

# Refraction and visual fatigue syndrome on watching the ULTRA HD 4k television curved screen system

## *Refracção e síndrome de fadiga visual no uso de sistema de televisão ULTRA- HD-3D- 4K de tela curva*

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### ABSTRACT

**Purpose:** To evaluate eye sensitivity disorder (similar to glare), with symptoms of visual fatigue, through watching television ULTRA HD-3D-55-inch 4K curved screen among volunteers with normal eye examination. **Methods:** A prospective, longitudinal, case-control study, with inclusion and exclusion criteria and groups formation enrolled by age range. A comparison of a video documentary presented with the ULTRA HD TV 4K and with the FULL HD TV before and after the previous tele-audience, consisting of an evaluation of three phases of the study regarding the case-control criteria. The main variable analyzed was a questionnaire of visual fatigue syndrome complaints which was compared with secondary variables as the contrast sensitivity test, amplitude of accommodation test, blink frequency test, and test of conjugated saccadic eye movements of big amplitude. Tablets with digital camera equipment were used for video recording of the blink frequency, and saccadic eye movements throughout the television audience. Statistical analysis with Chi Square test. **Results:** Eighty healthy volunteers were evaluated and assessed as expressiveness of statistical inference alpha ( $\alpha$ ) of 10%, without obtaining significance of 5% for complaints of a questionnaire Visual Fatigue Syndrome. Other statistical tests showed 5% of significance of data in a global inference research on the frequency of blinking and combined saccadic movements of great amplitude. **Conclusion:** High resolution television screens ULTRA HD 4K may cause complaints of eyestrain in a population with some uncommon characteristics (low eyelid blink frequency and conjugated saccades movements). The low statistical significant index could be increased in a research with a higher number of participants. The authors call attention to the possibility of increasing this visual fatigue effect in the future advent of Television System ULTRA HD 8K.

**Keywords:** Refraction; Audiovisual aids; Contrast sensitivity; Asthenopia; Accommodation, ocular; Blinking; Saccades; Vision, ocular/physiology

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## RESUMO

**Objetivo:** Avaliar uma possível desordem de sensibilidade ocular (similar a glare), com sintomas de fadiga visual, através da observação de tela de televisão ULTRA HD- 3D- 4K de tela curva de 55 polegadas, em voluntários com exame oftalmológico normal. **Métodos:** Um estudo prospectivo, longitudinal, caso-controle, com formação de grupos por faixa etária e com critérios de inclusão e exclusão. Uma comparação de um vídeo documentário gravado com resolução HD 4K e o mesmo documentário gravado em FULL HD antes e após a tele-audiência anterior consistindo numa avaliação de três fases do estudo com os mesmos critérios. A fadiga visual foi analisada por meio de um questionário padronizado de queixas de síndrome de fadiga visual comuns e comparado a teste de sensibilidade ao contraste, teste de amplitude de acomodação e convergência, teste de frequência de piscar e teste de movimentos sacádicos conjugados oculares de grande amplitude. Equipamentos acessórios como *tablets* com câmara digitais serão utilizados para gravação de vídeos da frequência de piscar, e de movimentos oculares sacádicos durante toda a audiência televisiva. Análise estatística com Teste de Qui quadrado, teste t de Student, teste de Tukey e teste F com análise de Variância foram feitos para dados em tabelas de contingência e gráficos caixa em Box Plot. Nível de significância estimado em 5%. **Resultados:** Oitenta voluntários normais foram avaliados e avaliados como inferência de expressividade estatística alpha ( $\alpha$ ) de 10%, sem obter significância de 5% para as queixas de um questionário de Síndrome de Fadiga Visual. Outros testes estatísticos revelam dados de significância de 5% numa inferência global da pesquisa quanto à frequência de piscar e de movimentos sacádicos conjugados oculares de grande amplitude. **Conclusão:** Telas de televisão de alta resolução ULTRA HD 4K, podem provocar queixas de fadiga visual numa população de características pouco comuns (com baixa frequência de piscar palpebral e movimentos sacádicos conjugados), mas existentes. O baixo índice de estatística significativa poderá revelar-se de maior expressão no uso de uma amostragem de pesquisa mais numerosa. Os autores chamam a atenção para a possibilidade de incremento desse efeito de fadiga visual no futuro advento de Sistema de Televisão ULTRA HD 8K.

**Descritores:** Refração; Recursos audiovisuais; Sensibilidade de contraste; Astenopia; Acomodação ocular; Piscadela; Movimentos sacádicos oculares; Visão ocular/fisiologia

## INTRODUCTION

Currently, high-definition televisions with great-length screens in inches have been a consumer trend of the world market. Many of these systems are mounted as 3D-HD (high-density stereopsis image resolution), whose advantage is presenting the best stereoscopic vision of television images<sup>1</sup>.

This type of resource reaches a maximum resolution with the television system 4K, also called ULTRA HD. This expedient is proclaimed with a holder of visual appeal of 3 fields discerning planes of images, generating a high resolution stereoscopic image. This convenience is further enhanced in the presence of a curved screen, arranged in a large size such as 55 inches.

However, some people mention certain visual discomfort after long exposure watching a certain type of TV screen, despite being fascinated by the beauty of colors and images<sup>2</sup>.

This work aims at evaluating this kind of perspective by psychophysical tests such as contrast sensitivity, accommodation and convergence, blink frequency test, and conjugated saccade movement test of great amplitude. These tests were performed before, immediately after and on the following day after watching the same TV program (60 minutes) in such 4K resolution screen.

Thus, attention was drawn to the hypothesis to be studied for a possible blinding eye sensitivity (of the glare type), as a supposed similarity to complaints of visual fatigue syndrome when looking at computer, tablet, laptop and notebook screens.

To avoid any doubts as to any influence of pathological ocular disorder, this type of study was carried out among subjects with normal eye examination, especially with emphasis on refractive aspects.

## METHODS

The present study evaluated 80 participants (40 men and 40 women) with a prospective, longitudinal, case-control study, with the formation of groups by age group.

The study followed the standards for research with human beings (Resolution 196/1996 of the Health Council), and was approved by the Research Ethics Committee. All volunteers signed the informed consent form.

### **Selection criteria**

The inclusion criterion was all participants being emmetropic and with visual acuity of 20/20 for far sight and J1 to near sight.

The inclusion criteria were: no complaint of headache or eyestrain, owning ULTRA HD-3D-4K curved screen TV, symptoms of asthenopia, colored contact lens wearers, patients with pterygium, ocular lubricant eyedrops users, Break up time test ( BUT ) < or equal to 15 seconds, users of antiallergic and eyedrops for glaucoma.

The study was conducted in the Ophthalmology ambulatory at Hospital Antônio Pedro in the period between November and December 2015.

The volunteers underwent refractive examination and perfect Stereopsis test (Titmus test); biomicroscopy on slit-lamp (Topcon SL-1E) to exclude dry eye or blepharitis; Break up time test (BUT); test with fluorescein staining (Alcon Brazil).

### **Formation of groups**

The participants were divided into four age groups: less than or equal to 20 years, 21 to 30 years, 31 to 40 years, and over 41 years of age.

In order to adequate the personal nature variables such as sex by hormonal factor (menarche), the same number of volunteers was determined for men and women: 10 individuals (mem/women) for each group.

Participants watched a DVD of a 4k-resolution tourism documentary on ULTRA HD 3D-4K TV of 55-inch curve screen (LG) compatible with said DVD. The TV show lasted 60 minutes and presented several static and moving color images, focused at distance or in close-up, with audio in English and Portuguese translation caption at the bottom of the screen. The documentary was always presented at the same time (09:00 am), in a room with temperature (24°C) and humidity control.

The TV was positioned 10 meters away from the viewers. The viewers sat on chairs with forearms and a coffee table in front of them (like school desks). The chairs were arranged in rows of 10 chairs.

All additional equipment to aid the search, such as tablets (CCE), pencils, and questionnaire forms were arranged on this coffee table. As a case-control criteria before and after watching TV (ULTRA HD-3D-4K), data was collected on the same variables surveyed in the study.

**Phases of the study**

The survey was conducted in three phases of steps:

- **1st phase of the study:** After the selection process and training of the research groups, these volunteers were evaluated by a hearing about the same TV show in FULL HD TV (LG), 24 hours prior to submission of the TV procedure and objective of this study.
- **2nd phase of the study:** Research procedure - Hearing of the 60-minute program on ULTRA HD 3D - 4K TV of 55-inch curve screen (LG). All the volunteers selected watched the same TV show under standardized conditions of the hearing room at the same time for all.
- **3rd phase of the study:** The next day, the same volunteers were subjected to a hearing of the same 60-minutes TV show in FULL HD at the same time.

In these steps, the volunteers underwent the same variables studied.

**Variables investigated**

Variables that could show a possible blinding eye sensitivity (Glare) were evaluated, with symptoms of visual fatigue when watching the screen of ULTRA HD-3D-4K curved screen TV (LG).

**Main variable**

- Questionnaire of visual fatigue syndrome and dry eye complaints (Annex 1)

*Secondary variables*

- Palpebral blink frequency: observed with the video focused on the volunteer's face, especially on both eyes.
- Wide-range conjugated saccade ocular movements: observed with the video focused on the volunteer's face, especially on both eyes.

- Sensitivity test to visual contrast: Method of Pelli-Robertson table: reading performed immediately after watching the show on ULTRA HD 4K TV

- Amplitude of accommodation: Refractometric method with the use of Greens refractor and Jaegger reading card.

**Equipment**

Each volunteer at the time of the study had on the coffee table before them a digital 6-inch tablet (CCE) with digital camera positioned faced to them, especially facing their eyes. The purpose of this equipment was to film the palpebral blink and the wide-range conjugated saccade ocular movements while watching the TV show in the three phases of this study.

The blink frequency of each volunteer and the frequency of the conjugated saccade ocular movement of the same volunteer were counted, checked and recounted.

**Statistical analysis**

This study showed the formation of 3 research groups based on age and four evaluation tests divided in three steps. Initially the univariate statistical analysis with 5% significance (p < 0.05) was used.

Statistically significant variables were subsequently evaluated by the F-test (ANOVA) to evaluate most expressive among these variables. Data was arranged in the form of a Box Plot or chart box to demonstrate its distribution. The tables the variables were arranged in the following distribution: questionnaire of visual fatigue syndrome complaints with qualitative data (Chi squared test - tabular analysis); blink frequency and saccade movement and sensitivity test to visual contrast as interval data with mean and standard deviation (t-Student test Bonferroni and Tukey).

For the sake of statistical adjustment and achieving a number of suitable sample for comparison, individuals were grouped in one group aged 21 to 30 and 31 to 40 (sum of groups 2 and 3). Thus, three age groups were determined for the statistical research: Group I (21 to 30 years), Group II (sum), and Group III (over 41 years).

**RESULTS**

The results of the questionnaire on complaints of visual fatigue syndrome (VFS) as a primary variable were arranged in table 1:

**Table 1**  
**Frequency of the 3 groups of volunteers with complaints of VFS in the questionnaire in the three phases of the research.**

VFS / Questionnaire	Group I			Group II			Group III		
	1 <sup>a</sup>	2 <sup>a</sup>	3 <sup>a</sup>	1 <sup>a</sup>	2 <sup>a</sup>	3 <sup>a</sup>	1 <sup>a</sup>	2 <sup>a</sup>	3 <sup>a</sup>
Phases of the study									
Gender	M F	M F	M F	M F	M F	M F	M F	M F	M F
Signals present	0 0	2 2	0 0	0 0	1 3	0 0	0 0	2 3	0 1
Signals absent	1 1 0 0	8 8	1 1 0 0	2 2 0 0	1 1 9 7	2 2 0 0	1 10 0	8 7 7	1 9 0
X <sup>2</sup> qui squared	NS		NS			0,10*	NS		

NS: Not significant. \*: P value only expressive for alpha inference (") of 0.10 (not significant for 5% significance). Statistical test: Chi squares test with Yates correction

The total sample of patients with some kind of visual complaint to the questionnaire of visual fatigue syndrome was 16.5% (13/80 volunteers). None of these patients indicated any complaint of VFS in the first phase of the study. Only 1 volunteer described some signs of VFS in the post-control step (3<sup>rd</sup> phase).

Even though, only among patients in Group III of phase 2 (search on 4K TV) of the study mentioned some significant statistical inference, although there was no significance in the global comparison of tabular data during the research (only significant in statistics for alpha inference 0.10).

Specific signs of Glare were reported in only 7 patients (8.75%), being the other signals described by volunteers as unspecific and of mild to moderate intensity.

Table 1 presented these positive results of VFS with respect to the secondary variables. The table was distributed in groups I, II and III, in accordance with present and absent signs of VFS.

Samples regarding the blink frequency and conjugated saccade movements frequency were the most common variables significantly involved in the cases of patients with complaints of visual fatigue syndrome.

**Table 2**  
**Distribution according to the secondary variables researched**

Secondary variables	Group I			Group II			Group III											
	1 <sup>a</sup>	2 <sup>a</sup>	3 <sup>a</sup>	1 <sup>a</sup>	2 <sup>a</sup>	3 <sup>a</sup>	1 <sup>a</sup>	2 <sup>a</sup>	3 <sup>a</sup>									
VFS	VFS+	VFS-	VFS+	VFS-	VFS+	VFS-	VFS+	VFS-	VFS+	VFS-	VFS+	VFS-	VFS+	VFS-	VFS+	VFS-	VFS+	VFS-
<b>Conjugated Saccade movement</b>	1869,1 ±102,21	2198,9 ±299,47	1798,4 ±9934	2200,1 ±159,4	1868,2 ±162,3	2159,6 ±326,4	1961 ±46,77	2273 ±225,2	1943 ±56,43	2222,1 ±32,12	1997 ±65,42	2291,5 ±87,65	2032,4 ±176,2	2108,9 ±171,8	1997,6 ±87,34	2084,8 ±162,21	2041,3 ±112,3	2134 ±102,3
<b>Test t Student/Tukey</b>	Not Significant		Significant		Significant		Significant		Significant		Not Significant		Not Significant		Significant		Not Significant	
<b>Blink frequency</b>	622,5 ±33,4	5721,4 ±97,79	615,7 ±45,13	712,7 ±96,51	689,1 ±59,43	731,4 ±76,2	769,1 ±85,63	764,3 ±99,79	664,33 ±43,21	734,72 ±88,43	679,4 ±67,98	764,3 ±99,79	713,5 ±44,15	760,75 ±76,69	643,4 ±14,5	705 ±67,32	721,5 ±67,23	713,2 ±50,3
<b>Student's/Tukey Test</b>	significant		significant		Not Significant		Not Significant		Significant		Significant		Not Significant		Significant		Not Significant	
<b>Amplitude of Accommodation</b>	-0,25 ±0,25	-0,07 ±0,23	0,01 ±0,20	0,15 ±0,20	0,17 ±0,09	-0,03 ±0,14	0,20 ±0,32	0,17 ±0,13	0,31 ±0,16	0,35 ±0,26	0,34 ±0,11	0,23 ±0,22	0,55 ±0,25	0,65 ±0,25	0,95 ±0,35	0,89 ±0,25	0,75 ±0,25	0,67 ±0,20
<b>Student's/Tukey Test</b>	Not Significant		Not Significant		Not Significant		Not Significant		Not Significant		Not Significant		Not Significant		Not Significant		Not Significant	
<b>Contrast sensitivity</b>	1,79 ±0,05	1,82 ±0,04	1,75 ±0,04	1,80 ±0,03	1,80 ±0,05	1,81 ±0,04	1,80 ±0,07	1,81 ±0,03	1,79 ±0,05	1,82 ±0,04	1,81 ±0,05	1,82 ±0,04	1,80 ±0,05	1,82 ±0,05	1,79 ±0,05	1,80 ±0,04	1,81 ±0,05	1,82 ±0,04
<b>Test t Student/Tukey</b>	Not Significant		Not Significant		Not Significant		Not Significant		Not Significant		Not Significant		Not Significant		Not Significant		Not Significant	

VFS + patients complaining of Visual Fatigue Syndrome reported in the questionnaire.  
 VFS - patients not complaining of Visual Fatigue Syndrome reported in the questionnaire.  
 Values expressed as mean and standard deviation. Statistical test: Student's t - Tukey test

Table 2 shows evidence of this, especially under conditions in which there is greater visual requirement, as in phase 2 of the study, in which complaints in the VFS questionnaire were more frequent.

Variables as amplitude of accommodation or visual contrast sensitivity did not reveal a standard of significant statistic participation.

Although having statistical standard of non-significant variables, the amplitude of accommodation has progressive physiological character, according to a greater increment of age group and their Groups I, II and III.

Graphs of the type Box-Plot had a group of volunteers with smaller blink frequency and a conjugated saccade movement

frequency, even in the event condition in which there is no greater visual requirement (subgroups highlighted with asterisks).

However, when in higher demand of visual effort, there was a perception of faint fatigue, not exactly revealing any refractive morbidity.

The graphs boxes (box plot) 1, 2, 3 and 4 evaluated the overall secondary multivariate analysis of all the research, corresponding to secondary variables.

The settings for statistical significance were related to Palpebral Blink Frequency and Conjugated Saccade Movements Frequency.

## DISCUSSION

The symptoms of visual fatigue syndrome are described in vague assessments related to dry eye symptoms and associated to complaints of asthenopia<sup>3</sup>.

Due to reading attention, there is a reduction in the frequency of natural blinking. This is further emphasized when looking at the screen of computers, *Tablets e Notebooks*<sup>3</sup>.

However this complaint of visual fatigue, although widely researched when related to reading and visual accommodation, is also described as looking at computer screens at a distance, and mainly as looking at TV screens.

Yano and Acosta reported the possibility of visual fatigue complaints when looking at TV screens as being related to stereopsis, its hypothesis correlation of its main imputed factor<sup>4,5</sup>.

However, these papers were based on HDTV-3D TV with crystal-liquid or plasma screens. Currently, its highest resolution is on LED screens (FULL HD), and ULTRA HD-4k imaging system.

The main feature of 4K TV screen image is its image resolution (ULTRA HD) of 3840 x 2160 dpi, higher than the FULL HD standard of 1920 X 1080 dpi. Their individual point-to-point features of brightness, contrast and color hue make the perception of 3-D stereopsis as a visualization of three planes of raised images<sup>1</sup>.

Even so, some viewers report the feeling of images moving in relation to one another, which requires constant higher attention and mobilization of eye focus.

This type of fatigue hardly related to ocular accommodation would be similar to the eyestrain generated after a long period of Perimetry or Campimetry examination, when measuring the visual field, whether central or peripheral. This is sometimes reported by the patient<sup>6</sup>.

In this research there was the possibility of having a group of people with normal ocular exam condition, which naturally shows a palpebral blink frequency and conjugated ocular saccade movement in a lesser degree of consistency<sup>7,8</sup>.

However, only a standardized study with healthy volunteers provably evaluated by refraction and complementary psychophysical tests could reveal some evidence of this trend.

This type of study is important because there is already research about the development of TV and even computers screens with ULTRA HD 8K resolution, with possible image resolution of 4220 X 2980 dpi. In this sense, the 3D image would present a visual impression in four relief plans. This would imply a greater visual effort, in which case distance would not require accommodation or asthenopia, would be involved in the blink frequency and conjugated saccade movements<sup>9</sup>.

The limitations of the study are the bias of measuring visual effort with a questionnaire, which may vary due to the subjectivity of the questions. Therefore, the questionnaire used was binary: present or absent (not using intensity orders). Still, most of the volunteers surveyed who responded positively to visual fatigue reported slight intensity complaints.

Another problem is the measurement of ocular saccade movements of large amplitude in which the perfect measurement is described with digital equipment to focus through pupillary reflexes of corneal illumination with laser light<sup>10</sup>.

The video recording of the volunteers' eye, however, facilitates its count and recount by more than a researcher, reducing any bias of methodological error that might be in the research<sup>11</sup>.

In conclusion, the authors argue that high-resolution ULTRA HD 4K TV screens may cause complaints of visual fatigue in a population with unusual, but existing characteristics (low frequency of palpebral blink and conjugated saccade movements).

The low index of significant statistics may prove to be of great value in the use of a larger sample.

The future advent of 8K-resolution TV screens can increase this dilemma, and although the Glare report between volunteers with complaints in this research is minimal, there may be some advantages in adding anti-glare screens in these types of devices<sup>12</sup>.

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## ANEXXX 1

### Questionnaire of Visual Fatigue Syndrome Research

After watching the TV documentary, mark the answer:

1) You experienced some visual discomfort:

YES  NO

2) If so, what kind:

Burning of the eyes

Blurred vision

Eye pain

Headache

Glare

Nausea

Tiredness

Sensation hard to be defined

### Palpebral Blink Frequency

*Observed through video focused on the face of the volunteer, in particular on both eyes.*

- The study only computed evaluations with full blinking, with extreme attention to differentiating them from conjugated saccade movements.

### Frequency of Conjugated Saccade Movements

*Observed through video focused on the face of the volunteer, in particular on both eyes.*

- The study only computed evaluations with full conjugated saccade movements, with extreme attention to differentiating them from palpebral blinking. Recounts were made in the analysis of the videos when needed.

### Sensitivity Test to Contrast

#### *Method of Pelli-Robertson table*

- Reading performed immediately after watching the show on ULTRA HD 4K TV

### Amplitude of accommodation

*Refractometric method with the use of Greens refractor and Jaegger reading card.*

- Start with negative lenses until complete blurring of reading to near sight, and then use positive lenses until complete definition of reading in J1.

- Annotation of the diopter degree difference because of amplitude of accommodation.