Study of the KTH report ”Visual adaptation for tunnel entrance - Final report” of November 2013

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Introduction and conclusions

The above-mentioned report describes tests, where observers are exposed to a sudden change between two situations, the first with a high level of luminance and the second with a low level of luminance. The result is the time it takes after the change for the observers to detect a small object.

The first situation represents the level of daylight for a driver in front of a tunnel portal, while the second situation represents the driver in the interior zone after having passed through the entrance and transition zones.

For a luminance of 6.000 cd/m^2 down to 2 cd/m^2, the time ranges from 0,5 to almost 10 seconds with an average of 4,4 seconds for all observers. There is a significant influence of the age of the observers.

Some tests were also done for a higher luminance of 8.000 cd/m^2 in the first situation. The results are similar, so in order to keep matters simple, only the above-mentioned tests based on 6.000 cd/m^2 are considered in the following.

Note: In an additional type of observations, k factor values were determined. These observations are not considered in this note.

The results are interesting, because they may justify a reduction of the lengths of the threshold and transition zones. On the average, the total length of the zones may perhaps correspond to 7 seconds of driving, when taking the majority of observers into account. For a driving speed of 90 km/h that would be 225 m.

For comparison, the entrance zone is conventionally assumed to have a length equal to a stopping distance at the given driving speed, while the length of the transition zone is assumed to correspond to 20 seconds of driving. For a driving speed of 90 km/h, the total length would be more than 600 m.

However, as the observations were carried out for a single step from the high down to the low luminance level, the report does not offer any explanation why time is needed, and how intermediate steps can be arranged.

The purpose of this note is, therefore, to study the visual conditions during the observations and, if possible, to provide the explanations. This involves calculations of visibility levels in accordance with Adrian, W., Visibility of targets: model for calculation. Lighting Research and Technology, 21/4, pp.181–188, 1989.

The observations and the results are accounted for in section 1, while an interpretation of the test results is given in section 2.

It is explained that the visibility level of the object is low at the low level of luminance and that just detecting the object may take some time. Additionally, the observers were allowed the time that they saw fit until pressing a button and may have spent additional time to be sure. Just reacting to press the button may also take additional time.

Therefore, the authors arranged some simple tests using PowerPoint slides with a more realistic visibility level of the object and presentation of the object in only one second – or even less.

These simple tests indicate that the time can be shorter than accounted for in the KTH report, and that luminances can be stepped down really fast. Adaptation is perhaps not an issue at all. This is a preliminary conclusion that should be tested for a number of observers.

It recognized that glare sets a limit for how fast luminances can be stepped down in practise. In each step, a driver is at location with a relatively high level of luminance and glare, but is looking forward one stopping distance to a location with a lower luminance level. Therefore, the luminance level one stopping distance ahead must be high enough to counteract the glare.

It is also recognized that visual comfort may set a limit to how fast luminance can be stepped down.

1. Observations and results

The tests involve a sudden change between the two situations shown in figures 1 and 2. The two situations are created in a box constructed with a reduced scale. The object in the two figures is a square with a size corresponding to 0,2 m as seen from a stopping distance of 155 m. The object is presented with a positive contrast of 20 %.

An observer spends at least 1 minute in the first situation in order to adapt. After the sudden change, the observer indicates when the object becomes visible by pressing a button. The time from the sudden change to the press of the button is the test result.

The test results are shown in figure 3, which also shows a regression line and two thinner lines that represent three times the standard deviation from the regression line.

The average test result is 4,4 seconds, but the spread among observers is fairly large as shown by the total range from 0,5 to almost 10 seconds. There is an influence of the age of the observers, which is significant at a 95 % level.

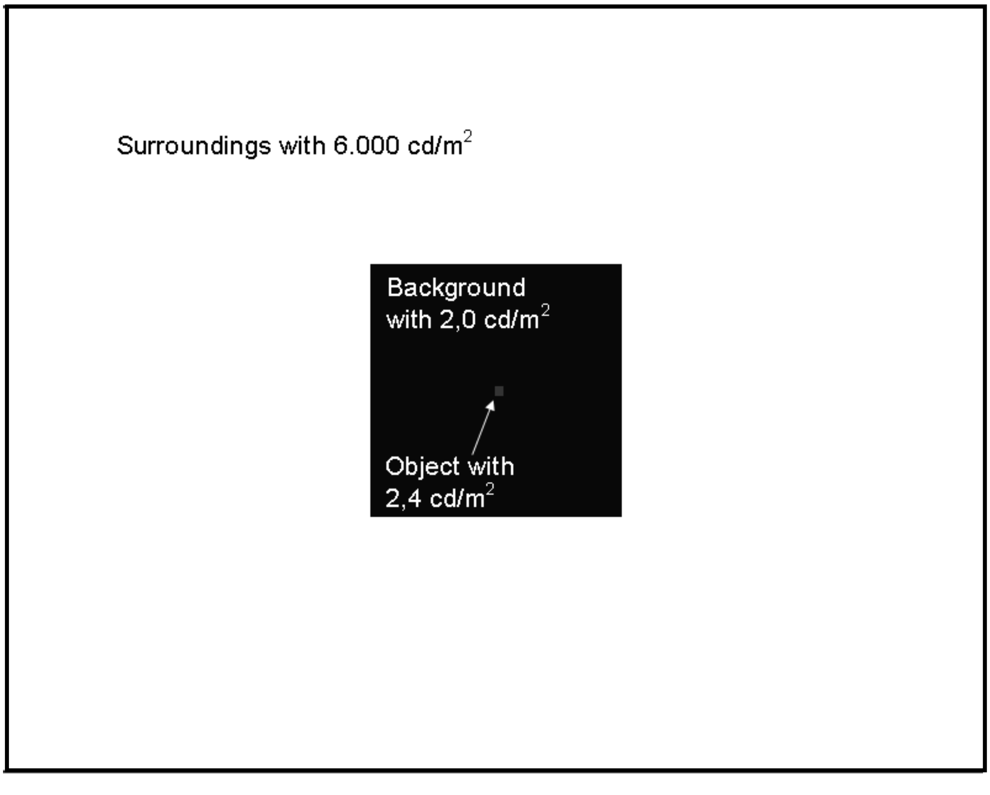

Figure 1: Situation 1.

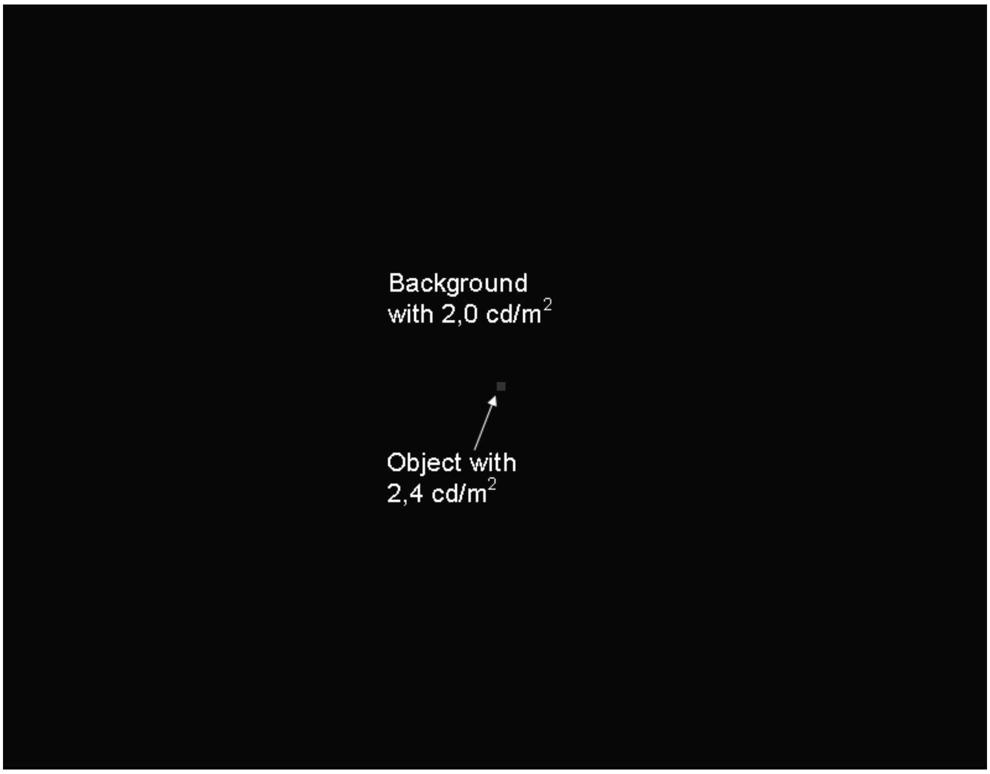

Figure 2: Situation 2.

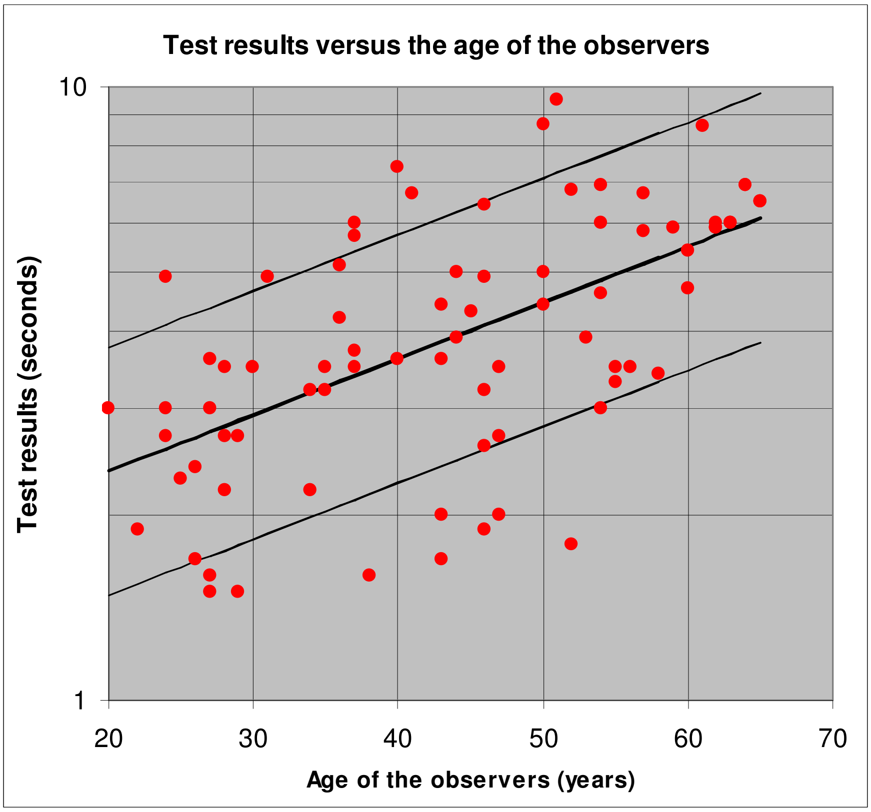

Figure 3: Test results versus the age of the observers.

2. Interpretation of the test results

In the first situation, refer to figure 1, the luminance of the surroundings of 6.000 cd/m^2 causes glare with an equivalent veiling luminance L_{seq} of approximately 300 cd. The situation is, therefore, equivalent to the situation shown in figure 4. This is massive glare that prevents detection of the object. In agreement with this, the calculated visibility level is low, only 0,2 as compared to a minimum for detection of 1.

In the second situation the visibility level is 2,2, which means that the object should be detectable. However, this may take some time as the visibility level starts at a low value and grows with time to the above-mentioned value as shown in figure 5. However, one or at most two seconds should be sufficient, and this leaves the question why observers on the average use 4,4 seconds and some observers even more time.

The following explanations are offered:

a. The luminance of 2 cd/m^2 in situation 2 corresponds to the road surface luminance in the inner zone that is low compared to luminance levels recommended for a stopping distance of 155 m.
b. The contrast of the object of 20 % is low compared the higher contrast values normally assumed in tests like this.
c. The observers were allowed the time that the thought they needed, and some may have spent additional time to be sure.
d. Just to react and press a button takes some time.

Items a. and b. together explain that the visibility level is low. It has probably been difficult to detect the object, while tests of this nature would normally be based on a higher visibility level.

Items c. and d. may account for additional use of time.

Because of this, the authors have done a simple test using a Power Point presentation with two slides A and B that correspond to the two situations with, however, a higher visibility level of the object and presentation of slide B in one second only.

Some details are:

a. Slide A shows a field with a luminance of approximately 240 cd/m^2, which is close to but not quite as high as the luminance of 302 cd/m^2 indicated in figure 4.
b. The object has been omitted in slide A, as it cannot be seen in any case.
c. Slide B has a luminance of 2,4 cd/m^2; which is a bit higher than the luminance of 2,0 cd/m^2 indicated in figure 2.
d. The object in slide B has a luminance of 3,2 cd/m^2 and, therefore, a higher contrast than in figure 2.
e. The slides are observed from a distance that corresponds a distance of 100 m to the object as compared to the distance of 155 m in the KTH test.

The matter d. and e. cause a raise of the visibility level. Taking observation during only one second into account, the value is approximately 4,5.

Slide A is presented until the observer has adapted to the high luminance, followed by presentation of slide B in one second. The criterion is if the object is detected or not within that single second.

The two authors do detect the object.

Another Power Point presentation has intermediate slides, together spanning the range from approximately 240 cd/m^2 down to approximately 2 cd/m^2 in seven steps with a reduction of the luminance in each step of approximately a factor of 2. In each of the seven steps, the slide is shown in one second with a visibility level of approximately 4,5. The object moves about from slide to slide, so that some search for it is needed in each step.

The authors do detect all the objects and can even do it in a faster sequence. The lower limit may be 0,5 second per step.

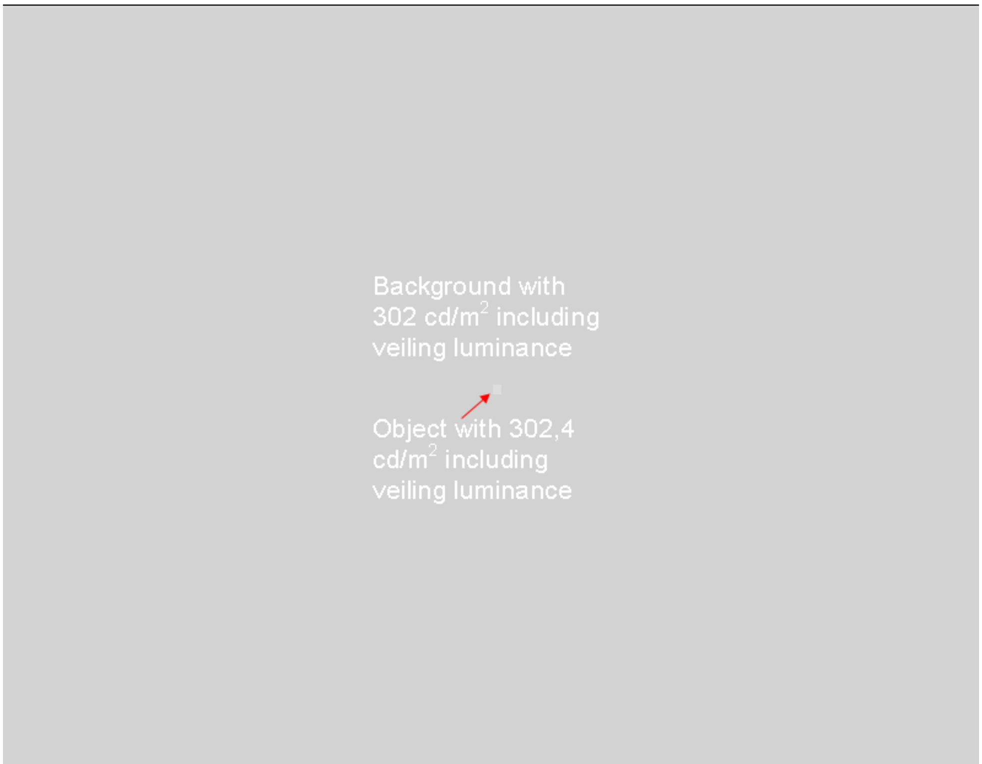

Figure 4: Situation that is equivalent with situation 1.

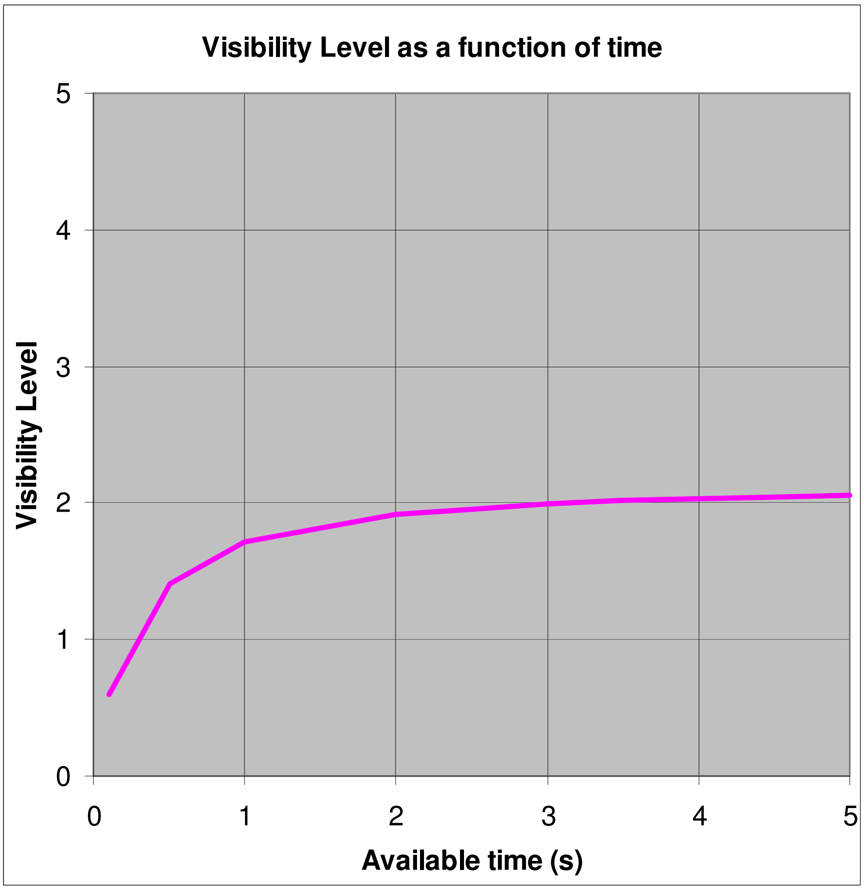

Figure 5: Increase of the visibility level with time.