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SERIES P: TERMINALS AND SUBJECTIVE AND  
OBJECTIVE ASSESSMENT METHODS

Audiovisual quality in multimedia services

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## **Subjective assessment methods for 3D video quality**

Recommendation ITU-T P.915

ITU-T

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# Recommendation ITU-T P.915

## Subjective assessment methods for 3D video quality

### Summary

Recommendation ITU-T P.915 describes non-interactive subjective assessment methods for evaluating the one-way overall video quality for three-dimensional (3D) video applications such as 3D videoconferencing, and 3D cable television. These methods can be used for several different purposes including, but not limited to, selection of algorithms, ranking of system performance and evaluation of the quality level during a video connection. ITU-T P.915 also outlines the characteristics of the source sequences to be used, such as duration, kind of content and number of sequences. Details within ITU-T P.915 are expected to change, based on experiments into how best to conduct 3DTV subjective tests.

### History

| Edition | Recommendation | Approval   | Study Group | Unique ID*                                                                      |
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\* To access the Recommendation, type the URL <http://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID. For example, <http://handle.itu.int/11.1002/1000/11830-en>.

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## Introduction

Stereoscopic three-dimensional (3D) television attempts to emulate the response of the human binocular visual system to the relative depth perception of objects. This Recommendation applies to stereoscopic imaging that directs a different view of the same scene to each eye. The images of the objects depicted in the scene have different relative positions in the left-and right-view. 3D television viewing does not perfectly recreate the real viewing experience, because the normal formulae for accommodation (i.e., focus) and vergence (i.e., eye angle) do not apply. A variety of displays produce this effect, including stereoscopic and autostereoscopic displays, using glasses with polarized lenses or shutters; and 2D televisions using complementary colour anaglyphs and glasses with coloured filters.

Assessment factors generally applied to monoscopic (two-dimensional or 2D) television pictures can be applied to stereoscopic television systems. In addition, there are many factors unique to stereoscopic television systems. These include factors such as depth resolution, which is the spatial resolution in depth direction, depth motion (i.e., motion or movements along the depth direction), and visual comfort.

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# Recommendation ITU-T P.915

## Subjective assessment methods for 3D video quality

### 1 Scope

This Recommendation describes subjective evaluation of 3D video. Topics include assessment methods, subjective scales, environmental conditions, viewing distance, display size and data analysis. These experiments can answer different questions, such as video quality, depth quality, naturalness, visual discomfort, quality of experience, viewing experience and presence.

The applications of the subjective assessment methods for 3D video quality described in this Recommendation include, but are not limited to obtaining perceptual 3D video quality.

This Recommendation contains insufficient information for the following applications. While most of the information provided herein applies, additional constraints are required:

- medical applications;
- immersive, virtual reality environments (e.g., gaming, caves, head mounted displays);
- augmented reality.

### 2 References

The following ITU-T Recommendations and other references contain provisions, which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T P.78] Recommendation ITU-T P.78 (1996), *Subjective testing method for determination of loudness ratings in accordance with Recommendation P.76.*
- [ITU-T P.800] Recommendation ITU-T P.800 (1996), *Methods for subjective determination of transmission quality.*
- [ITU-T P.800.2] Recommendation ITU-T P.800.2 (2013), *Mean opinion score interpretation and reporting.*
- [ITU-T P.914] Recommendation ITU-T P.914 (2016), *Display requirements for 3D video quality assessment.*
- [ITU-T P.916] Recommendation ITU-T P.916 (2016), *Information and guidelines for assessing and minimizing visual discomfort and visual fatigue from 3D video.*
- [ITU-T P.1401] Recommendation ITU-T P.1401 (2012), *Methods, metrics and procedures for statistical evaluation, qualification and comparison of objective quality prediction models.*
- [ITU-R BT.500-13] Recommendation ITU-R BT.500-13 (2012), *Methodology for the subjective assessment of the quality of television pictures.*
- [ITU-R BT.1788] Recommendation ITU-R BT.1788 (2007), *Methodology for the subjective assessment of video quality in multimedia applications.*

[ITU-R BT.2021-1] Recommendation ITU-R BT.2021 (2015), *Subjective methods for the assessment of stereoscopic 3DTV systems*.

[ITU-R BT.2160-2] Report ITU-R BT.2160-2 (10/2011), *Features of three-dimensional television video systems for broadcasting*.

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

**3.1.1 double stimulus** [b-ITU-T P.913]: A quality rating method where the subject is presented with two stimuli; the subject then rates both stimuli in the context of the joint presentation (e.g., a rating that compares the quality of one stimulus to the quality of the other).

**3.1.2 hypothetical reference circuit (HRC)** [b-ITU-T P.913]: A fixed combination of a video encoder operating at a given bit rate, network condition and video decoder. The term HRC is preferred when vendor names should not be identified.

**3.1.3 least distance of distinct vision (reference seeing distance)** [b-ITU-T P.913]: The closest distance at which someone with normal vision (20/20 vision) can comfortably look at something..

**3.1.4 processed** [b-ITU-T P.913]: The reference stimuli presented through a system under test.

**3.1.5 processed video sequence (PVS)** [b-ITU-T P.913]: The impaired version of a video sequence.

**3.1.6 reference** [b-ITU-T P.913]: The original version of each source stimulus. This is the highest quality version available of the audio sample, video clip or audiovisual sequence.

**3.1.7 sequence** [b-ITU-T P.913]: A continuous sample of audio, video or audiovisual content.

**3.1.8 single stimulus** [b-ITU-T P.913]: A quality rating method where the subject is presented with one stimulus and rates that stimulus in isolation (e.g., a viewer watches one video clip and then rates it).

**3.1.9 source** [b-ITU-T P.913]: The content material associated with one particular audio sample, video clip or audiovisual sequence (e.g., a video sequence depicting a ship floating in a harbour).

**3.1.10 stimulus** [b-ITU-T P.913]: Audio sequence, video sequence or audiovisual sequence.

**3.1.11 subject** [b-ITU-T P.913]: A person who evaluates stimuli by giving an opinion.

**3.1.12 terminal** [b-ITU-T P.913]: Device or group of devices used to play the stimuli during a subjective experiment [e.g., a laptop with earphones, or a Blu-ray player with an liquid crystal display (LCD) monitor and speakers].

#### 3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

**3.2.1 depth quality:** The ability of the system to deliver a sensation of depth. The presence of monocular cues (such as linear perspective, blur and gradients) conveys some sensation of depth even in standard 2D images. Stereoscopic 3D images contain also disparity information which provides additional depth information and thus an enhanced sense of depth as compared to 2D.

**3.2.2 frame effect:** The effect of 3D pictures appearing highly unnatural when objects positioned in front of the screen approach the screen frame. The effect is generally reduced with a larger screen, because observers are less conscious of the existence of the frame when the screen is larger.

**3.2.3 naturalness:** The perception of the stereoscopic image as being a truthful representation of reality (i.e., perceptual realism). The stereoscopic image may present different types of distortion that make it less natural. For example, stereoscopic objects are sometimes perceived as unnaturally large or small (puppet theatre effect) or they appear unnaturally thin (cardboard effect).

**3.2.4 picture quality:** The quality of rendering of texture and motion, the level of visibility of visual artifacts and rendering details. The perceived quality of the video provided by the system. This is a main determinant of the performance of any video system. Picture quality is mainly affected by technical parameters and errors introduced by, for example, encoding or transmission processes or 3D video format conversions such as 2D plus depth to stereoscopic images.

**3.2.5 quality of experience (QoE):** The degree of satisfaction of the user of an application or service. It results from the fulfilment of his or her expectations with respect to the utility or enjoyment of the application or service in the light of the user's personality and current state.

NOTE – Definition based on that appearing in [b-Qualinet, 2014].

**3.2.6 sense of presence:** The subjective experience of being in one place or environment even when situated in another.

**3.2.7 visual experience:** The overall quality of experience of the images in terms of immersion, perceived image quality as well as depth rendering considering the shape and the dimension of objects.

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

|         |                                                  |
|---------|--------------------------------------------------|
| 2AFC-PC | two Alternative Forced Choice Pair Comparison    |
| 3AFC-PC | three Alternative Forced Choice Pair Comparison  |
| 2D      | two Dimensional                                  |
| 2DTV    | two Dimensional Television                       |
| 3D      | three Dimensional                                |
| 3DMV    | three Dimensional Multiview                      |
| 3DTV    | three Dimensional Television                     |
| ACR     | Absolute Category Rating                         |
| ACR-HR  | ACR with Hidden Reference                        |
| ARD     | Adaptive Rectangular Design                      |
| CCR     | Comparison Category Rating                       |
| CI      | Confidence Interval                              |
| DCR     | Degradation Category Rating                      |
| DMOS    | Differential Mean Opinion Score                  |
| DSCS    | Double Stimulus Comparison Scale                 |
| DSCQS   | Double Stimulus using a Continuous Quality Scale |
| DSIS    | Double Stimulus Impairment Scale                 |
| DV      | Differential Viewer score                        |

|        |                                                        |
|--------|--------------------------------------------------------|
| FPC    | Full Pair Comparison                                   |
| HDTV   | High Definition Television                             |
| LCD    | Liquid Crystal Display                                 |
| LDDV   | Least Distance of Distinct Vision                      |
| LPCC   | Linear Pearson Correlation Coefficient                 |
| MCI    | Mean Confidence Interval                               |
| MOS    | Mean Opinion Score                                     |
| ORD    | Optimized Rectangular Design                           |
| PVS    | Processed Video Sequence                               |
| QoE    | Quality of Experience                                  |
| REF    | Reference                                              |
| RGB    | Red–Green–Blue                                         |
| RSD    | Reference Seeing Distance                              |
| S3D    | Stereoscopic three Dimensional television              |
| SAMVIQ | Subjective Assessment of Multimedia VIdeo Quality      |
| SQAM   | Sound Quality Assessment Material                      |
| SS     | Single Stimulus                                        |
| YUV    | luminance (Y) – blue luminance (U) – red luminance (V) |

## 5 Conventions

"3D" in this Recommendation refers to a technology that projects dedicated views for each eye. The ultimate goal is these views depict the same situation as would be seen in reality (e.g., horizontally shifted). The technology as a whole can include more than two views, as per a multi-view autostereoscopic display. This can be noted as S3D for stereoscopic 3DTV, or 3DMV for multiview.

## 6 Selection of 3D source content

In order to evaluate 3D visual experience and other terms defined in this Recommendation in various circumstances, the content should cover a wide range of 3D videos. In particular, 3D content with a variety of texture, depth and motion should be used for accurate assessment.

The 3D test sequences should be selected according to the goal of the test and recorded on a digital storage system. When the experimenter is interested in comparing results from different laboratories, it is necessary to use a common set of source sequences to eliminate a further source of variation.

The selection of the test material should be motivated by the experimental question addressed in the study. For example, the content of the test sequences (sport, drama, film, etc.) and their spatiotemporal and depth characteristics should be representative of the programmes delivered by the service under study. [b-Pinson, 2013] provides guidance on choosing suitable scenes for 3D subjective tests.

### 6.1 Visual comfort

The selected stereoscopic test sequences content should be normally comfortable to watch. See [ITU-T P.916] for information on visual comfort.

## 6.2 Source signal recordings

The source signal provides the reference stimuli and the input for the system under test.

The quality of the reference stimuli should be as high as possible. As a guideline, the video signal should be recorded in uncompressed multimedia files using one of the following two formats: YUV (4:2:2 or 4:4:4 sampling) or RGB (24 or 32 bits). Usually the audio signal is taken from a high quality audio production. The audio CD quality is often the reference (16 bits, 44.1 kHz) such as the sound quality assessment material (SQAM) from the European Broadcasting Union (EBU), but if possible audio masters with a minimum of 16 bits and 48 kHz are preferred.

## 6.3 Spatial and temporal information

The selection of test scenes is an important issue. In particular, the spatial and temporal perceptual information of the scenes are critical parameters. These parameters play a crucial role in determining the amount of video compression that is possible, and consequently, the level of impairment that is suffered when the scene is transmitted over a fixed-rate digital transmission service channel. Relevant video test scenes must be chosen such that their spatial and temporal information is consistent with the video services that the digital transmission service channel is intended to provide. The set of test scenes should span the full range of spatial and temporal information of interest to users of the devices under test.

## 6.4 Optional subjective methods for 3D reference scene selection: Visual experience and visual comfort requirements

To conduct a subjective test on 3D video, it is desirable to select a set of original scene contents (reference video) with a maximum visual comfort. Preferably, 3D original scene contents should have visual comfort similar to the 2D version of that content, for short viewing durations. In fact, the main goal of 3D video subjective tests is to evaluate the impact of 3D video technologies or image processing algorithms on viewers' opinion in terms of visual experience, image quality and visual comfort. In case of visual discomfort issues with reference scene contents, visual discomfort may interact with the other quality scales and adversely affect related results, resulting in much more difficulty in evaluating the contribution of 3D technologies to guaranteeing an optimal visual experience. Therefore, to ensure a fair comparison of technologies as well as reliable and stable results, the following procedures are recommended for reference scene content selection.

Perform a subjective video quality experiment on the reference scenes (only). The experiment will consist of two sessions: (1) rating visual comfort and (2) rating visual experience. Each session will include the 3D reference, and also the 2D version of that reference (e.g., left eye view).

Select reference sequences where:

- the 3D version has the same level of visual comfort as the 2D version for a short viewing duration (e.g., no significant difference from a statistical point of view);
- the 3D version has a higher (i.e., better) visual experience than the 2D version from a statistical point of view.

The difference between the 2D and 3D version, i.e., the added value of 3D and the visual discomfort added by well-shot 3D sequences is often small. The difference may only be measurable with an appropriate subjective assessment method, such as pair comparison.

These 3D reference selection criteria can be obtained from previous subjective tests (e.g., performed by other laboratories). These 3D reference selection criteria can be gathered simultaneously with the target 3D experiment.

Preferably, select scene contents of various video complexities in terms of texture, motion and depth. In fact, to evaluate the impact of the scene content on results, it is important to select original test sequences of different depth levels as well as natural and synthetic ones.

## 6.5 Discrepancies between left and right images

In stereo 3D systems, a binocular 3D image is formed by presenting the left and right image to their respective eye. If discrepancies arise between these two images, they can cause psychophysical stress, and in some cases 3D viewing can fail. For example, when shooting and displaying stereoscopic 3DTV programmes, there may be geometrical, optical, electrical or temporal asymmetries, such as size inconsistency, vertical shift, rotation error, and luminance or colour levels between the left and right images. For the production of natural scene content using two independent video cameras, the main issue is to guarantee that the asymmetries of the views are under perceptual limits.

Annex 4 of [ITU-R BT.2160-2] provides limits for tolerances. The limits depend on viewing conditions and source material type.

In addition to the abovementioned recommendation, Table 1 illustrates visibility thresholds obtained from subjective experiments using an impairment scale and for a viewing distance of 4.5 times the display height [b-Wei, 2012].

**Table 1 – Visibility thresholds related to left and right view asymmetries**

| Parameter          | Description                                    | Visibility threshold |
|--------------------|------------------------------------------------|----------------------|
| Vertical disparity | Vertical shift difference (local or global)    | 0.4%                 |
| Rotation           | Rotation difference between the two views      | 0.25°                |
| Focal length       | Magnification difference                       | 0.5%                 |
| Black level        | Black level difference between the two views   | 3%                   |
| White level        | White level difference between the two views   | 10%                  |
| Colorimetry        | Colorimetry difference considering RGB signals | 10%                  |
| Temporal           | Temporal asymmetry (shooting or visualization) | To be tested         |

## 6.6 Duration of stimuli

The methods in this Recommendation are intended for stimuli that range from 5 to 20 s in duration. Sequences of 8 to 10 s are highly recommended. For longer durations, it becomes difficult for viewers to take into account all of the quality variations and score properly in a global evaluation. The temporal forgiveness effects becomes important when the time duration of a stimulus is high (see [b-Hands, 2001]).

Extra source content may be required at the beginning and end of each source stimulus. For example, when creating a 10 s processed stimulus, the source might have an extra 2 s of extra content before and after, to give a total of 14 s. The purpose of the extra content is to allow the audio and video coders to stabilize, and prevent the propagation of unrelated content into the processed stimuli (e.g., after the occurrence of digital transmission errors). The extra content should be discarded during editing. This technique is advised when analysing hardware coders or transmission errors.

In order to limit the duration of a test, stimulus durations of 10–15 s are preferred. This also diminishes subjects' fatigue.