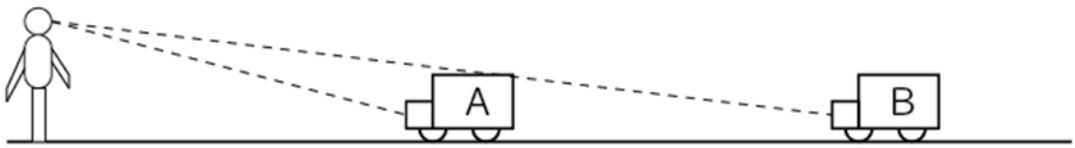

Figure 5.1. Relationship between the distance and the position of lights in the field of vision

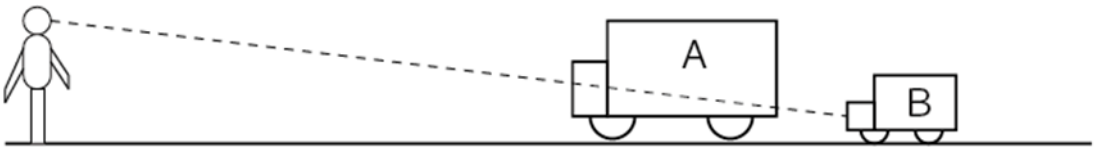

Figure 5.2. Position of the headlights in a larger vehicle

As shown in Figure 5.3, another optical illusion can occur when a vehicle is descending a slope as it approaches. In this case, the lights appear higher in the field of vision. If the pedestrian is unaware of the descending slope, he may judge the vehicle to be farther away than it actually is.

Because vehicles have two headlights, the distance between the two headlights also gives the pedestrian an idea of distance. This can help the pedestrian correct his perception of distance. However, because motorcycles have only one headlight, it is easier for the pedestrian to mistake the distance of motorcycles.

When driving on highways at nighttime, a long-distance bus running parallel to a passenger vehicle appears to be farther away than the passenger vehicle. The taillights of large vehicles are positioned relatively higher on the body. In comparison, the taillights of passenger vehicles are positioned lower. When these are running in parallel, if a driver following behind these two vehicles judges distance based on the height of the taillights, the large vehicle will appear to be farther ahead than the passenger vehicle.

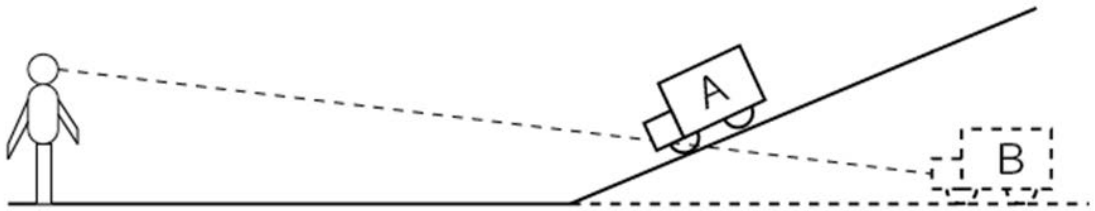

Figure 5.3. Position of the headlights of a vehicle approaching on a descending slope

Countermeasures

1. Nighttime measures should be taken to make vehicles more visible. For example, trucks decorated with neon lights can be easily identified as large vehicles. Neon decorations are desirable from the perspective of judging distance correctly.
2. If possible, laws and regulations should be enacted mandating that the height of headlights be uniform, regardless of size of vehicle.
3. Measures should be taken for easy recognition of vehicle size at night. Special lights can be attached to the back of large vehicles so they can be easily recognized from behind. Highly visible reflecting panels should be added to help in estimating distance.

6. Optical Illusions Related to Speed

Phenomenon

A driver underestimates the speed of his own vehicle immediately after exiting a tunnel.

Cause

From the perspective of a driver, nearby scenes (such as the walls of a tunnel) flash by at high speed. Because the eye adjusts to this speed, and because more distant scenes appear to be moving more slowly after exiting the tunnel, the driver underestimates his own speed.

Countermeasures

1. To allow enough space for the eyes to adjust after exiting a tunnel, sharp curves and highway exits should not be placed near a tunnel exit.

7. Optical Illusions Confusing Right and Left

Phenomenon

Corner mirrors are often installed on the two sides of an intersection with poor visibility. A driver mistakes a vehicle approaching from the right to be coming from the left, and vice versa.

Reason

Figure 7.1 shows a street with two corner mirrors. The mirror on the left reflects traffic approaching from the right, and the mirror on the right reflects traffic approaching from the left. As a result, a vehicle approaching from the street on the right-hand side of the intersection will appear on the mirror on the left. Conversely, a vehicle approaching from the left will appear on the mirror on the right. When carelessly glancing at the mirrors, the driver may mistake the direction from which the other vehicle is approaching the intersection.

Figure 7.1. Intersection with two corner mirrors
(Takayama City, Gifu Prefecture; photo by Kokichi Sugihara)

Countermeasures

The direction of the corner mirrors, as seen from the perspective of a driver approaching the intersection as shown in Figure 7.1, can be reversed. However, in the case of this particular intersection, a total of four corner mirrors have been installed, including two at the closer end of the intersection. All four face the center of the intersection and are designed to help vehicles approaching the intersection from all four directions. Therefore, merely changing the direction of the mirrors cannot be an effective countermeasure.

Supplementary Explanation

The risk of mistaking left for right exists in other situations as well. The following are two typical situations.

(1) Assume that a driver has turned his head around to drive backward. In this situation, the left-right direction for the head facing backward is the opposite of the left-right direction for the body (especially the feet). This may be one of the causes for mistaking the brake and accelerator pedals.

(2) Assume a driver is using a back-mounted camera and monitor mounted in front of the driver to drive backward. The left-right direction for the driver's body is the opposite of the left-right direction appearing in the monitor. In this situation, the driver may be uncertain which way to turn the wheel.

8. Optical Illusion Related to Taillights and Brake Lamp at Tunnel Entrance

Phenomenon

When entering a tunnel, drivers will turn on their headlights. Drivers of vehicles that are following behind will respond by stepping on the brakes. This braking response is frequently the cause of traffic congestion.

Cause

Turning on the headlights at a tunnel entrance causes the taillights to also be turned on. From this, a driver in a vehicle that is following behind judges that the leading vehicle is braking. If the distance between the two vehicles is small, the driver of the second vehicle will apply the brakes.

Figure 8.1. In the picture on the left, the driver has turned on the headlights but has not applied the brakes to slowdown. On the right, the brake lamp has been lit because the driver has applied the brakes. In the situation depicted on the left, drivers following behind may apply their brakes after mistakenly thinking that the leading vehicle is slowing down. (Tokyo Metropolitan Area; photo by Akiyasu Tomoeda)

Countermeasures

1. Drivers should remember to use the high-mounted stop lamp of the leading vehicle to judge whether the leading vehicle is braking.
2. Sufficient distance should be maintained between vehicles.
3. Brake lamps should be different in appearance from taillights that turn on with the headlights.

9. Recessed Wall to Make Pedestrians More Visible

Figure 9.1 is the floor plan of an underground parking area. As shown here, an entranceway nearly the width of a car has been made for pedestrians.

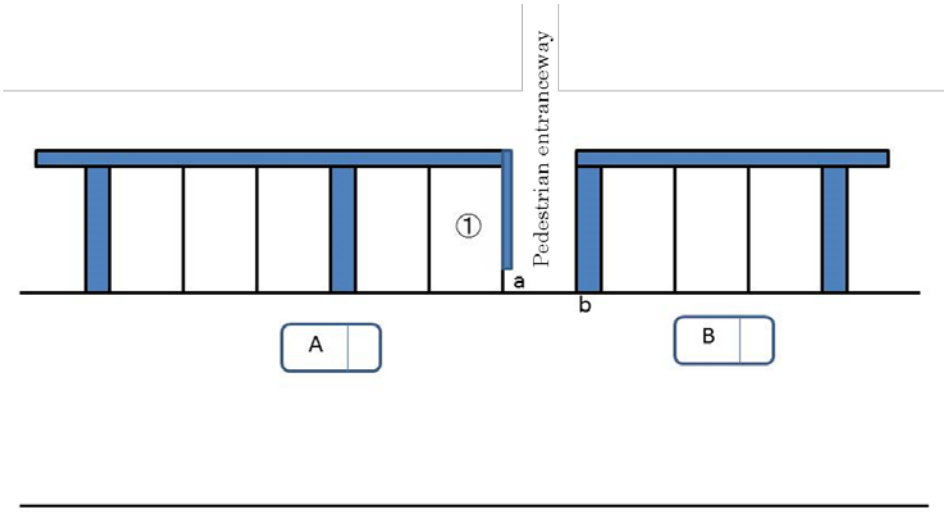

Figure 9.1. Floor plan of an underground parking area

Figure 9.2 provides a head-on view of the pedestrian entrance. Wall (a) is slightly recessed to make pedestrians more visible to vehicles approaching from the left.

Figure 9.2. Pedestrian entranceway built between parking spaces.
Compared to the wall on the right, the left wall is slightly recessed.
The left wall shows many signs of having been hit by vehicles.
(Nagoya City; photos in Figures 9.2, 9.3, and 9.4 by Kokichi Sugihara)

Vehicles backing into this parking space frequently hit the left wall. The reason for this is probably the following. Suppose a vehicle in Position A in Figure 9.1 decides to back into the empty Parking Space (1). The driver then moves to Position B before starting to back into the parking space. As shown in Figure 9.1, the pedestrian entranceway can be seen from Position A. However, as shown in Figure 9.4, a driver in Position B cannot see Wall (a) when he turns his head around. As a result, the driver mistakenly thinks that Parking Space (1) is next to Wall (b), and can therefore easily hit Wall (a) as he backs into the space. (Municipal underground parking area in Nagoya)

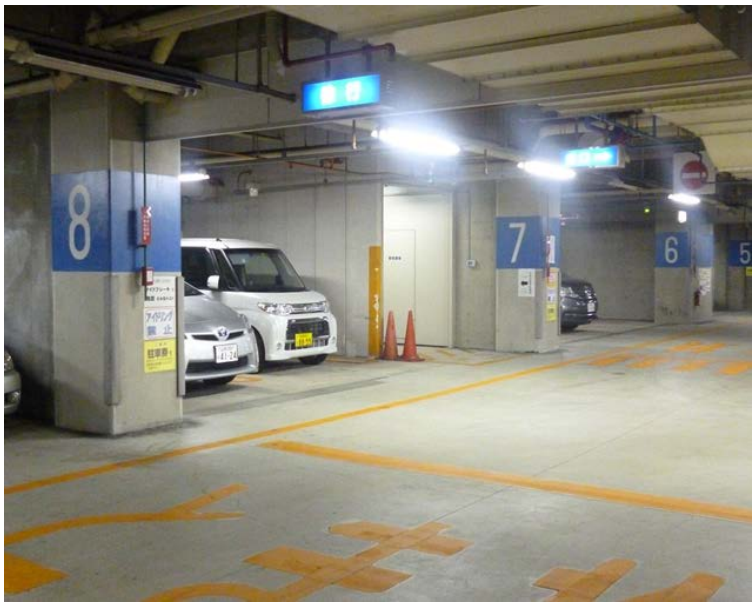

Figure 9.3. Pedestrian entranceway as seen from the vehicle driving on the left-hand side

Figure 9.4. View of the pedestrian entranceway when turning around from beyond the entranceway

Countermeasures

Some measure should be taken to remind the driver of recessed Wall (a). For example, a rope can be hung from the ceiling to indicate in a highly visible way where Wall (a) would be if it were the same length as Wall (b).

10. Blind Spot Created by Railing

Phenomenon

In Figure 10.1, a portion of the railing is circled as seen head-on. From this angle, the railing does not obstruct the view and approaching traffic can be seen. In Figure 10.2, the same portion is circled as seen from the side. When approaching the intersection, traffic coming from the left cannot be easily seen due to the angle of the rails.

Seen from a distance, there may be no approaching traffic. But by the time the driver reaches the intersection, another vehicle may also be close to the intersection. A collision can result if the driver enters the intersection relying on an earlier judgment made at a distance.

Figure 10.1. Railing as seen from before the intersection
(Tokyo Metropolitan Area; photos in Figures 10.1, 10.2, and 10.3 by Akiyasu Tomoeda)

Figure 10.2. Railing as seen from near the intersection.
The railing creates a blind spot and hides approaching traffic.

Figure 10.3. View of vehicle immediately before entering the intersection. Numerous collisions have occurred at this intersection. The approaching vehicle can be seen from this position, but the lower portion of the vehicle becomes completely hidden when it is seen from a position closer to the intersection, making it difficult to spot.

Countermeasures

1. Use thinner rails, reduce the number of rails, or use horizontal rails instead of vertical so that visibility is not affected by the angle from which the rails are seen.
2. Use transparent boards instead of rails.

Conclusion

This booklet covers various known and imaginable optical illusions and visual effects that can cause traffic accidents. In most cases, these have not been subjected to sufficient scientific observation and review. However, considering that traffic accidents cause very serious social loss, we have decided to publish this booklet at this stage of our study because we believe it is important to make every possible contribution to reducing traffic accidents by sharing the available information as widely as possible.

We earnestly hope that this booklet will stimulate discussion and verification among related organizations and individuals, thereby contributing to a better understanding of the role of optical illusions in accidents and to the development of effective preventive measures.

Acknowledgments

In the course of studying optical illusions, we exchanged information with various groups, which gradually led us to appreciate the crucial relation between traffic accidents and optical illusions. We take this opportunity to acknowledge our indebtedness to the following individuals from whom we directly received valuable information. Similarly, we benefited greatly from our discussions with them. These are Riichi Takahashi, advisor to the Japan Science and Technology Agency's Mathematics Program; Yoichi Ohashi of the Shanghai Japanese School; Hiromi Ono, formerly of the Ministry of Internal Affairs and Communications; Tetsuo Asano of Nagoya Expressway Public Corporation; Hiroshi Wakabayashi of Meijo University; Hiroyuki Hagura of Digital Hollywood University; Kiyoka Kyuba of Times24 Co., Ltd.; Shinjiro Aoki; and Daisuke Kitagawa. We also thank the members of the Setagaya (Tokyo) Police Station for their assistance in conducting road sign tests, and members of the mass media who provided us with extensive information on road signs and related optical illusions. We are also grateful to the many visitors to the Illusion Museum operated by this Project, and acknowledge our debt to the information that they provided and the time they took to engage in discussions with us.

Reference: Positive Use of Optical Illusions

Efforts have been made toward positive use of optical illusions as a means to promote traffic safety. However, the use of optical illusions is equivalent to fooling the eye of the observer. Therefore, in many instances it remains unclear whether optical illusions can truly contribute to safety. Normally, the best way to ensure safety is to correctly recognize what is actually happening in the environment. The use of optical illusions goes against this principle. Therefore, various optical illusions that are currently in use will be listed in this section without making any value judgments.

1. Anamorphosis

Drivers can more easily read signs written on the road surface if the lettering is elongated. Lettering that is easier to read when seen from a specific angle is referred to as "anamorphosis." Broadly speaking, anamorphosis constitutes a class of optical illusions because the lettering is difficult to read head-on but easier to read when seen from a specific angle. This can be said to be an appropriate way of using optical illusions to convey messages to drivers.

2. Image Bump

An "image bump" is used instead of a physical speed bump and consists of a drawing that appears like a three-dimensional block that has been placed on the road. Drivers may mistake this for a speed bump (or may drive cautiously wondering whether there is a speed bump ahead). In either case, the desired effect is for drivers to slow down. This type of sign is referred to as an "image bump."

The effect of an image bump is lost when drivers come to know what it is through frequent passage. On the other hand, the proliferation of image bumps may lead drivers to mistake an actual physical speed bump for an image bump. Such occurrences can result in dangerous loss of control as drivers run over a speed bump without slowing down.

Efforts have also been made to use shadowed diamond-shaped signs on the road surface to give the impression to drivers that the sign is slightly elevated. While the purpose seems to be to alert drivers, the effectiveness of this method is unclear.

3. Changing the Interval of Repeated Patterns

Repeated patterns appearing at decreasing intervals in the direction of traffic have been used on highway and tunnel walls to give the impression to drivers that their speed is increasing. An example of this are the "optical dots" used near the Bijogi Junction on the Saitama Omiya Route of the Metropolitan Expressway. (Figure A1)

It has been recently found that even if patterns are passing through the field of vision at the same speed, decreasing the intervals between patterns gives the impression of increased speed.

Figure A1. Road with optical dots
(Photo courtesy of Metropolitan Expressway Co., Ltd.)

4. Slanted Lines Placed inside Lane Lines

In some streets, slanted lines have been painted on the inside of lane lines to help drivers recognize the outer limits of the car lane. Another purpose is said to be to alert drivers by giving the impression that the car lane is narrower than it actually is. Evidence seems to show that this makes driving easier for drivers.

Figure A2. Street with row of parallelograms (Photo by Yasushi Yamaguchi)

5. Speed-Reduction Markers

Speed-reduction markers are widely used in streets and roads. It is said that the first of such markers were introduced in the United Kingdom and consisted of straight lines drawn across the road. In Japan, a variety of patterns are currently in use based on the guidelines of the National Police Agency. There are many reports that these markers are effective in reducing speed.

6. Melody Road (Extracted and Translated from Japanese Wikipedia)

Grooves are etched into the asphalt surface of roads at set intervals so that as a vehicle drives over the grooves, the vibrations caused by the wheels can be heard inside the car as a musical melody. The groove intervals are adjusted so that the melody can be heard correctly only when the vehicle is being driven at a designated or safe speed. This encourages drivers to avoid speeding (speed reduction effect). On the other hand, the grooves add to road noise and are therefore unsuited for use in urban areas.

The following persons (listed in alphabetical order by last name) participated in the discussions for preparing this booklet.

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