ISA Recommendation

Human Factor Testing on the Index of Healthy and Comfortable Lighting - Test Method and Technical Requirements Based on Physiological Function of Human Eyes

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International Solid State Lighting Alliance

Technical Committee on Standardization

This recommendation is prepared by ISA Technical Committee on Standardization.
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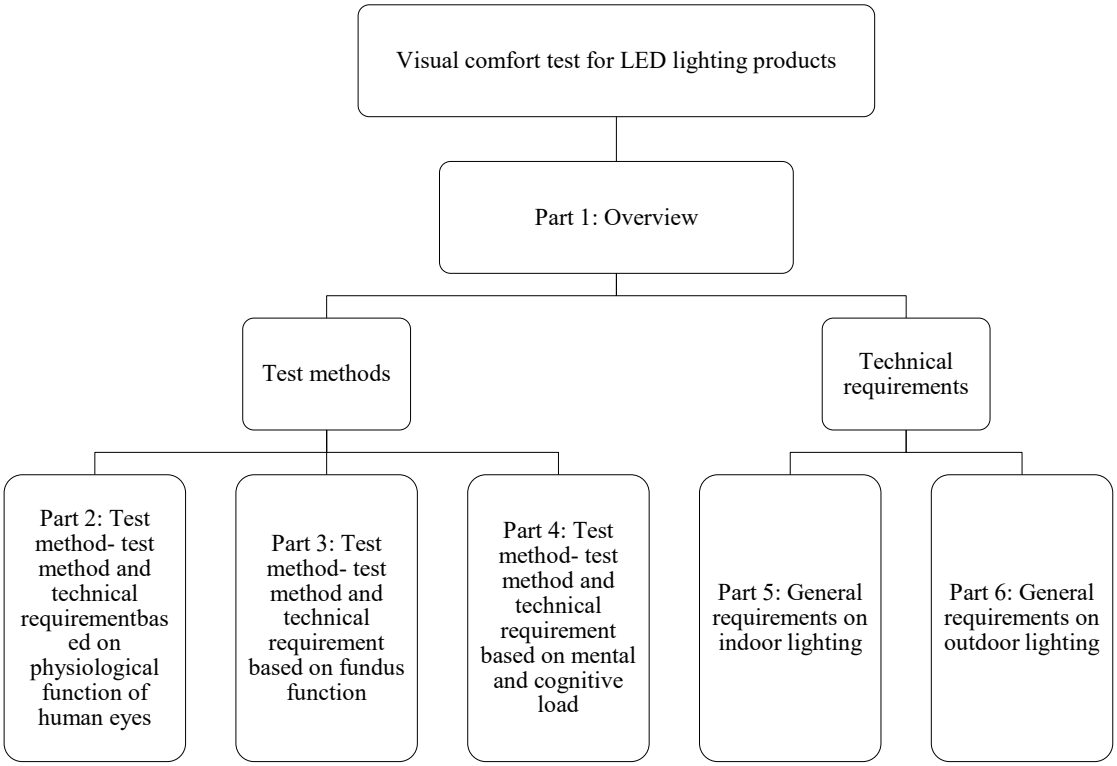
Contents

Preface

This standard is applied to the effects of LED lighting products on the visual health, based on the test methods and technical requirements for physiological function of human eyes; and it can be used to evaluate the effects of LED lighting products on physiological function of human eyes and changes of visual fatigue.

The structure of this series of standards:



Introduction

With the coming of information society, the information intake has become an integral part of human life, learning, work, growth and development. Moreover, 70% -90% of information accessed by human is from the vision, thus the visual health not only affects the health of human body, but also plays an important role in the human life, learning, work and growth.

Visual fatigue has a direct relationship with the use environment of eyes. And the influence of lighting environment is also an incentive for the increasing rate of myopia in young people. Therefore, the monitoring on the feature changes of physiological function of human eyes in lighting environment can effectively reflect the effects of external lights on the human eyes.

LED is an emerging lighting product, and it is necessary to take quantitative evaluations on the user experiences with it, especially for its various effects on the human eyes in high illuminance. Thus, the differences among LED lighting products with different light parameters can be found so that they are given full consideration during the whole process of design, manufacture, test and use. Also, these evaluations will guide the manufacturers to produce healthy products with minimum safety risk, enhance the competitiveness of their products, and create living and working conditions with “safety, health and efficiency”.

This series of standards will provide an evaluation on the lighting products based on the changes of physiological function of human eyes and then on the classification of their visual comfort to guide enterprises to effectively evaluate the influence degree of lighting on the health of human vision (visual fatigue/visual comfort) and to provide energy saving, healthy and comfortable lighting products.

Visual Comfort Test for LED Lighting Products

Part 2: Test method- Test method and technical requirements based on physiological function of human eyes

1. Scope

This standard is applied to the effects of LED lighting products on the visual health, and specifies the test methods and technical requirements for physiological function of human eyes; and it can be used to evaluate the effects of LED lighting products on physiological function of human eyes and changes of visual fatigue.

This standard is applicable to indoor and outdoor lighting with LED lights, such as: LED down lamps, LED tube lights, LED flat lamps, LED lamps, LED street lamps and so on.

2. Normative references

The terms in the following documents are referred to be part of this standard. For dated references, their subsequent revisions are all inapplicable to this standard. For undated references, their latest editions apply to this standard.

ISO 8995-1-2002 Lighting of work places - Part 1: Indoor

ISO 8995-3-2006 Lighting of work place - Part 3: Lighting requirements for safety and security of outdoor work places

BS EN 62471-2008 Photobiological safety of lamps and lamp systems

IEC 62031-2008 LED modules for general lighting - Safety specifications

3. Terms and definitions

3.1 Visual Comfort Index (VICO Index)

Visual Comfort Index (VICO Index) is an index to evaluate the effects of lighting products on the physiological function changes of human vision and visual fatigue based on visual optometry and subjective cognition. Moreover, VICO Index is independent of the physical indexes of lighting products (color temperature, color rendering index, illuminance, luminance, stroboflash, etc.), and it reflects an objective and quantitative evaluation on the effects of lighting products to the physiological function of human vision completely from the perspective of visual function of human eyes. And it is mainly applied to evaluate the effects of lighting products on the visual fatigue of human eyes in visual optometry - axial length and corneal diopter.

3.2 Dominant Eye

The dominant eye is also called the watch eye or preponderance eye. From the aspect of human physiology, everyone has a dominant eye, which may be the left or the right. And the image seen by the dominant eye is accepted first by the brain.

3.3 Binocular fusion

It refers to the fusion or binding ability of the binocular retinal imaging for both eyes to obtain binocular vision, which includes the sense fusion and the motion fusion. And the sense fusion is the ability of both eyes to combine the sensory information to form a single image; the motion fusion is the ability of both eyes to keep the image in motion consistent.

3.4 Binocular balance

The image size, shape, clarity, contrast, and orientation of the same object on the left and right retina are all the same. And when observing the object with same distance, the regulation and tracking ability of both eyes are also the same.

3.5 Color discrimination

It refers to the discriminating ability of human eyes to color difference.

3.6 User experience

It refers to the subjective feelings of users generated during the use process of product.

3.7 Refractive status, RS

It refers to the refraction conditions of the tested eye, that is, the imaging conditions in the retina of objects at infinity. The inspection on the refractive status of the eye is called optometry.

3.8 Accommodative convergence/accommodation ratio, AC/A

The ratio of accommodative convergence (AC) to stimulus accommodation (A) can reflect the relationship of associative motion between accommodative convergence and accommodation. AC refers to the convergence accompanied by accommodation and caused by the excitement of regulating center when the eyes stare at the object in limited distance, and the eye regulation stimulates the eye axis inward convergence. A refers to the change in refractive ability of eyes during the attention changing process between distant and nearby objects.

3.9 Higher order aberrations, HOAs

A dot-like target does not form an ideal image through an optical system, but occurs an optical defect and forms a blurred diffuse spot. At this moment, the shape of the image is very similar to the object, but not exactly the same, and the difference between them is called aberration. If the order expansion of aberration is greater than or equal to 3, it is called high order aberration.

3.10 Modulation transfer function, MTF

Modulation transfer function (MTF) is an optical function that evaluates the imaging quality of an optical system. And it reflects the attenuation degree of the amplitude of the sinusoidal intensity distribution function after passing through an optical system. That is, the change of image over modulation degree. When the modulation degree varies with the spatial frequency, it is called the modulation transfer function.

4. Technical requirements

4.1 This standard does not contain the requirements on electrical safety and environmental protection. Therefore, the lighting products shall meet the relevant standards of quality and environmental protection on their labels before the test on visual comfort is taken.

4.2 Product manufacturers shall follow the principle of user visual comfort protection in the design process.

4.3 Requirements on Visual Comfort Index (VICO Index)

Visual Comfort Index (VICO Index) is classified into five levels, and the higher the level the higher the fatigue degree of human vision, that is, the greater the effect of lighting environment provided by the lighting product being tested on the visual comfort of human eyes. The specific quantitative classification is shown in Table 1.

Table 1 Quantitative classification of Visual Comfort Index (VICO Index)

Level	Level 1	Level 2	Level 3	Level 4	Level 5
Test Score	0＜VICO≤1	1＜VICO≤2	2＜VICO≤3	3＜VICO≤4	4＜VICO≤5
Vision State	No feeling of fatigue	Mild feeling of fatigue	Obvious feeling of fatigue, but within the tolerable range	Increased feeling of fatigue, with various symptoms of eye discomfort	Severe feeling of fatigue, with obvious and intolerable discomfort symptoms
Test Conclusion		Pass		Failed	

Note: the symptoms of eye discomfort include tears, blurred vision, eye itching, photophobia, eye swelling, foreign body sensation, vertigo, dry eyes, headaches, dizziness, nausea, vomiting and other syndromes.

5. Test methods

5.1 Subject requirements

5.11 Sample size

In general, the number of subjects involved in the test on physiological function of human eyes shall be ensured more than or equal to 20. Depending on the specific objectives of the study and the actual conditions, the sample size may be increased accordingly.

5.1.2 Subject screening

Subjects were screened mainly from four aspects: the visual status, gender, age, and education background.

a) The current clinical test methods of vision shall be used to collect and screen the basic information of subjects from the refraction, the dominant eye, binocular fusion, binocular vision balance, color recognition, regulation and convergence, intraocular pressure and other aspects. And the subjects with severe refraction and recessive eye disease shall be excluded to avoid the effects on the test results due to the eye disease.

b) Age screening is used to determine the distribution of main user for the product to be tested. In principle, the subjects shall be selected from the target users for the product under test.

c) The gender ratio of the subjects recruited shall be ensured to be 1: 1 as far as possible.

d) The screening on education background is used to determine the difficulty degree of the test for the subjects to ensure the effectiveness of the testing process.

5.1.3 Subject instruction

The tester shall explain to the participants the object of experiment and any adverse effects when exposed to the LED light source used in the test. And the “Informed Consent Form” shall be signed to ensure the test taken under the true will of subjects.

5.1.4 Subject preparation

Subjects shall ensure adequate rest and sleep before the test, so as not to affect the test results due to accumulative fatigue. Prior to each test, subjects shall take a rest in the dark room with both eyes closed at least fifteen minutes to ensure the best vision function.

5.2 Test Environment

The environment for human test shall be controlled at room temperature with the relative humidity less than 85%, and be kept from stray lights effectively. The setting of the test environment shall be simulated according to the applicable environment of the LED lighting products to be tested, as close as possible to the actual applications. Meanwhile, the cross-effects of other light sources on the test product shall be avoided, and the lighting environment for the test shall be ensured mainly coming from the LED lighting

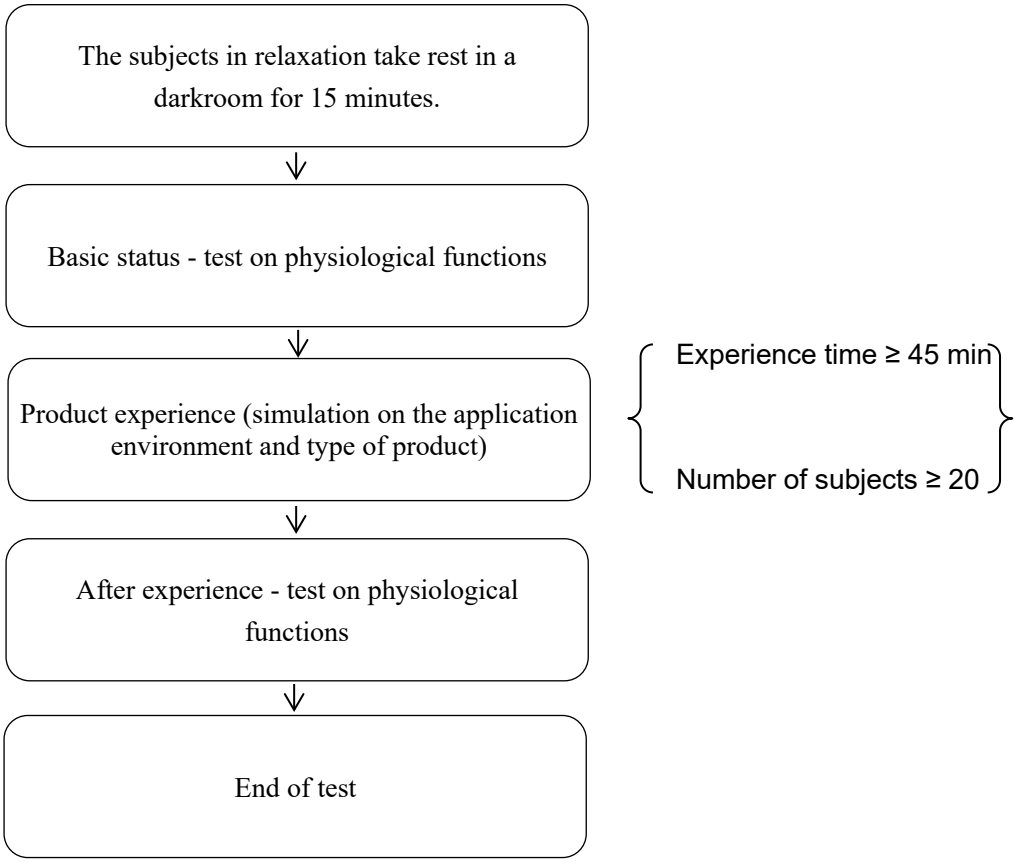
product under test.

5.3 Test for physiological function of human eyes

5.3.1 Test procedure

The brief test process for physiological function of human eyes is shown in Figure 1.

Fig.1 The brief test process for physiological function of human eyes



5.3.2 Test methods

In the LED light source environment being tested, the data on various types of visual function of subjects are collected before and after the loading test, and the specific test items are as follows:

a. Basic diopter test

The values of basic diopter are measured for both eyes by an ophthalmic refractometer.

b. Test for AC/A ratio of human eyes

The AC/A ratios of subject's eyes are measured by an optometry combined table.

c. Test for higher order aberration of human eyes and visual modulation transfer function

The higher order aberration HOAS and the visual modulation transfer function MTF of

subject's eyes are measured by a wavefront analyzer.

Note: Load tasks can include reading, daily work, information retrieval, etc. Test instruments include wavefront analyzer, magic visual chart box, optometry combined table and ophthalmic refractometer.

5.3.3 Product experience

Under the experimental environment of LED lighting products to be tested, the subjects were required to complete the load task in specified time. The contents of the task shall be consistent with the cultural ability and work habits of the subjects to ensure that the working intensity for each participant was maintained at a constant level during the experiment, without significant difference.

5.3.4 Subjective evaluation

After completing the process of product experience, the subjects shall fill in a subjective rating scale for the visual comfort test of the LED lighting environment, and give honest feedback on their subjective feelings during the experiment.

5.4 Result calculation

The index differences of AC/A ratio, higher order aberration and MTF data before and after the test on physiological function of human eyes and the basic diopter values measured for all subjects are entered into the special calculation software of VICO index for the evaluation model of visual comfort. And the VICO exponential result V_x of the single test for subject is obtained finally by the special calculation software.

The VICO index V_y of the LED lighting product under test is calculated from the test results of all the subjects (the number is n) of this test according to the following formula.

$$V_y = \frac{\sum_{x=1}^{n} V_X}{n}$$

In this formula, V_x is the VICO test result of single subject; V_y is the average value of VICO test results for all subjects (the number is n) for the test, that is, the test result of visual comfort for the LED lighting product.

The establishment process of evaluation model for visual comfort is shown in Appendix A.

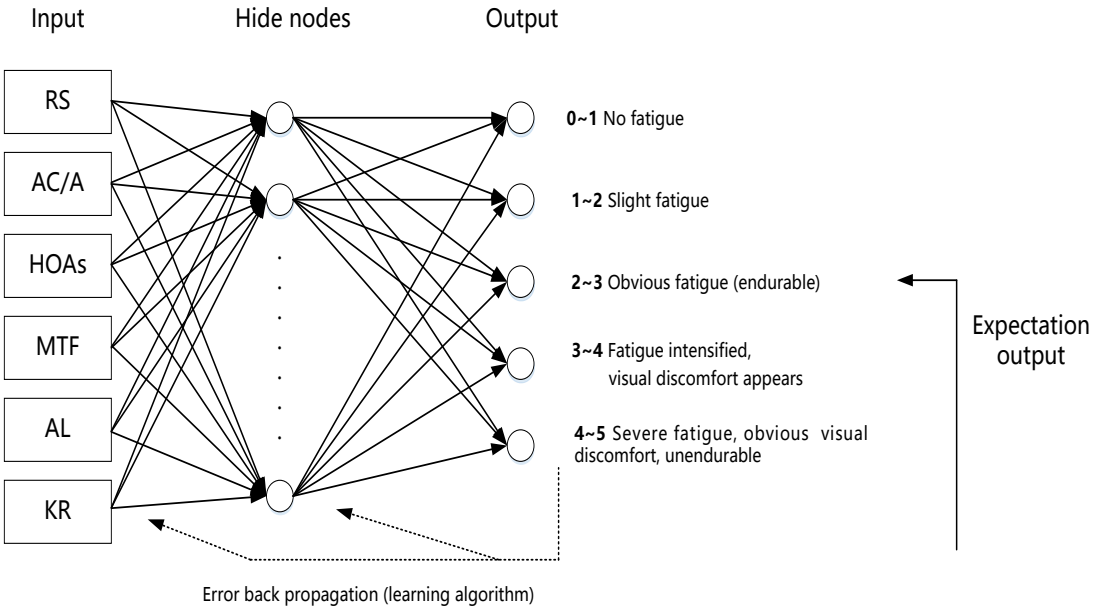
Appendix A
(Reference appendix)

Establishment process of evaluation model for visual comfort

The model of visual comfort is based on the theory of multi-parameter evaluation and the theory of BP neural network.

BP (Back Propagation) network is a multi-layer feedforward network trained by the algorithm of error back propagation and was proposed by the scientist group of Rumelhart and McCelland (1986). By far, it is one of the most widely used neural network models. BP network can learn and store a large amount of mapping relation on input- output mode, without the need on mathematical equations to describe the mathematical relationship in advance. Its learning rule is to adjust the weights and thresholds of the network through back propagation by use of the steepest descent method so as to minimize the sum of squares of network errors. The topological structure of BP neural network model consists of input layer, hide layer and output layer, as shown in Figure A.1.

Fig.A.1 The structure of prediction model for BP neural network of visual fatigue



The objective visual parameters can be obtained by the test. In order to ensure the stability of the network, four objective indexes of both eyes for each subjective are taken as the input layer P (Input) of the network, and the subjective scores of the user during the test are taken as the output layer T (Output). The training of the network is completed by a toolbox of Matlab R2013b neural network. The number of nodes in the hidden layer is

determined by the trial and error method. Based on the error value obtained by many times of training on neural networks with different numbers, the hidden layer with 25 nodes is selected for the model with better approximation and stronger generalization ability, as shown in Figure A.2.

Fig.A.2 The model diagram of artificial neural network

In order to improve the generalization ability of the network model, the input and output parameters above are normalized so that the data are in the interval [0, 1], and the processing formula is:

$$\hat{x} = x - x_{min} xmax - xmin$$

The group for drafting this standard collected the data on physiological parameters of eyes from almost ten thousand subjects, built a database on human visual function with large sample size, and then analyzed the changes on the visual function parameters under different fatigue status.

Based on the database of human eyes with large sample size, the prediction model of neural network can characterize the fatigue status of eyes effectively, and can evaluate the lighting products and display products quickly and effectively via the quantified grading method.

Appendix B
(Normative appendix)

Template for Informed Consent Form of Subject

Dear Sir/Madam_____:

Thank you very much for participating in this pilot project_____. The specific content of this experiment is_____. As an experimental participant, please read carefully the followings to ensure your interest and safety during the experiment. Finally, I do hope you can cooperate with the experimental staff actively in the process so as to complete the scheduled experiment. In case of any problems, please contact us freely. And thanks again for your participation and support.

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Informed Consent of Form for Experiment

Experiment Objective

The objective of this experiment is _____via the method of_____.

Experiment Procedure

Before this experiment, the experimental staff will record the general information of subjects.

In the actual experiment, ____(Instructions on experiment procedure)_____.

Potential Risks

Long-term viewing and reading in the experiment may cause many reactions, such as _____, which are normal experimental response, and the discomfort will disappear after a period of time. When the subject has a strong sense of discomfort in the test process, he or she can request to stop the experiment and take a rest immediately, then continue the experiment after feeling normal. When the subject feels unable to continue, he or she can request to stop the experiment at any time.

Privacy

Data collected in this experiment may be published in academic journals/books, or for

scientific research purposes. However, the name of the participant or other private identification information will not appear in any published or teaching books without prior permission from the participant.

I have read the informed consent of form for experiment _____and have full knowledge of its content thereof. And the signature below indicates that I have fully understood the nature and risks of this experiment and agreed to participate in it. And I voluntarily participate in this experiment and have the right to withdraw freely during its process.

Signature of subject: Date of signature: