Impairment Detection Ability of Subjects for Different Test Conditions in D-Cinema

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Abstract

In this paper some consideration are provided on the ability of a generic viewer to assess impairments when performing a formal subjective test. The case under consideration here, is not covered by the current literature related to subjective assessment, in what it deals with the assessment of D-Cinema. In this case the need for a strong ability of impairment recognition is the dominant factor. Furthermore, the distance from the screen is not any longer limited by the interlaced structure of the signal (as in the TV case) but it pushes to the distance form the screen to very low values. Here two test methods are examined and the minimum viewing distance is evaluated in relation with the ability of the human eyes to assess areas of the screen, with or without any effort. In this analysis the case of the MPEG test on D-Cinema is considered as a good example of application of these test methodologies. Finally some consideration on the decrease of impairment recognition ability, of the human subjects, as a function of the viewing from the screen, is given.

Keywords:

D-Cinema, Subjective assessment, Contrast Sensitivity Function (CSF), viewing distance, MPEG, TV.

1 Introduction

Recommendation ITU-R BT.500-10 [1] states in paragraph 2.1.1.1 ("*General viewing conditions for subjective assessments in laboratory environment*") that the viewers, participating to a formal subjective assessment test, have to seat in front of the screen under an angle lower than 30°.

This value has been introduced, following the results of many laboratory experiments performed from the 50s to the 70s, considering various aspects, among which a relevant one is the need to provide to the subjects the ability to explore the images under test ***"in a comfortable way"***.

Furthermore the SMPTE Engineering Guideline [2] describing the "Design of Effective Cine Theatres" provides useful indications of which are the limits of a generic viewer when he/she is watching a movie in a theatre. These indications may be used to envisage which are the limits of a "comfortable visi In the SMPTE report three different tasks are defined related to the ability of a viewer to perform different tasks; for each of them "acceptable angles" are provided:

- The angles from which a viewer is capable to recognise words, and therefore carefully analyse details, moving the eyes only or with moderate head movements (i.e. in a "comfortable way"),
- The angles from which a viewer may recognise a symbol, and therefore requires more eyes and head movements,
- The angle beyond which the colour discrimination fades away, and therefore requires strong head movements, close to the limit of the easy head movement.

The considerations made in this paper are based on the assumption that, if an image quality assessment has to be done, the subjects must be put in condition to perform their task in the best and less tiring condition; i.e. in a way that they move the eyes only, with some (very few) moderate head movements:
on of details" assessing a D-Cinema video material.

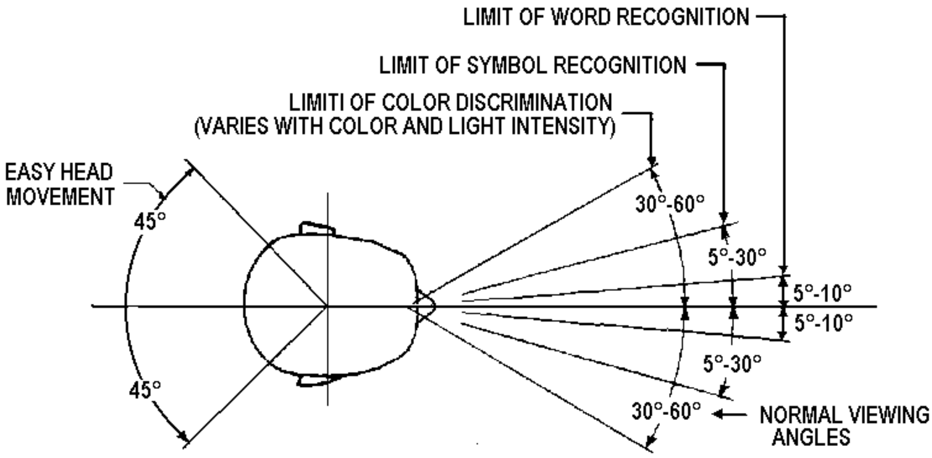

Figure 1 – Limits for a "comfortable vision of details"

This assessment conditions may be defined as a "comfortable way" to perform a task. This assumption applies as much as the test sessions length approaches to half an hour; this length is estimated as an upper limit value. In this paper we will try to analyse under which conditions, the subjects participating to a formal subjective test perform in "comfortable way" their task.

This analysis will be done taking into account:

- The case of test methods based on sequential presentation of the images (e.g. DSCQS described in [1]),
- The case of test methods based on side by side presentation of the images (e.g. the DS3PDS test method as described in [3]),

For the above cases it will be computed:

- which portion of the image under test may be assessed (i.e. explored by the subject's eyes) in a "comfortable way", i.e. not exceeding the angles from which a viewer is capable to recognise words,
- which portion of the image under test may be assessed, requiring more eyes and head movements.

The computations will be performed considering viewing distances, ranging from 1H to 3H, where H is the screen height, with incremental steps of 0,5 H.

Finally some values of the accuracy provided by the HVS (Human Visual System) at the above considered distances will be given, taking into account the raster of the D-Cinema, as currently under test in MPEG [3]. All these considerations are also provided in light of a better understanding of the test procedures under execution in the framework of the MPEG activity for the D-Cinema.

2 D-Cinema subjective test viewing distance

Document N4076 describes the test condition for the D-Cinema Evaluation Procedures.

Among the others, viewing distances from 1.5 H to 3H are considered, with the aim of getting as many as possible information related to the visibility of the impairments that a D-Cinema distribution proposal can introduce.

In the same document two test method are described:

- a sequential test method called DSPDS (Double Stimulus Perceived Difference Scale) for which viewers are requested to look into subsequent video clips, among them one is the original (not degraded image) and the other is the distribution purposes coded one.
- A side by side test method called DS3PDS (Double Stimulus Split-Screen Perceived Difference Scale) for which viewers are requested to look into a screen split into two equal regions; the leftmost show half of original (not degraded image) whilst the right sided one shows the same half of the distribution purposes coded one. The experiment is reproduced twice showing, during the first run the right halves and in the second run the left halves (i.e. R vs. R* and L vs. L*).

This paper tries also to provide an indication of which could be the best viewing distance, at which a subject will produce the best performance and the less stressing effort, in evaluating the quality of D-Cinema images.

3 Test methods and viewing distances

Let us see what happens modifying the distance from the screen, to which the subjects are seated, when they assess the quality of D-Cinema scenes.
For computational simplicity, we will fix the dimensions of our screen equal to 24' x 13' (in this case the screen aspect ratio is around 1,8), and assuming that the sampling raster of the images projected on the screen is made of 1080 lines of 1920 pixels each. Therefore all computations made in the following paragraphs, has been done taking into account these screen dimensions and raster.
Here below a comparison of the degree of visibility of the screen obtainable performing the following test procedures is computed:
- Sequential (DSPDS),
- split screen (DS3PDS),

For each of the above listed cases the 1 H, 1,5 H, 2 H, 2,5 H and 3H distances from the screen have been considered (H = screen height). For all the above distances from the screen, it is assumed that all the subjects are seated viewing the center of the screen from an angle lower than 30°, as dictated by [1]. We will now try to investigate at which distance the subjects can explore in a "comfortable way" the projected scenes.

4 Effort required by different test methods

We assume (for computational simplicity reasons) that the portion of the screen seen in a "comfortable way" by the viewer (**S_{vis}**) can be considered shaped as a circle. Figure 2 depicts the case of the sequential test method (i.e. DSPDS), for which the diameter (L_{vis}) of **S_{vis}**, is given by (1):

$$L_{vis} = 2 \cdot d \cdot H \cdot \tan(\alpha) \qquad (1)$$

where **dH** is the distance from the screen (computed in multiples of the screen height **H**) and **2α** is the angle under which the subjects perform their task in a "comfortable way" (10° to 20°). Later on, the area for which subjects are requested to perform more stressing assessments (under a 60° angle) are also given, for comparison purposes. It will be here shown that the diameter **L_{vis}** of a viewable surface changes according to:
- The subjects distance **d** from the screen,
- The effort required to the subject (as function of the angles related to the proposed task),
- The test method used.

Therefore here below we will compute, for the three methods the values of the diameter (**L_{vis}**) of an object assessable in a "*comfortable way*" as a function of the viewing distance. All values of **L_{vis}** will be computed in feet.

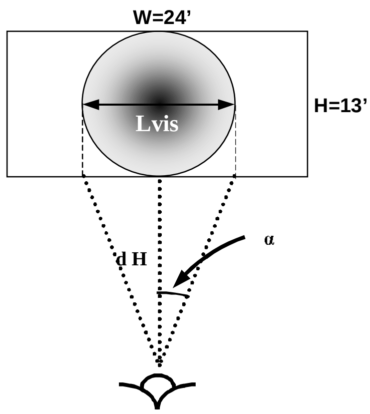

Figure 2 – Example of visible area in a sequential test

Sequential (DSPDS) test method

This case is applicable to any test method based on sequential exposition of the "stimula" to the subjects. Table 1 and Table 2 provide the value of the area for a "huge" and comfortable effort respectively, for distances from the screen ranging from 1H to 3H

distance from the screen (in H)	*L_{vis} @ 60°*
1	**15,01**
1,5	**22,52**
2	***Full screen***
2,5	***Full screen***
3	***Full screen***

Table 1 – Values of Lvis for huge effort (60° angle) in the sequential test case

distance from the screen (in H)	*L_{vis} @ 20°*
1	**4,58**
1,5	**6,88**
2	**9,17**
2,5	**11,46**
3	**13,75**

Table 2 – Values of L_{vis} for a comfortable effort (20° angle) in the sequential test case

Split screen (DS3PDS) test method

In a DS3PDS test the subjects are requested to assess, at the same time, the left half of the screen with the right half of the screen.

This implies that, any objects to be assessed using this test method, will demand the subjects to move ***very quickly*** their attention to the corresponding one located on the other half of the screen. In this way a subject will have to move his/her sight direction into two points that are at a distance equal to the half of the screen width. Furthermore we have to consider the dimension of the object under estimation; should it be close to a single point the movement of the subjects sight should be equal to **W/2**; as the dimension of the object to assess become considerable (e.g. different than those of an ideal point), the movement required to examinee it increases.

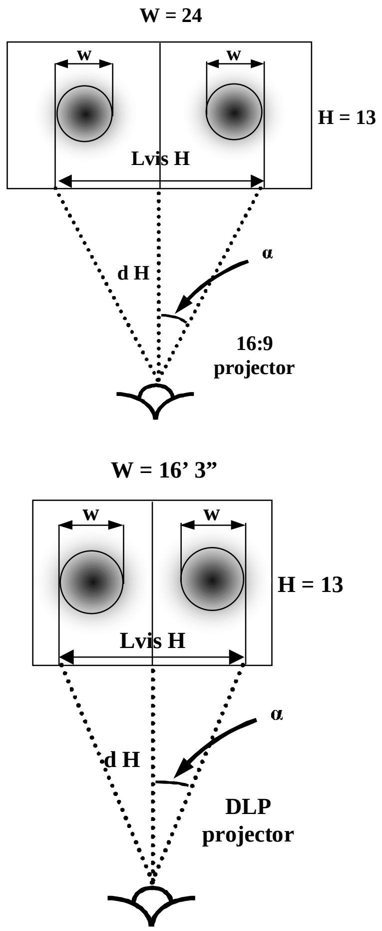

Figure 3 – Viewing condition for a side by side test case (16:9 and DLP cases)

From these considerations it comes out that, if the subjects have to assess an object whose dimension is **w**, the movement required to their sight will be:

$$\mathbf{W/2} + \mathbf{w}.$$

Therefore, in this case, the diameter $\mathbf{L_{vis}}$ of the viewable surface, is given by **W/2** + **w**.

For this test method the case of a 16' 3" x 13' screen (see Figure 3) will be taken into consideration also. This screen size is the one illuminated by the DLP projector, used in the MPEG D-Cinema tests. Figure 3 depicts the two cases; on the left side the 24' x 13' case is shown; on the right side the 16'3" x 13' case is shown. Values of $\mathbf{L_{vis}}$ and **w** are given in feet.

distance from the screen (in H)	L_{vis} *@ 60°*	**w** *@ 60°*
1	**15,01**	**3,01**
1,5	**22,52**	**10,52**
2	***Full screen***	***Half screen***
2,5	***Full screen***	***Half screen***
3	***Full screen***	***Half screen***

Table 3 – Values of Lvis and w for huge effort (60° angle) for a 24' x 13' screen

distance from the screen (in H)	*Lvis @ 60°*	*w @ 60°*
1	**15,01**	**7,01**
1,5	***Full screen***	***Half screen***
2	***Full screen***	***Half screen***
2,5	***Full screen***	***Half screen***
3	***Full screen***	***Half screen***

Table 4 – Values of L_{vis} ***and*** *w* ***for huge effort (60° angle) for DLP screen***

distance from the screen (in H)	*L @ 20°*	*w @ 20°*
1	**4,58**	**0,00**
1,5	**6,88**	**0,00**
2	**9,17**	**0,00**
2,5	**11,46**	**0,00**
3	**13,75**	**1,75**

Table 5 – Values of L_{vis} ***and*** *w* ***for comfortable effort (20° angle) for a 24' x 13' screen***

distance from the screen (in H)	*L @ 20°*	*w @ 20°*
1	**4,58**	**0,00**
1,5	**6,88**	**0,00**
2	**9,17**	**1,17**
2,5	**11,46**	**3,46**
3	**13,75**	**5,75**

Table 6 – Values of L_{vis} ***and*** *w* ***for comfortable effort (20° angle) for DLP screen***

From the above tables it is interesting to note that if a test designer wants to put into a comfortable assessment condition the subjects, this test method cannot be considered particularly suited.

In fact we can see that only with a 16'3" x 13' screen, the subjects are provided with some case in which they have chances to perform “some how” their task. This in any case limits the width of a assessable object to 5,75 feet and at a 3H distance from the screen. Closer distances are very stressing. This lead to the next paragraph in which the decrease in detail resolution of the Human Visual System (HVS) is considered.

5 Impairments visibility

The human eye is a very sophisticated machinery, that unfortunately does not go beyond very limited boundaries due to the overall bandwidth of the system made up of the eye, the optical nerve and the brain cortex. Many studies have been carried out ([4], [5], [6] and [7]) to provide a reliable functional representation of the ability of the human eye to resolve details in a fixed or moving image. The contrast sensitivity function (2) proposed by Manos and Sakrison is plotted in Figure 4.

$$A(f) = 2{,}6 \cdot (0{,}0192 + 0{,}114 \cdot f) \cdot e^{-(0{,}114 \cdot f)^{1.1}} \qquad (2)$$

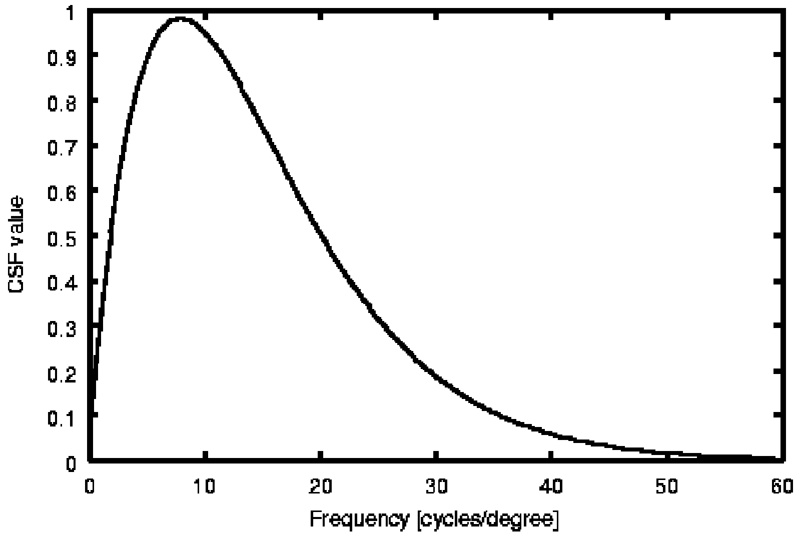

Figure 4 - Contrast sensitivity function

To apply this model to our purpose we must first find out the maximum number of cycles per degree seen by the viewer at a given relative distance **d**.
For a screen of height **H** and **n** lines displayed, at the maximum frequency (Nyquist) 1 cycle spans a height of $\mathbf{h_c}$ given by:

$$h_c = \frac{H}{n/2} \qquad (3)$$

Considering a viewing distance of **dH**, the length **x** covered by 1° angle is

$$x = d \cdot H \cdot \tan(1°) \cong d \cdot H \cdot \frac{2 \cdot \pi}{360} \qquad (4)$$

The spatial frequency $\mathbf{f_s}$ is:

$$f_s = \frac{x}{h_c} \cong \frac{\pi}{360} \cdot n \cdot d \qquad (5)$$

covered by 1 cycle.
If we plot the visibility of detail as function of the distance from the screen (for a given raster dimensions), we can see in Figure 5, that for the MPEG D-Cinema test (assuming the 1080 and 1024 vertical raster values), we have the maximum ability to discriminate detail at 1H; nevertheless the 1,5 H represents still an excellent distance. The 3 H case provides a loss of about one three times the ability of resolving details compared with the 1,5H distance .
The interesting fact is given by the plot of the TV cases (PAL and NTSC), that sound as a confirmation of the good practice of placing subjects at 4H and 6H. This results as a good compromise between the need of resolving details and the necessity to avoid the visibility of the line structure of the TV signal.
Finally, it should noted that the two curves in figure 5 have be to read with some care. In fact the number of the number of lines in (2) has been set to one half of the rater for both the TV and the D-Cinema cases, but for different reasons; in the TV case the figure of one half the raster lines is mandatory due to the interlaced structure of the TV raster, while in the case of D-Cinema, the figure of one half the raster lines is dictated by the visibility of the maximum displayable vertical frequency.

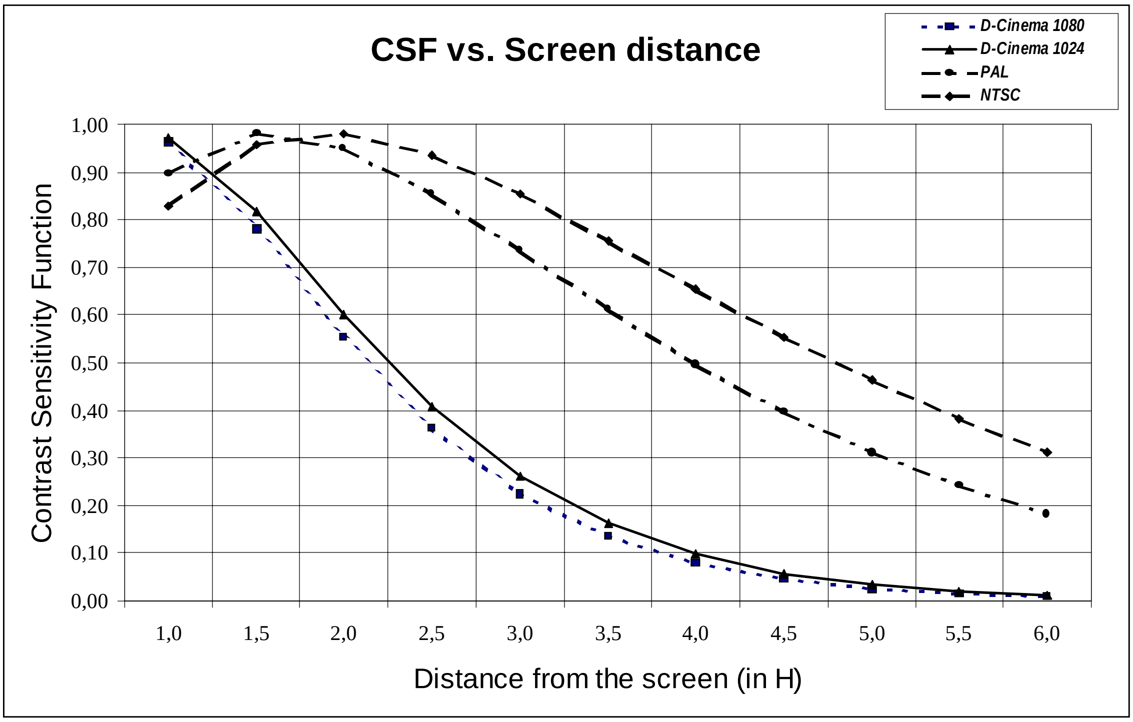

Figure 5 – CSF (visibility degree) as function of the distance from the screen for a 1080 (D-Cinema), 1024 (DLP projector), 576 (PAL) and 480 (NTSC) lines raster

6 Conclusions

If a D-Cinema formal subjective test is conducted using a sequential test method (e.g. DSCQS [1] or DSPDS [3]) at a 1,5H distance from the screen (H = the screen height), a comfortable way to assess all the details of moving images under test is provided, together with a good ability of details resolution.

Using a "side by side" test method (e.g. DS3PDS [3]) we get some "acceptable" viewing condition only at 3H, while at 1,5 H, there are no chances to have a "comfortable" assessment of the moving images under test. Furthermore, even if the Side by Side method is used at 3H, there is still a strong limitation of the viewable size of an object under observation, that cannot be wider than the 75% of the whole viewable area.

Finally some computations of the ability of the Human Visual System to resolve details are provided (based on the use of the Contrast Sensitivity Function - CSF) from which it results that, for a D-Cinema raster (based on 1080 lines), the HVS details resolution features at 3 H, is three times lower than at 1.5 H.

This paper takes into account some of the test conditions of the D-Cinema test under progress in MPEG (ISO/JEC SC29-WG11).

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