RECOMMENDATION ITU-R BT.500-8

METHODOLOGY FOR THE SUBJECTIVE ASSESSMENT OF THE QUALITY OF TELEVISION PICTURES

(Question ITU-R 211/11)

(1974-1978-1982-1986-1990-1992-1994-1995-1998)

The ITU Radiocommunication Assembly,

considering

a) that a large amount of information has been collected about the methods used in various laboratories for the assessment of picture quality;

b) that examination of these methods shows that there exists a considerable measure of agreement between the different laboratories about a number of aspects of the tests;

c) that the adoption of standardized methods is of importance in the exchange of information between various laboratories;

d) that routine or operational assessments of picture quality and/or impairments using a five-grade quality and impairment scale made during routine or special operations by certain supervisory engineers, can also make some use of certain aspects of the methods recommended for laboratory assessments;

e) that the introduction of new kinds of television signal processing such as digital coding and bit-rate reduction, new kinds of television signals using time-multiplexed components and, possibly, new services such as enhanced television and HDTV may require changes in the methods of making subjective assessments;

f) that the introduction of such processing, signals and services, will increase the likelihood that the performance of each section of the signal chain will be conditioned by processes carried out in previous parts of the chain,

recommends

1 that the general methods of test, the grading scales and the viewing conditions for the assessment of picture quality, described in the following Annexes should be used for laboratory experiments and whenever possible for operational assessments;

2 that, in the near future and notwithstanding the existence of alternative methods and the development of new methods, those described in §§ 4 and 5 of Annex 1 to this Recommendation should be used when possible; and

3 that, in view of the importance of establishing the basis of subjective assessments, the fullest descriptions possible of test configurations, test materials, observers, and methods should be provided in all test reports;

4 that, in order to facilitate the exchange of information between different laboratories, the collected data should be processed in accordance with the statistical techniques detailed in Annex 2 to this Recommendation.

NOTE 1 – Information on subjective assessment methods for establishing the performance of television systems is given in Annex 1.

NOTE 2 – Description of statistical techniques for the processing of the data collected during the subjective tests is given in Annex 2.

ANNEX 1

Description of assessment methods

1 Introduction

Subjective assessment methods are used to establish the performance of television systems using measurements that more directly anticipate the reactions of those who might view the systems tested. In this regard, it is understood that it may not be possible to fully characterize system performance by objective means; consequently, it is necessary to supplement objective measurements with subjective measurements.

In general, there are two classes of subjective assessments. First, there are assessments that establish the performance of systems under optimum conditions. These typically are called quality assessments. Second, there are assessments that establish the ability of systems to retain quality under non-optimum conditions that relate to transmission or emission. These typically are called impairment assessments.

To conduct appropriate subjective assessments, it is first necessary to select from the different options available those that best suit the objectives and circumstances of the assessment problem at hand. To help in this task, after the general features reported in § 2, some information is given in § 3 on the assessment problems addressed by each method. Then, the two main recommended methods are detailed in §§ 4 and 5. Finally, general information on alternative methods under study is reported in § 6.

The purpose of this Annex is limited to the detailed description of the assessment methods. The choice of the most appropriate method is nevertheless dependent on the service objectives the system under test aims at. The complete evaluation procedures of specific applications are therefore reported in other ITU-R Recommendations.

2 Common features

General viewing conditions for subjective assessments are given. Specific viewing conditions, for subjective assessments of specific systems, are given in the related Recommendations.

2.1 General viewing conditions

Different environments with different viewing conditions are described.

The laboratory viewing environment is intended to provide critical conditions to check systems. General viewing conditions for subjective assessments in the laboratory environment are given in § 2.1.1.

The home viewing environment is intended to provide a means to evaluate quality at the consumer side of the TV chain. General viewing conditions in § 2.1.2 reproduce a near to home environment. These parameters have been selected to define an environment slightly more critical than the typical home viewing situations.

Some aspects relating to the monitors resolution and contrast are discussed.

2.1.1 Laboratory environment

2.1.1.1 General viewing conditions for subjective assessments in laboratory environment

The assessors' viewing conditions should be arranged as follows:

a) Ratio of luminance of inactive screen to peak luminance: ≤ 0.02

b) Ratio of the luminance of the screen, when displaying only black level in a completely dark room, to that corresponding to peak white: ≈ 0.01

c) Display brightness and contrast: set up via PLUGE (see Recommendations ITU-R BT.814 and ITU-R BT.815)

d) Maximum observation angle relative to the normal (this number applies to CRT displays, whereas the appropriate numbers for other displays are under study): 30°

e) Ratio of luminance of background behind picture monitor to peak luminance of picture: ≈ 0.15

f) Chromaticity of background: D_{65}

g) Other room illumination: low

2.1.2 Home environment

2.1.2.1 General viewing conditions for subjective assessments in home environment

a) Ratio of luminance of inactive screen to peak luminance: ≤ 0.02 See § 2.1.4

b) Display brightness and contrast:
(see Recommendations ITU-R BT.818 and ITU-R BT.815) set up via PLUGE

c) Maximum observation angle relative to the normal (this number applies to CRT displays, whereas the appropriate numbers for other displays are under study): 30°

d) Screen size for a 4/3 format ratio:
This screen size should satisfy rules of “preferred viewing distance” (PVD).

e) Screen size for a 16/9 format ratio:This screen size should satisfy rules of “preferred viewing distance” (PVD).

f) Monitor processing:
Without digital processing

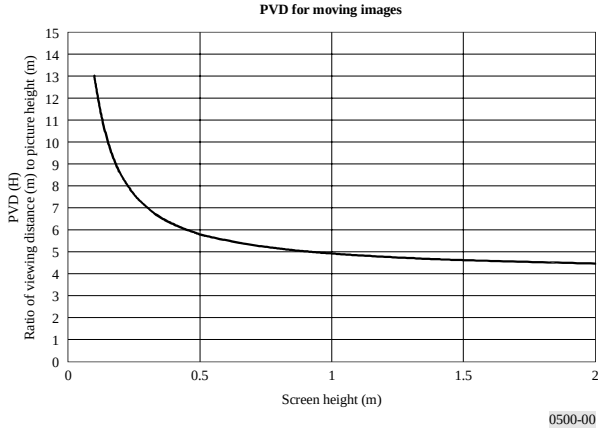
g) Monitor resolution:
See § 2.1.3

h) Peak luminance:
200 cd/m^2

i) Environmental illuminance on the screen: (Incident light from the environment falling on the screen, should be measured perpendicularly to the screen).
200 lux

The viewing distance and the screen sizes are to be selected in order to satisfy the PVD. The PVD (in function of the screen sizes) is shown in the following Table and graph. Figures could be valid both for SDTV and HDTV as very little difference was found.

Screen diagonal (in)		Screen height (H)	PVD
4/3 ratio	16/9 ratio	(m)	(H)
12	15	0.18	9
15	18	0.23	8
20	24	0.30	7
29	36	0.45	6
60	73	0.91	5
> 100	> 120	> 1.53	3-4



This table and graph are intended to give information on the PVD and related screen sizes to be adopted in the Recommendations for specific applications.

2.1.3 Monitor resolution

The resolution of professional monitors, equipped with professional CRTs, usually complies with the required standards for subjective assessments in their luminance operating range.

Not all monitors can reach a 200 cd/m^2 peak luminance.

To check and report the maximum and minimum resolutions (centre and corners of the screen) at the used luminance value might be suggested.

If consumer TV sets with consumer CRTs are used for subjective assessments, the resolution could be inadequate, depending on the luminance value.

In this case it is strongly recommended to check and report the maximum and minimum resolutions (centre and corners of the screen) at the used luminance value.At present the most practical system available to subjective assessments performers, in order to check monitors or consumer TV sets resolution, is the use of a swept test pattern electronically generated.

A visual analysis allows to check the resolution. The visual threshold is estimated to be -12/-20 dB. The main drawback of this system is the aliasing created by the shadow mask that makes the visual evaluation hard, but, on the other hand, the aliasing presence indicates that the video frequency signal exceeds the limits given by the shadow mask, which under samples the video signal.

Further studies on CRTs definition testing could be recommended.

2.1.4 Monitor contrast

Contrast could be strongly influenced by the environment illuminance.

Professional monitors CRTs seldom use technologies to improve their contrast in a high illuminance environment, **so it is possible they do not comply with the requested contrast standard if used in a high illuminance environment.**

Consumer CRTs use technologies to get a better contrast in a high illuminance environment.

To calculate the contrast of a given CRT, the screen reflection coefficient (K) of such CRT is needed. In the best case the screen reflection coefficient is approximately K = 6%.

With a diffused environment *"I"* illuminance of 200 lux and a K = 6%, a 3.82 cd/m^2, luminance reflection of inactive screen areas is calculated with the following formula:

$$Lreflected = \frac{I}{\pi} \cdot K$$

With the given values, the reflected luminance (expressed in cd/m^2) is nearly 2% of the incident Illuminance (expressed in lux).

The CRT is considered not to have "mirror like" reflections on the front glass, whose exact influence on contrast is difficult to quantify because it is very dependant on lighting conditions.

In §§ 2.1.1 and 2.1.2, the contrast ratio CR is expressed as:

$$CR = L_{min.} / L_{max.}$$

where:

$L_{min.}$: luminance of inactive areas under ambient illumination (cd/m^2)

(with the given values $L_{min.} = Linactive\ areas + Lreflected$ = 3.82 cd/m^2).

$L_{max.}$: luminance of white areas under ambient illumination (cd/m^2)

(with the given values $L_{max.} = Lwhite + Lreflected$ = 200 + 3.82 cd/m^2).

With such values a *CR* = 0.018 is computed, strictly close to the 0.02 value stated in §§ 2.1.1.1 and 2.1.2.1 - Item a).

2.2 Source signals

The source signal provides the reference picture directly, and the input for the system under test. It should be of optimum quality for the television standard used. The absence of defects in the reference part of the presentation pair is crucial to obtain stable results.

Digitally stored pictures and sequences are the most reproducible source signals, and these are therefore the preferred type. They can be exchanged between laboratories, to make system comparisons more meaningful. Video or computer tapes are possible formats.

In the short term, 35 mm slide-scanners provide a preferred source for still pictures. The resolution available is adequate for evaluation of conventional television. The colorimetry and other characteristics of film may give a different subjective appearance to studio camera pictures. If this affects the results, direct studio sources should be used, although this is often much less convenient. As a general rule, slide-scanners should be adjusted picture by picture for best possible subjective picture quality, since this would be the situation in practice.

Assessments of downstream processing capacity are often made with colour-matte. In studio operations, colour-matte is very sensitive to studio lighting. Assessments should therefore preferably use a special colour-matte slide pair, which will consistently give high-quality results. Movement can be introduced into the foreground slide if needed.

It will be frequently required to take account of the manner in which the performance of the system under test may be influenced by the effect of any processing that may have been carried out at an earlier stage in the history of the signal. It is therefore desirable that whenever testing is carried out on sections of the chain that may introduce processing distortions, albeit non-visible, the resulting signal should be transparently recorded, and then made available for subsequent tests downstream, when it is desired to check how impairments due to cascaded processing may accumulate along the chain. Such recordings should be kept in the library of test material, for future use as necessary, and include with them a detailed statement of the history of the recorded signal.

2.3 Selection of test materials

A number of approaches have been taken in establishing the kinds of test material required in television assessments. In practice, however, particular kinds of test materials should be used to address particular assessment problems. A survey of typical assessment problems and of test materials used to address these problems is given in Table 1.

TABLE 1

Selection of test material*

Assessment problem	Material used
Overall performance with average material	General, “critical but not unduly so”
Capacity, critical applications (e.g. contribution, post-processing, etc.)	Range, including very critical material for the application tested
Performance of “adaptive” systems	Material very critical for “adaptive” scheme used
Identify weaknesses and possible improvements	Critical, attribute-specific material
Identify factors on which systems are seen to vary	Wide range of very rich material
Conversion among different standards	Critical for differences (e.g. field rate)

* It is understood that all test materials could conceivably be part of television programme content. For further guidance on the selection of test materials, see Appendices 1 and 2 to Annex 1.

Some parameters may give rise to a similar order of impairments for most pictures or sequences. In such cases, results obtained with a very small number of pictures or sequences (e.g. two) may still provide a meaningful evaluation.

However, new systems frequently have an impact which depends heavily on the scene or sequence content. In such cases, there will be, for the totality of programme hours, a statistical distribution of impairment probability and picture or sequence content. Without knowing the form of this distribution, which is usually the case, the selection of test material and the interpretation of results must be done very carefully.

In general, it is essential to include critical material, because it is possible to take this into account when interpreting results, but it is not possible to extrapolate from non-critical material. In cases where scene or sequence content affects results, the material should be chosen to be "critical but not unduly so" for the system under test. The phrase "not unduly so" implies that the pictures could still conceivably form part of normal programme hours. At least four items should, in such cases, be used: for example, half of which are definitely critical, and half of which are moderately critical.

A number of organizations have developed test still pictures and sequences. It is hoped to organize these in the framework of the ITU-R in the future. Specific picture material is proposed in the Recommendations addressing the evaluation of the applications.

Further ideas on the selection of test materials are given in Appendices 1 and 2.

2.4 Range of conditions and anchoring

Because most of the assessment methods are sensitive to variations in the range and distribution of conditions seen, judgement sessions should include the full ranges of the factors varied. However, this may be approximated with a more restricted range, by presenting also some conditions that would fall at the extremes of the scales. These may be represented as examples and identified as most extreme (direct anchoring) or distributed throughout the session and not identified as most extreme (indirect anchoring).

2.5 Observers

At least 15 observers should be used. They should be non-expert, in the sense that they are not directly concerned with television picture quality as part of their normal work, and are not experienced assessors (see Note 1). Prior to a session, the observers should be screened for (corrected-to-) normal visual acuity on the Snellen or Landolt chart, and for normal colour vision using specially selected charts (Ishihara, for instance). The number of assessors needed depends upon the sensitivity and reliability of the test procedure adopted and upon the anticipated size of the effect sought.

NOTE 1 – Preliminary findings suggest that non-expert observers may yield more critical results with exposure to higher quality transmission and display technologies.

A study of consistency between results at different testing laboratories has found that systematic differences can occur between results obtained from different laboratories. Such differences will be particularly important if it is proposed to aggregate results from several different laboratories in order to improve the sensitivity and reliability of an experiment.

A possible explanation for the differences between different laboratories is that there may be different skill levels amongst different groups of non-expert assessors. Further research needs to be undertaken to assess the validity of this hypothesis and, if proven, to quantify the variations contributed by this factor. However, in the interim, experimenters should include as much detail as possible on the characteristics of their assessment panels to facilitate further investigation of this factor. Suggested data to be provided could include: occupation category (e.g. broadcast organization employee, university student, office worker, ...), gender, and age range.

2.6 Instructions for the assessment

Assessors should be carefully introduced to the method of assessment, the types of impairment or quality factors likely to occur, the grading scale, the sequence and timing. Training sequences demonstrating the range and the type of the impairments to be assessed should be used with illustrating pictures other than those used in the test, but of comparable sensitivity. In the case of quality assessments, quality may be defined as to consist of specific perceptual attributes.

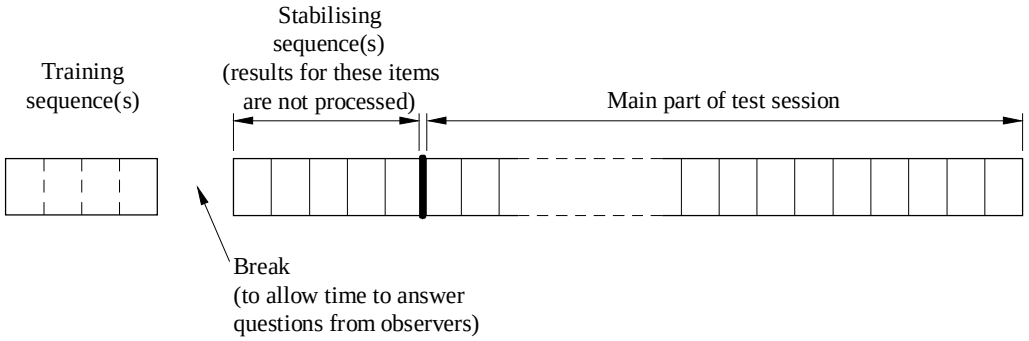
2.7 The test session

A session should last up to half an hour. At the beginning of the first session, about five "dummy presentations" should be introduced to stabilize the observers' opinion. The data issued from these presentations must not be taken into account in the results of the test. If several sessions are necessary, about three dummy presentations are only necessary at the beginning of the following session.

A random order should be used for the presentations (for example, derived from Graeco-Latin squares); but the test condition order should be arranged so that any effects on the grading of tiredness or adaptation are balanced out from session to session. Some of the presentations can be repeated from session to session to check coherence.

FIGURE 1

Presentation structure of test session



2.8 Presentation of the results

Because they vary with range, it is inappropriate to interpret judgements from most of the assessment methods in absolute terms (e.g. the quality of an image or image sequence).

For each test parameter, the mean and 95% confidence interval of the statistical distribution of the assessment grades must be given. If the assessment was of the change in impairment with a changing parameter value, curve-fitting techniques should be used. Logistic curve-fitting and logarithmic axis will allow a straight line representation, which is the preferred form of presentation. More information on data processing is given in Annex 2 to this Recommendation.

The results must be given together with the following information:

– details of the test configuration;

– details of the test materials;

– type of picture source and display monitors (see Note 1);

– number and type of assessors (see Note 2);

– reference systems used;

– the grand mean score for the experiment;

– original and adjusted mean scores and 95% confidence interval if one or more observers have been eliminated according to the procedure given below.

NOTE 1 – Because there is some evidence that display size may influence the results of subjective assessments, experimenters are requested to explicitly report the screen size, and make and model number of displays used in any experiments.

NOTE 2 – There is evidence that variations in the skill level of viewing panels (even amongst "non-expert" panels) can influence the results of subjective viewing assessments. To facilitate further study of this factor experimenters are requested to report as much of the characteristics of their viewing panels as possible. Relevant factors might include: the age and gender composition of the panel or the education or employment category of the panel.

3 Selection of test methods

A wide variety of basic test methods have been used in television assessments. In practice, however, particular methods should be used to address particular assessment problems. A survey of typical assessment problems and of methods used to address these problems is given in Table 2.

TABLE 2

Selection of test methods

Assessment problem	Method used	Description
Measure the quality of systems relative to a reference	Double stimulus continuous quality method (1)	Rec. ITU-R BT.500, § 5
Measure the robustness of systems (i.e. failure characteristics)	Double stimulus impairment method (1)	Rec. ITU-R BT.500, § 4
Quantify the quality of systems (when no reference is available)	Ratio-scaling method (2) or categorical scaling, under study	Report ITU-R BT.1082
Compare the quality of alternative systems (when no reference is available)	Method of direct comparison, ratio-scaling method or categorical scaling, under study	Report ITU-R BT.1082
Identify factors on which systems are perceived to differ and measure their perceptual influence	Method under study	Report ITU-R BT.1082
Establish the point at which an impairment becomes visible	Threshold estimation by forced-choice method or method of adjustment, under study	Report ITU-R BT.1082
Determine whether systems are perceived to differ	Forced-choice method, under study	Report ITU-R BT.1082
Measure the quality of stereoscopic image coding	Double stimulus continuous quality method (3)	Rec. ITU-R BT.500, § 5

(1) Some studies on contextual effects were carried out for the Double stimulus continuous quality method and the Double stimulus impairment method. It was found that the results of the Double stimulus impairment method are biased to a certain degree by contextual effects. More details are given in Annex 1 Appendix 3.

(2) Some studies suggest that this method is more stable when a full range of quality is available.

(3) Due to the possibility of high fatigue when evaluating stereoscopic images, the overall duration of a test session should be shortened to be less than 30 minutes.

4 The double-stimulus impairment scale method (the "EBU method")

4.1 General description

A typical assessment might call for an evaluation of either a new system, or the effect of a transmission path impairment. The initial steps for the test organizer would include the selection of sufficient test material to allow a meaningful evaluation to be made, and the establishment of which test conditions should be used. If the effect of parameter variation is of interest, it is necessary to choose a set of parameter values which cover the impairment grade range in a small number of roughly equal steps. If a new system, for which the parameter values cannot be so varied, is being evaluated, then either additional, but subjectively similar, impairments need to be added, or another method such as that in § 5 should be used.

The double-stimulus (EBU) method is cyclic in that the assessor is first presented with an unimpaired reference, then with the same picture impaired. Following this, he is asked to vote on the second, keeping in mind the first. In sessions, which last up to half an hour, the assessor is presented with a series of pictures or sequences in random order and with random impairments covering all required combinations. The unimpaired picture is included in the pictures or sequences to be assessed. At the end of the series of sessions, the mean score for each test condition and test picture is calculated.

The method uses the impairment scale, for which it is usually found that the stability of the results is greater for small impairments than for large impairments. Although the method sometimes has been used with limited ranges of impairments, it is more properly used with a full range of impairments.

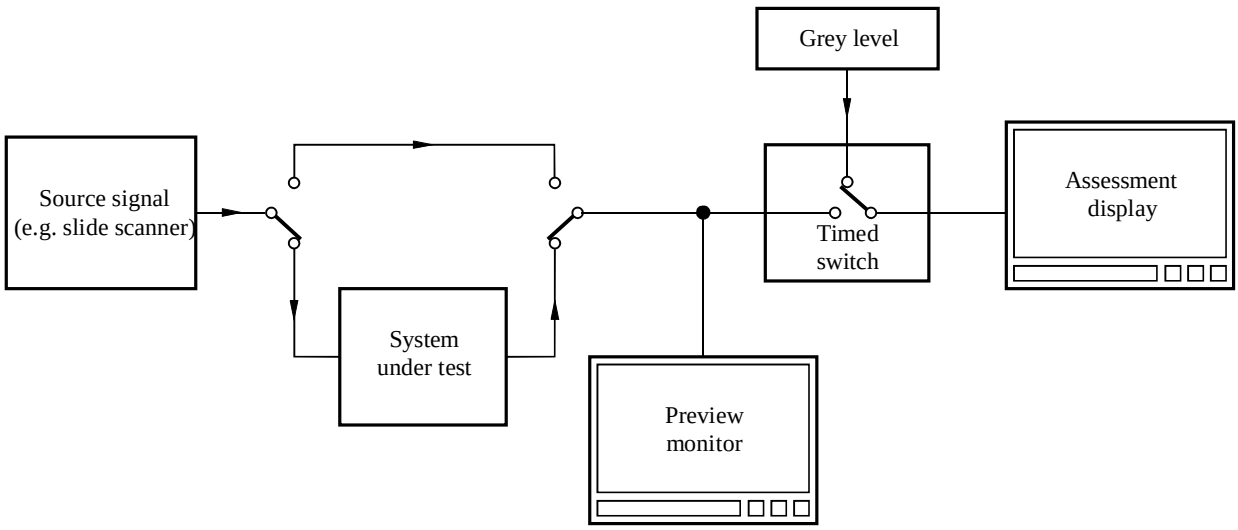
4.2 General arrangement

The way viewing conditions, source signals, test material and the observers and the presentation of results are defined or selected in accordance with § 2.

The generalized arrangement for the test system should be as shown in Fig. 2.

FIGURE 2

General arrangement for test system for double-stimulus impairment scale method



The assessors view an assessment display which is supplied with a signal via a timed switch. The signal path to the timed switch can be either directly from the source signal or indirectly via the system under test. Assessors are presented with a series of test pictures or sequences. They are arranged in pairs such that the first in the pair comes direct from the source, and the second is the same picture via the system under test.

4.3 Presentation of the test material

A test session comprises a number of presentations. There are two variants to the structure of presentations, I and II outlined below.

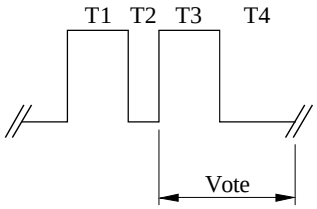
Variant I: The reference picture or sequence and the test picture or sequence are presented only once as is shown in Fig. 3a).

Variant II: The reference picture or sequence and the test picture or sequence are presented twice as is shown in Fig. 3b).

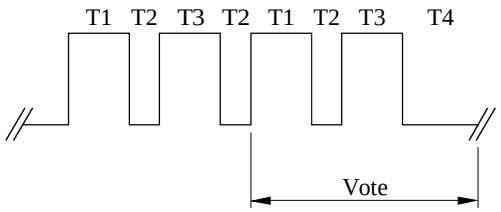
Variant II, which is more time consuming than variant I, may be applied if the discrimination of very small impairments is required or moving sequences are under test.

FIGURE 3

Presentation structure of test material



a) Variant I



b) Variant II

D__

Phases of presentation:

T1 = 10 s Reference picture
T2 = 3 s Mid grey produced by a video level of around 200 mV
T3 = 10 s Test condition
T4 = 5-11 s Mid grey

Experience suggests that extending the periods T1 and T3 beyond 10 s does not improve the assessors' ability to grade the pictures or sequences.

4.4 Grading scales

The five-grade impairment scale should be used:

5 imperceptible

4 perceptible, but not annoying

3 slightly annoying

2 annoying

1 very annoying

Assessors should use a form which gives the scale very clearly, and has numbered boxes or some other means to record the gradings.

4.5 The introduction to the assessments

At the beginning of each session, an explanation is given to the observers about the type of assessment, the grading scale, the sequence and timing (reference picture, grey, test picture, voting period). The range and type of the impairments to be assessed should be illustrated on pictures other than those used in the tests, but of comparable

sensitivity. It must not be implied that the worst quality seen necessarily corresponds to the lowest subjective grade. Observers should be asked to base their judgement on the overall impression given by the picture, and to express these judgements in terms of the wordings used to define the subjective scale.

The observers should be asked to look at the picture for the whole of the duration of T1 and T3. Voting should be permitted only during T4.

4.6 The test session

The pictures and impairments should be presented in a pseudo-random sequence and, preferably in a different sequence for each session. In any case, the same test picture or sequences should never be presented on two successive occasions with the same or different levels of impairment.

The range of impairments should be chosen so that all grades are used by the majority of observers; a grand mean score (averaged overall judgements made in the experiment) close to three should be aimed at.

A session should not last more than roughly half an hour, including the explanations and preliminaries; the test sequence could begin with a few pictures indicative of the range of impairments; judgements of these pictures would not be taken into account in the final results.

Further ideas on the selection of levels of impairments are given in Appendix 2.

5 The double-stimulus continuous quality-scale method

5.1 General description

A typical assessment might call for evaluation of a new system or of the effects of transmission paths on quality. The double-stimulus method is thought to be especially useful when it is not possible to provide test stimulus test conditions that exhibit the full range of quality.

The method is cyclic in that the assessor is asked to view a pair of pictures, each from the same source, but one via the process under examination, and the other one directly from the source. He is asked to assess the quality of both.

In sessions which last up to half an hour, the assessor is presented with a series of picture pairs (internally random) in random order, and with random impairments covering all required combinations. At the end of the sessions, the mean scores for each test condition and test picture are calculated.

5.2 General arrangement

The way viewing conditions, source signals, test material, the observers and the introduction to the assessment are defined or selected in accordance with § 2. The test session is as described in § 4.6.

The generalized arrangement for the test system should be as shown in Fig. 4 below.

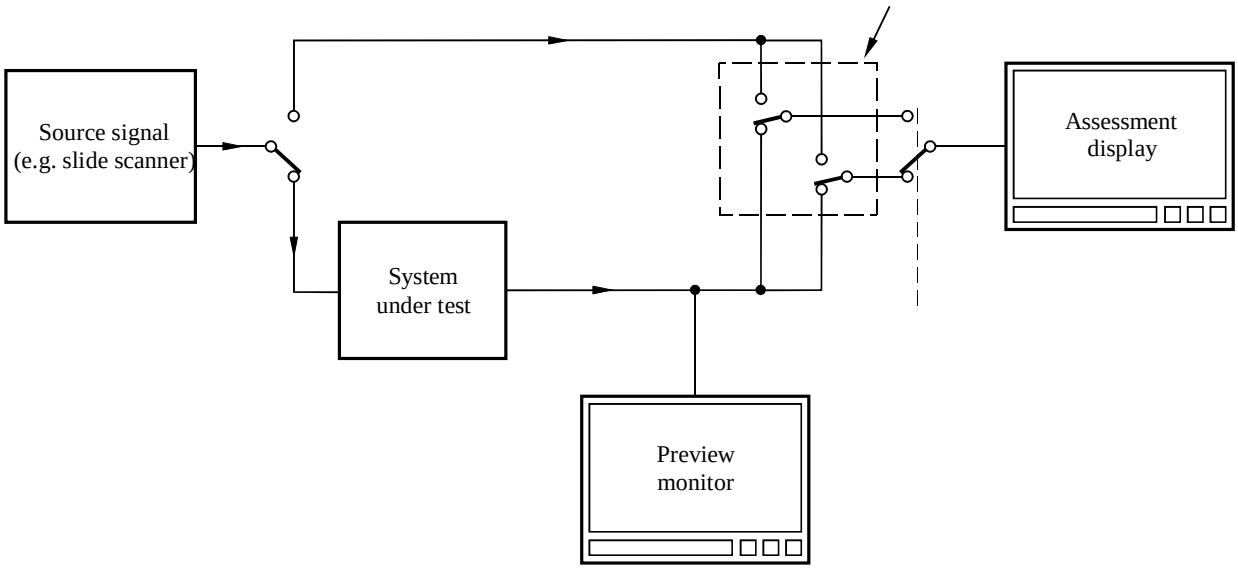
There are two variants to this method, I and II, outlined below.

Variant I: The assessor, who is normally alone, is allowed to switch between two conditions A and B until he is satisfied that he has established his opinion of each. The A and B lines are supplied with the reference direct picture, or the picture via the system under test, but which is fed to which line is randomly varied between one test condition and the next, noted by the experimenter, but not announced.

Variant II: The assessors are shown consecutively the pictures from the A and B lines, to establish their opinion of each. The A and B lines are fed for each presentation as in variant I above. The stability of results of this variant with a limited range of quality is considered to be still under investigation.

FIGURE 4

General arrangement for test system for double-stimulus continuous quality-scale method



5.3 Presentation of the test material

A test session comprises a number of presentations. For variant I which has a single observer, for each presentation the assessor is free to switch between the A and B signals until the assessor has the mental measure of the quality associated with each signal. The assessor may typically choose to do this two or three times for periods of up to 10 s. For variant II which uses a number of observers simultaneously, prior to recording results, the pair of conditions is shown one or more times for an equal length of time to allow the assessor to gain the mental measure of the qualities associated with them, then the pair is shown again one or more times while the results are recorded. The number of repetitions depends on the length of the test sequences. For still pictures, a 3-4 s sequence and five repetitions (voting during the last two) may be appropriate. For moving pictures with time-varying artefacts, a 10 s sequence with two repetitions (voting during the second) may be appropriate. The structure of presentations is shown in Fig. 5.

Where practical considerations limit the duration of sequences available to less than 10 s, compositions may be made using these shorter sequences as segments, to extend the display time to 10 s. In order to minimize discontinuity at the joints, successive sequence segments may be reversed in time (sometimes called “palindromic” display). Care must be taken to ensure that test conditions displayed as reverse time segments represent causal processes, that is, they must be obtained by passing the reversed-time source signal through the system under test.

5.4 Grading scale

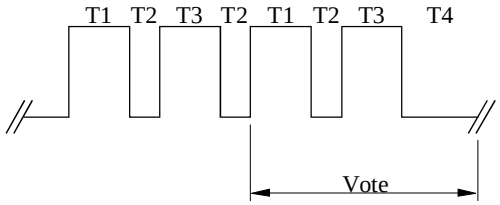
The method requires the assessment of two versions of each test picture. One of each pair of test pictures is unimpaired while the other presentation might or might not contain an impairment. The unimpaired picture is included to serve as a reference, but the observers are not told which is the reference picture. In the series of tests, the position of the reference picture is changed in pseudo-random fashion.

The observers are simply asked to assess the overall picture quality of each presentation by inserting a mark on a vertical scale. The vertical scales are printed in pairs to accommodate the double presentation of each test picture. The scales provide a continuous rating system to avoid quantizing errors, but they are divided into five equal lengths which correspond to the normal ITU-R five-point quality scale. The associated terms categorizing the different levels are the same as those normally used; but here they are included for general guidance and are printed only on the left of the first

scale in each row of ten double columns on the score sheet. Fig. 6 shows a section of a typical score sheet. Any possibility of confusion between the scale divisions and the test results is avoided by printing the scales in blue and recording the results in black.

FIGURE 5

Presentation structure of test material

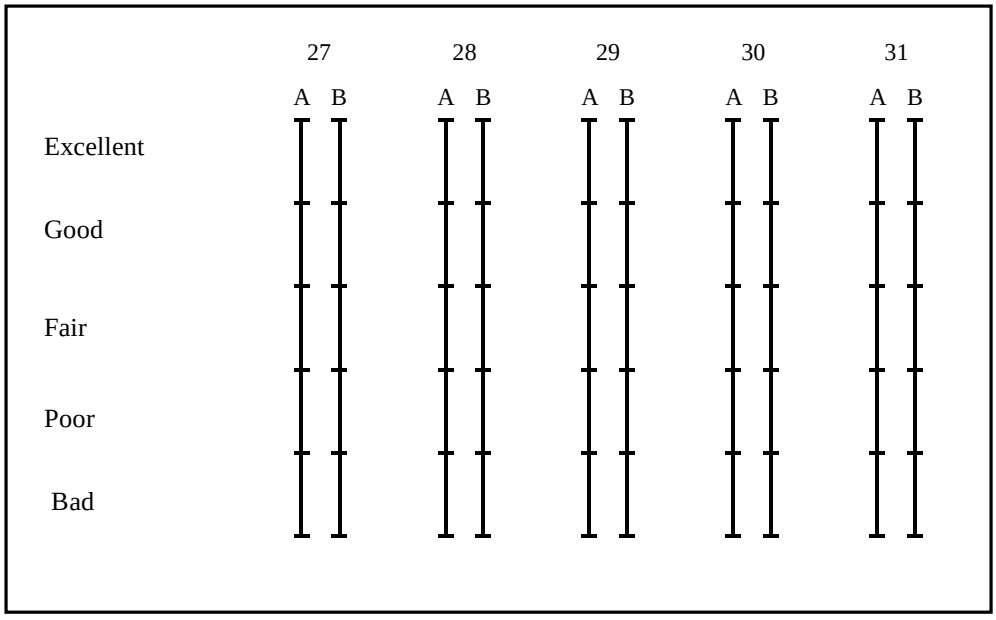


Phases of presentation:

T1 =	10 s	Test sequence A
T2 =	3 s	Mid grey produced by a video level of around 200 mV
T3 =	10 s	Test sequence B
T4 =	5-11 s	Mid grey

FIGURE 6

Portion of quality-rating form using continuous scales*



* In planning the arrangement of test items within a test session for the Double Stimulus Continuous Quality Scale Method it is desirable that the experimenter should include checks to give confidence that the experiment is free of systematic errors. However, the method for performing these confidence checks is under investigation.

5.5 Analysis of the results

The pairs of assessments (reference and test) for each test condition are converted from measurements of length on the score sheet to normalized scores in the range 0 to 100. Then, the differences between the assessment of the reference and the test condition are calculated. Further procedure is described in Annex 2.

Experience has shown that the scores obtained for different test sequences are dependent on the criticality of the test material used. A more complete understanding of codec performance can be obtained by presenting results for different test sequences separately, rather than only as aggregated averages across all the test sequences used in the assessment.

If results for individual test sequences are arranged in a rank order of "test sequence criticality" on an abscissa it is possible to present a crude graphical description of the picture content failure characteristic of the system under test. However this form of presentation only describes the performance of the codec it does not provide an indication of the likelihood of occurrence of sequences with a given degree of criticality (see Appendix 1 to Annex 1 of this Recommendation). Further studies of test sequence criticality and the probability of occurrence of sequences of a given level of criticality are required before this more complete picture of system performance can be obtained.

5.6 Interpretation of the results

When using this Double Stimulus Continuous Quality Scale (DSQCS) method, it could be hazardous, and even wrong, to derive conclusions about the quality of the conditions under test by associating numerical DSQCS values with adjectives coming from other tests protocols (e.g. imperceptible, perceptible but not annoying, ... coming from the DSIS method).

It is noted that results obtained from the DSCQS method should not be treated as absolute scores but as differences of scores between a reference condition and a test condition. Thus, it is erroneous to associate the scores with a single quality description term even with those which come from the DSCQS protocol itself (e.g. excellent, good, fair, ...).

In any test procedure it is important to decide acceptability criteria before the assessment is commenced. This is especially important when using the DSCQS method because of the tendency for inexperienced users to misunderstand the meaning of the quality scale values produced by the method.

6 Alternative methods of assessment

In appropriate circumstances, the single-stimulus and stimulus-comparison methods should be used.

6.1 Single-stimulus methods

In single-stimulus methods, a single image or sequence of images is presented and the assessor provides an index of the entire presentation.

6.1.1 General arrangement

The way viewing conditions, source signals, range of conditions and anchoring, the observers, the introduction to the assessment and the presentation of the results are defined or selected is in accordance with § 2.

6.1.2 Selection of test material

For laboratory tests, the content of the test images should be selected as described in § 2.3.

Once the content is selected, test images are prepared to reflect the design options under consideration or the range(s) of one (or more) factors. When two or more factors are examined, the images can be prepared in two ways. In the first, each image represents one level of one factor only. In the other, each image represents one level of every factor examined but, across images, each level of every factor occurs with every level of all other factors. Both methods permit results to be attributed clearly to specific factors. The latter method also permits the detection of interactions among factors (i.e. non-additive effects).

6.1.3 Test session

The test session consists of a series of assessment trials. These should be presented in random order and, preferably, in a different random sequence for each observer. When a single random order of sequences is used there are two variants to the structure of presentations I (Single Stimulus - SS) and II (Single Stimulus with Multiple Repetition - SSMR) as listed below:

a) The test pictures or sequences are presented only once in the test session; at the beginning of the first sessions some dummy sequences should be introduced (as described in § 2.7); experiment normally ensures that the same image is not presented twice in succession with the same level of impairment.

   A typical assessment trial consists of three displays: a mid grey adaptation field, a stimulus, and a mid grey post-exposure field. The duration of these displays vary with viewer task, materials and the opinions or factors considered, but 3, 10 and 10 s respectively are not uncommon. The viewer index, or indices, may be collected during display of either the stimulus or the post-exposure field.

b) The test pictures or sequences are presented three times organizing the test session into three presentations, each of them including all the pictures or sequences to be tested only once; the beginning of each presentation is announced by a message on the monitor (e.g. “Presentation 1”); the first presentation is used to stabilize the observer’s opinion; the data issued from this presentation must not be taken into account in the results of the test; the scores assigned to the pictures or sequences are obtained by taking the mean of the data issued from the second and third presentations; the experiment normally ensures that the following limitations to the random order of the pictures or sequences inside each presentation are applied:

   – a given picture or sequence is not located in the same position in the other *Presentations*;

   – a given picture or sequence is not immediately located before the same picture or sequence in the other *Presentations*.

A typical assessment trial consists of two displays: a stimulus and a mid grey post-exposure field. The duration of these displays may vary with viewer task, materials and the opinions or factors considered, but 10 and 5 s respectively are suggested. The viewer index, or indices, have to be collected during display of the post-exposure field only.

Variant II (SSMR) introduces a clear overhead in the time required to perform a test session (45 s vs. 23 s, for each picture or sequence under test); nevertheless, it decreases the strong dependence of the results of variant I from the order of the pictures or sequences inside a session.

Furthermore, experimental results show that variant II allows a span of about 20% within the range of the votes.

6.1.4 Types of single-stimulus methods

In general, three types of single-stimulus methods have been used in television assessments.

6.1.4.1 Adjectival categorical judgement methods

In adjectival categorical judgements, observers assign an image or image sequence to one of a set of categories that, typically, are defined in semantic terms. The categories may reflect judgements of whether or not an attribute is detected (e.g. to establish the impairment threshold). Categorical scales that assess image quality and image impairment, have been used most often, and the ITU-R scales are given in Table 3. In operational monitoring, half grades sometimes are used. Scales that assess text legibility, reading effort, and image usefulness have been used in special cases.

This method yields a distribution of judgements across scale categories for each condition. The way in which responses are analysed depends upon the judgement (detection, etc.) and the information sought (detection threshold, ranks or central tendency of conditions, psychological “distances” among conditions). Many methods of analysis are available.

6.1.4.2 Numerical categorical judgement methods

A single-stimulus procedure using an 11-grade numerical categorical scale (SSNCS) was studied and compared to graphic and ratio scales. This study, described in Report ITU-R BT.1082, indicates a clear preference in terms of sensitivity and stability for the SSNCS method when no reference is available.

TABLE 3

ITU-R quality and impairment scales

Five-grade scale	
Quality	Impairment
5 Excellent 4 Good 3 Fair 2 Poor 1 Bad	5 Imperceptible 4 Perceptible, but not annoying 3 Slightly annoying 2 Annoying 1 Very annoying

6.1.4.3 Non-categorical judgement methods

In non-categorical judgements, observers assign a value to each image or image sequence shown. There are two forms of the method.

In continuous scaling, a variant of the categorical method, the assessor assigns each image or image sequence to a point on a line drawn between two semantic labels (e.g. the ends of a categorical scale as in Table 3). The scale may include additional labels at intermediate points for reference. The distance from an end of the scale is taken as the index for each condition.

In numerical scaling, the assessor assigns each image or image sequence a number that reflects its judged level on a specified dimension (e.g. image sharpness). The range of the numbers used may be restricted (e.g. 0-100) or not. Sometimes, the number assigned describes the judged level in "absolute" terms (without direct reference to the level of any other image or image sequence as in some forms of magnitude estimation. In other cases, the number describes the judged level relative to that of a previously seen "standard" (e.g. magnitude estimation, fractionation, and ratio estimation).

Both forms result in a distribution of numbers for each condition. The method of analysis used depends upon the type of judgement and the information required (e.g. ranks, central tendency, psychological "distances").

6.1.4.4 Performance methods

Some aspects of normal viewing can be expressed in terms of the performance of externally directed tasks (finding targeted information, reading text, identifying objects, etc.). Then, a performance measure, such as the accuracy or speed with which such tasks are performed, may be used as an index of the image or image sequence.

Performance methods result in distributions of accuracy or speed scores for each condition. Analysis concentrates upon establishing relations among conditions in the central tendency (and dispersion) of scores and often uses analysis of variance or a similar technique.

6.2 Stimulus-comparison methods

In stimulus-comparison methods, two images or sequences of images are displayed and the viewer provides an index of the relation between the two presentations.

6.2.1 General arrangement

The way viewing conditions, source signals, range of conditions and anchoring, the observers, the introduction to the assessment and the presentation of the results are defined or selected in accordance with § 2.

6.2.2 The selection of test material

The images or image sequences used are generated in the same fashion as in single-stimulus methods. The resulting images or image sequences are then combined to form the pairs that are used in the assessment trials.

6.2.3 Test session

The assessment trial will use either one monitor or two well-matched monitors and generally proceeds as in single-stimulus cases. If one monitor is used, a trial will involve an additional stimulus field identical in duration to the first. In this case, it is good practice to ensure that, across trials, both members of a pair occur equally often in first and second positions. If two monitors are used, the stimulus fields are shown simultaneously.

Stimulus-comparison methods assess the relations among conditions more fully when judgements compare all possible pairs of conditions. However, if this requires too large a number of observations, it may be possible to divide observations among assessors or to use a sample of all possible pairs.

6.2.4 Types of stimulus-comparison methods

Three types of stimulus-comparison methods have been used in television assessments.

6.2.4.1 Adjectival categorical judgement methods

In adjectival categorical judgement methods, observers assign the relation between members of a pair to one of a set of categories that, typically, are defined in semantic terms. These categories may report the existence of perceptible differences (e.g. SAME, DIFFERENT), the existence and direction of perceptible differences (e.g. LESS, SAME, MORE), or judgements of extent and direction. The ITU-R comparison scale is shown in Table 4.

TABLE 4

Comparison scale

–3	Much worse
–2	Worse
–1	Slightly worse
0	The same
+1	Slightly better
+2	Better
+3	Much better

This method yields a distribution of judgements across scale categories for each condition pair. The way that responses are analysed depends on the judgement made (e.g. difference) and the information required (e.g. just-noticeable differences, ranks of conditions, “distances” among conditions, etc.)

6.2.4.2 Non-categorical judgement methods

In non-categorical judgements, observers assign a value to the relation between the members of an assessment pair. There are two forms of this method:

– In continuous scaling, the assessor assigns each relation to a point on a line drawn between two labels (e.g. SAME-DIFFERENT or the ends of a categorical scale as in Table 4). Scales may include additional reference labels at intermediate points. The distance from one end of the line is taken as the value for each condition pair.

– In the second form, the assessor assigns each relation a number that reflects its judged level on a specified dimension (e.g. difference in quality). The range of numbers used may be constrained or not. The number assigned may describe the relation in "absolute" terms or in terms of that in a “standard” pair.

Both forms result in a distribution of values for each pair of conditions. The method of analysis depends on the nature of the judgement and the information required.

6.2.4.3 Performance methods

In some cases, performance measures can be derived from stimulus-comparison procedures. In the forced-choice method, the pair is prepared such that one member contains a particular level of an attribute (e.g. impairment) while the other contains either a different level or none of the attribute. The observer is asked to decide either which member contains the greater/lesser level of the attribute or which contains any of the attribute; accuracy and speed of performance are taken as indices of the relation between the members of the pair.

6.3 Single Stimulus Continuous Quality Evaluation (SSCQE)

The introduction of digital television compression will produce impairments to the picture quality which are scene-dependent and time-varying. Even within short extracts of digitally-coded video, the quality can fluctuate quite widely depending on scene content, and impairments may be very short-lived. Conventional ITU-R methodologies alone are not sufficient to assess this type of material. Furthermore, the double stimulus method of laboratory testing does not replicate the single stimulus home viewing conditions. It was considered useful, therefore, for the subjective quality of digitally-coded video to be measured continuously, with subjects viewing the material once, without a source reference.

As a result, the following new SSCQE technique has been developed and tested.

6.3.1 Continuous assessment of overall quality

6.3.1.1 Recording device and set-up

An electronic recording handset connected to a computer should be used for recording the continuous quality assessment from the subjects. This device should have the following characteristics:

– slider mechanism without any sprung position

– linear range of travel of 10 cm

– fixed or desk-mounted position

– samples recorded twice a second.

6.3.1.2 General form of the test protocol

Subjects should be presented with test sessions of the following format:

– Programme Segment (PS): a PS corresponds to one programme type (e.g. sport, news, drama) processed according to one of the Quality Parameters (QP) under evaluation (e.g. bit rate); each PS should be at least 5 min long;

– Test Session (TS): a TS is a series of one or more different combinations PS/QP without separation and arranged in a pseudo-random order. Each TS contains at least once all the PS and QP but not necessarily all the PS/QP combinations; each TS should be between 30 and 60 min duration;

– Test Presentation (TP): a TP represents the full performance of a test. A TP can be divided in TSs to cope with maximum duration requirements and in order to assess the quality over all the PS/QP pairs. If the number of PS/QP pairs is limited, a TP can be made of a repetition of the same TS to perform the test on a long enough period of time.

For service quality evaluation, audio may be introduced. In this case, selection of the accompanying audio material should be considered at the same level of importance as the selection of video material, prior to the test performance.

The simplest test format would use a single PS and a single QP.

6.3.1.3 Viewing parameters

Viewing conditions should be those currently specified in Recommendations ITU-R BT.500, ITU-R BT.1128, ITU-R BT.1129 and ITU-R BT.710.

6.3.1.4 Grading scales

Subjects should be made aware in the test instructions that the range of travel of the handset slider mechanism corresponds to the continuous quality scale as described in § 5.4.

6.3.1.5 Observers

At least fifteen subjects, non-experts, should be employed with conditions as currently recommended in § 2.5.

6.3.1.6 Instructions to the observers

In the case of service quality evaluation (with accompanying audio), observers should be instructed to consider the overall quality rather than the video quality only.

6.3.1.7 Data presentation, results processing and presentation

Data should be collated from all test sessions. A single graph of mean quality rating as a function of time, $q(t)$, can therefore be obtained as the mean of all observers' quality gradings per programme segment, quality parameter or per entire test session (see example in Fig. 7).

This data can be converted to a histogram of probability, $P(q)$, of the occurrence of quality level q (see example in Fig. 8).

6.3.2 Calibration of continuous quality results and derivation of a single quality rating

Whilst it has been shown that memory-based biases can exist in longer single rating DSCQS sessions of digitally-coded video, it has recently been verified that such effects are not significant in DSCQS assessments of 10 s video excerpts. Consequently, a possible second stage in the SSCQE process, currently under study, would be to calibrate the quality histogram using the existing DSCQS method on representative 10 s samples extracted from the histogram data.

Conventional ITU-R methodologies employed in the past have been able to produce single quality ratings for television sequences. Experiments have been performed which have examined the relationship between the continuous assessment of a coded video sequence, and an overall single quality rating of the same segment. It has already been identified that the human memory effects can distort quality ratings if noticeable impairments occur in approximately the last 10-15 s of the sequence. However, it has also been found that this human memory effects could be modelled as a decaying exponential weighting function. Hence a possible third stage in the SSCQE methodology would be to process these continuous quality assessments, in order to obtain an equivalent single quality measurement. This is currently under study.

6.4 Remarks

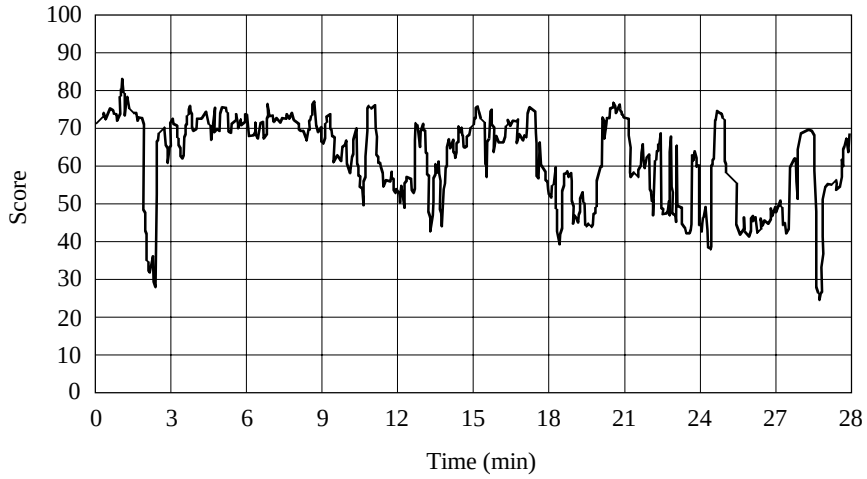
Other techniques, like multidimensional scaling methods and multivariate methods, are described in Report ITU-R BT.1082, and are still under study.

All of the methods described so far have strengths and limitations and it is not yet possible to definitively recommend one over the others. Thus, it remains at the discretion of the researcher to select the methods most appropriate to the circumstances at hand.

The limitations of the various methods suggest that it may be unwise to place too much weight on a single method. Thus, it may be appropriate to consider more "complete" approaches such as either the use of several methods or the use of the multidimensional approach.

FIGURE 7

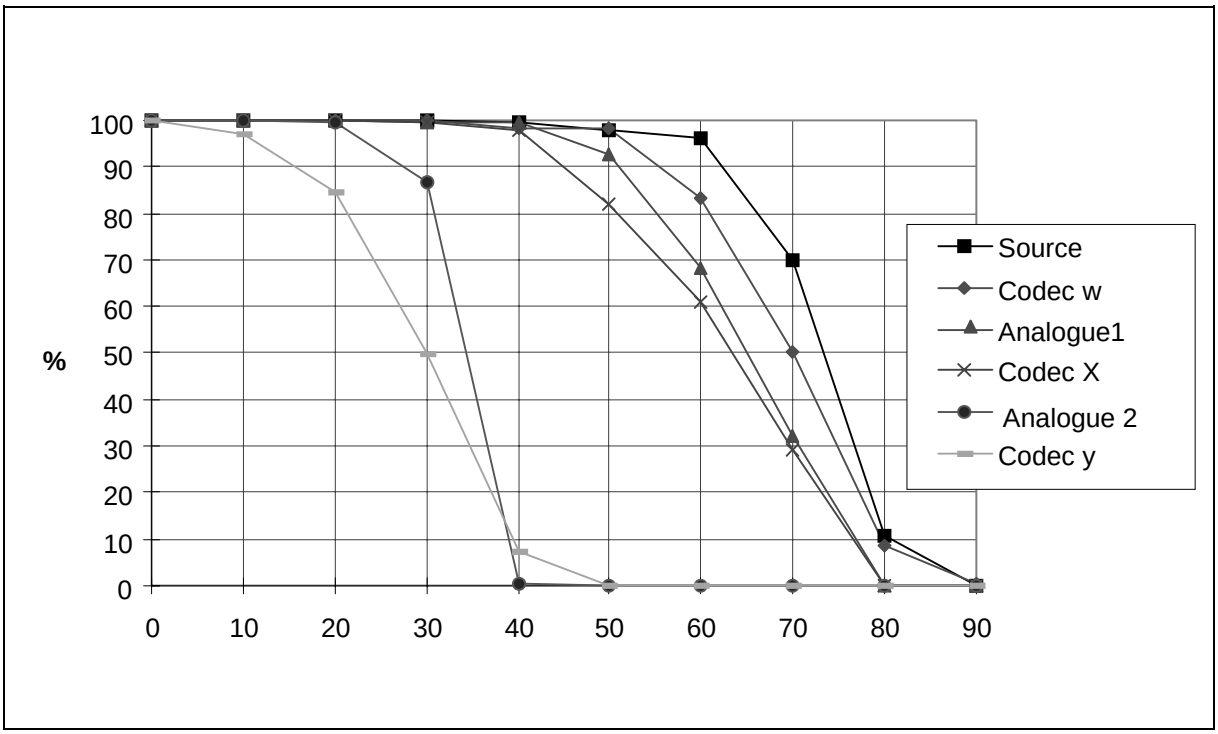
Test condition. Codex X/Programme segment: Z



0500-07

figure 8

Mean of scores of voting sequences on programmes segment Z



APPENDIX 1

TO ANNEX 1

Picture-content failure characteristics

1 Introduction

Following its implementation, a system will be subjected to a potentially broad range of programme material, some of which it may be unable to accommodate without loss in quality. In considering the suitability of the system, it is necessary to know both the proportion of programme material that will prove critical for the system and the loss in quality to be expected in such cases. In effect, what is required is a picture-content failure characteristic for the system under consideration.

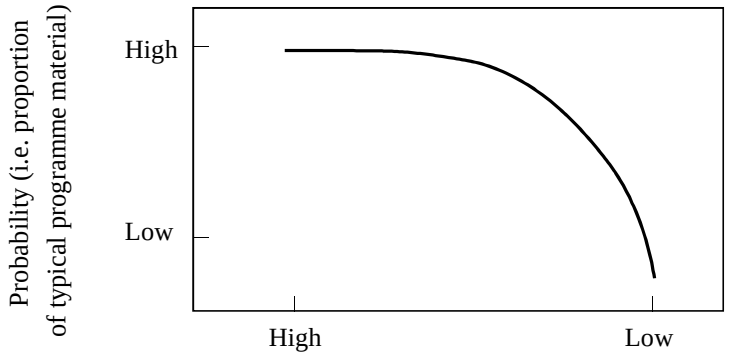
Such a failure characteristic is particularly important for systems whose performance may not degrade uniformly as material becomes increasingly critical. For example, certain digital and adaptive systems may maintain high quality over a large range of programme material, but degrade outside this range.

2 Deriving the failure characteristic

Conceptually, a picture-content characteristic establishes the proportion of the material likely to be encountered in the long run for which the system will achieve particular levels of quality. This is illustrated in Fig. 9.

FIGURE 9

Graphical representation of a possible picture-content failure characteristic



A picture-content failure characteristic may be derived in four steps:

– *Step 1:* involves the determination of an algorithmic measure of “criticality” which should be capable of ranking a number of image sequences, which have been subjected to distortion from the system or class of systems concerned, in such a way that the rank order corresponds to that which would be obtained had human observers performed the task. This criticality measure may involve aspects of visual modelling.

– *Step 2*: involves the derivation, by applying the criticality measure to a large number of samples taken from typical television programmes, of a distribution that estimates the probability of occurrence of material which provides different levels of criticality for the system, or class of systems, under consideration. An example of such a distribution is illustrated in Fig. 10.

– *Step 3*: involves the derivation, by empirical means, of the ability of the system to maintain quality as the level of criticality of programme material is increased. In practice, this requires subjective assessment of the quality achieved by the system with material selected to sample the range of criticality identified in Step 2. This results in a function relating the quality achieved by the system to the level of criticality in programme material. An example of such a function is given in Fig. 11.

– *Step 4*: involves the combination of information from Steps 2 and 3 in order to derive a picture-content failure characteristic of the form given in Fig. 9.

FIGURE 10

Probability of occurrence of material of differing levels of criticality

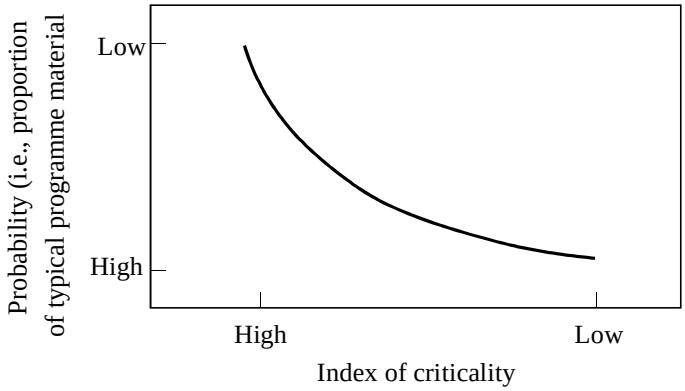
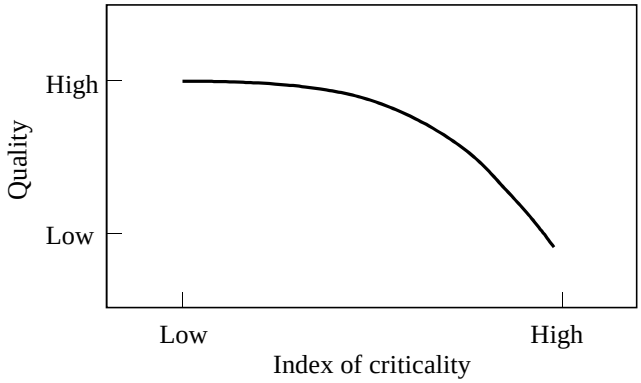


FIGURE 11

A possible function relating quality to the criticality of programme material



3 Use of the failure characteristic

In providing an overall picture of the performance likely to be achieved over the range of possible programme material, the failure characteristic is an important tool for considering the suitability of systems. The failure characteristic can be used in three ways:

– to optimize parameters (e.g. source resolution, bit rate, bandwidth) of a system at the design stage to match it more closely to the requirements of a service;

– to consider the suitability of a single system (i.e. to anticipate the incidence and severity of failure during operation);

– to assess the relative suitabilities of alternative systems (i.e. to compare failure characteristics and determine which system would be more suitable for use). It should be noted that, while alternative systems of a similar type may use the same index of criticality, it is possible that systems of a dissimilar type may have different indices of criticality. However, as the failure characteristic expresses only the probability that different levels of quality will be seen in practice, characteristics can be compared directly even when derived from different, system-specific indices of criticality.

While the method described in this Recommendation provides a means of measuring the picture-content failure characteristic of a system, it may not fully predict the acceptability of the system to the viewer of a television service. To obtain this information it may be necessary for a number of viewers to watch programmes encoded with the system of interest, and to examine their comments.

An example of picture-content failure characteristics for digital television is described in Annex 1 to Recommendation ITU-R BT.1129.

APPENDIX 2

TO ANNEX 1

Method of determining a composite failure characteristic for programme content and transmission conditions

1 Introduction

A composite failure characteristic relates perceived image quality to probability of occurrence in practice in a way that explicitly considers both programme content and transmission conditions.

In principle, such a characteristic could be derived from a subjective study that involves sufficient numbers of observations, times of test, and reception points to yield a sample that represents the population of possible programme content and transmission conditions. In practice, however, an experiment of this sort may be impracticable.

The present Appendix describes an alternative, more readily realized procedure for determining composite failure characteristics. This method consists of three stages:

– programme-content analysis,

– transmission-channel analysis,

– derivation of composite failure characteristics.

2 Programme-content analysis

This stage involves two operations. First, an appropriate measure of programme content is derived and, second, the probabilities with which values of this measure occur in practice are estimated.

A programme-content measure is a statistic that captures aspects of programme content that stress the ability of the system(s) under consideration to provide perceptually faithful reproductions of programme material. Clearly, it would be advantageous if this measure were based on an appropriate perceptual model. However, in the absence of such a model, a measure that captures some aspect of the extent of spatial diversity within and across video frames/fields might suffice, provided this measure enjoys a roughly monotonic relation with perceived image quality. It may be necessary to use different measures for systems (or classes of systems) that use fundamentally different approaches to image representation.

Once an appropriate measure has been selected, it is necessary to estimate the probabilities with which the possible values of this statistic occur. This can be done in one of two ways:

– with the empirical procedure, a random sample of perhaps 200 10 s programme segments in a studio format suited in resolution, frame rate, and aspect ratio to the system(s) considered is analysed. Analysis of this sample yields relative frequencies of occurrence for values of the statistic which are taken as estimates of probability of occurrence in practice; or

– with the theoretical method, a theoretical model is used to estimate the probabilities. It should be noted that, although the empirical method is preferred, it may be necessary in specific cases to use the theoretical method (e.g. when there is not sufficient information about programme content, such as with the emergence of new production technologies).

The foregoing analyses will result in a probability distribution for values of the content statistic (see also Appendix 1). This will be combined with the results of the transmission-conditions analysis to prepare for the final stage of the process.

3 Transmission-channel analysis

This stage also involves two operations. First, a measure of transmission-channel performance is derived. And, second, the probabilities with which values of this measure occur in practice are estimated.

A transmission-channel measure is a statistic that captures aspects of channel performance that influence the ability of the system(s) under consideration to provide perceptually faithful reproductions of source material. Clearly, it would be advantageous if this measure were based on an appropriate perceptual model. However, in the absence of such a model, a measure that captures some aspect of the stress imposed by the channel might suffice, provided this measure enjoys a roughly monotonic relation with perceived image quality. It may be necessary to use different measures for systems (or classes of systems) that use fundamentally different approaches to channel coding.

Once an appropriate measure has been selected, it is necessary to estimate the probabilities with which the possible values of this statistic occur. This can be done in one of two ways:

– with the empirical procedure, channel performance is measured at perhaps 200 randomly selected times and reception points. Analysis of this sample yields relative frequencies of occurrence for values of the statistic which are taken as estimates of probability of occurrence in practice; or

– with the theoretical method, a theoretical model is used to estimate the probabilities. It should be noted that, although the empirical method is preferred, it may be necessary in specific cases to use the theoretical method (e.g. when there is not sufficient relevant information about channel performance, such as with the emergence of new transmission technologies).

The foregoing analyses will result in a probability distribution for values of the channel statistic. This will be combined with the results of the programme-content analysis to prepare for the final stage of the process.

4 Derivation of composite failure characteristics

This stage involves a subjective experiment in which programme content and transmission conditions are varied jointly according to probabilities established in the first two stages.

The basic method used is the double-stimulus continuous quality procedure and, in particular, the 10 s version recommended for motion sequences (see Annex 1, § 5). Here, the reference is a picture at studio quality in an appropriate format (e.g. one with resolution, a frame rate, and an aspect ratio appropriate to the system(s) considered). In contrast, the test presents the same picture as it would be received in the system(s) considered under selected channel conditions.

Test material and channel conditions are selected in accordance with probabilities established in the first two stages of the method. Segments of test material, each of which has been analysed to determine its predominant value according to the content statistic, comprise a selection pool. Material is then sampled from this pool such that it covers the range of possible values of the statistic, sparsely at less critical levels and more densely at more critical levels. Possible values of the channel statistic are selected in a similar way. Then, these two independent sources of influence are combined randomly to yield combined content and channel conditions of known probability.

The results of such studies, which relate perceived image quality to probability of occurrence in practice, are then used to consider the suitability of a system or to compare systems in terms of suitability.

APPENDIX 3

TO ANNEX 1

Contextual effect

Contextual effects occur when the subjective rating of an image is influenced by the order and severity of impairments presented. For example, if a strongly impaired image is presented after a string of weakly impaired images, viewers may inadvertently rate this image lower than they normally might have.

A group of four laboratories in different countries investigated possible contextual effects associated with the results of three methods (double stimulus continuous quality scale method, double stimulus impairment scale method variant II and a comparison method) used to evaluate picture quality. Test material was produced using MPEG (ML@MP) coding along with reduction of horizontal resolution. Four basic test conditions (B1, B2, B3, B4) along with six contextual test conditions were applied to each test series, one depicting weak contextual impairments and the other depicting strong impairments. The three test methods were applied to both test series. Contextual effects are the difference between the results for the test containing predominantly weak impairments and the test containing predominantly strong impairments. The basic test conditions B2 and B3 were used to determine contextual effects.

Results of the combined laboratories indicate no contextual effects for the DSCQS method. For the DSIS and comparison methods contextual effects were evident and the strongest effect was found for the DSIS method variant II. Results indicate that predominantly weak impairments can cause lower ratings for an image whereas predominantly strong impairments can cause higher ratings.

Results of the investigation suggest that the DSCQS method is the better method to minimize contextual effects for subjective picture quality assessment recommended by ITU-R.

More information about the investigation mentioned above is given in Report 1082.

ANNEX 2

Analysis and presentation of results

1 Introduction

In the course of a subjective experiment to assess the performance of a television system, a large amount of data is collected. These data, in the form of observers' score sheets, or their electronic equivalent, must be condensed by statistical techniques to yield results in graphical and/or numerical/formulae/algorithm form which summarize the performance of the systems under test.

The following analysis is applicable to the results of single-stimulus methods, the double stimulus impairment scale (DSIS) method, and the DSCQS method for the assessment of television picture quality which are found in this Recommendation (§§ 4, 5 and 6 in Annex 1) and to other alternative methods using numerical scales. In the first and the second case, the impairment is rated on a five-point or multi-point scale. In the last case, continuous rating scales are used and the results (differences of the ratings for the reference picture and the actual picture under test) are normalized to integer values between 0 and 100.

2 Common methods of analysis

Tests performed according to the principles of methods described in Annex 1 will produce distributions of integer values e.g. between 1 and 5 or between 0 and 100. There will be variations in these distributions due to the differences in judgement between observers and the effect of a variety of conditions associated with the experiment, for example, the use of several pictures or sequences.

A test will consist of a number of presentations (L). Each presentation will be one of a number of test conditions (J) applied to one of a number of test sequences/test images (K). In some cases each combination of test sequence/test image and test condition may be repeated a number of times (R).

2.1 Calculation of mean scores

The first step of the analysis of the results is the calculation of the mean score, $\bar{u}_{jkr}$, for each of the presentations :

$$\bar{u}_{jkr} : \frac{1}{N}\sum_{i=1}^{N} u_{ijkr} \tag{1}$$

where:

u_{ijk}: score of observer i for test condition j, sequence/image k, repetition r

N: number of observers.

Similarly, overall mean scores, $\bar{u}_j$ and $\bar{u}_k$, could be calculated for each test condition and each test sequence/image.

2.2 Calculation of confidence interval

When presenting the results of a test all mean scores should have an associated confidence interval which is derived from the standard deviation and size of each sample.

It is proposed to use the 95% confidence interval which is given by:

$$[\bar{u}_{jkr} - \delta_{jkr}, \bar{u}_{jkr} + \delta_{jkr}]$$

where:

$$\delta_{jkr} = 1.96\frac{S_{jkr}}{\sqrt{N}} \tag{2}$$

The standard deviation for each presentation, S_{jkr}, is given by:

$$S_{jkr} = \sqrt{\sum_{i=1}^{N}\frac{(\bar{u}_{jkr} - u_{ijkr})^2}{(N-1)}} \tag{3}$$

With a probability of 95%, the absolute value of the difference between the experimental mean score and the "true" mean score (for a very high number of observers) is smaller than the 95% confidence interval, on condition that the distribution of the individual scores meets certain requirements.

Similarly, a standard deviation S_j could be calculated for each test condition. It is noted however that this standard deviation will, in cases where a small number of test sequences/test images are used, be influenced more by differences between the test sequences used than by variations between the assessors participating in the assessment.

2.3 Screening of the observers

2.3.1 Screening for DSIS, DSCQS and alternative methods except SSCQE method

First, it must be ascertained whether this distribution of scores for test presentation is normal or not using the β_2 test (by calculating the kurtosis coefficient of the function, i.e. the ratio of the fourth order moment to the square of the second order moment). If β_2 is between 2 and 4, the distribution may be taken to be normal. For each presentation the scores u_{ijkr} of each observer must be compared with the associated mean value, $\bar{u}_{jkr}$, plus the associated standard deviation, S_{jkr}, times two (if normal) or times $\sqrt{20}$ (if non-normal), P_{jkr}, and to the associated mean value minus the same standard deviation times two or times $\sqrt{20}$, Q_{jkr}. Every time an observer's score is found above P_{jkr} a counter associated with each observer, P_i, is incremented. Similarly, every time an observer's score is found below Q_{jkr} a counter associated with each observer, Q_i, is incremented. Finally, the following two ratios must be calculated: $P_i + Q_i$ divided by the total number of scores from each observer for the whole session, and $P_i - Q_i$ divided by $P_i + Q_i$ as an absolute value. If the first ratio is greater than 5% and the second ratio is less than 30%, then observer i must be eliminated (see Note 1).

NOTE 1 – This procedure should not be applied more than once to the results of a given experiment. Moreover, use of the procedure should be restricted to cases in which there are relatively few observers (e.g. fewer than 20), all of whom are non-experts.

This procedure is recommended for the EBU method (DSIS); it has also been successfully applied to the double-stimulus continuous quality-scale method and alternative methods.

The above process can be expressed mathematically as:

For each test presentation, calculate the mean, $\bar{u}_{jkr}$, standard deviation, S_{jkr}, and kurtosis coefficient, $\beta_{2\,jkr}$, where $\beta_{2\,jkr}$ is given by:

$$\beta_{2\,jkr} = \frac{m_4}{(m_2)^2} \text{ with } m_x = \frac{\sum_{i=1}^{N} (u_{ijkr} - \bar{u}_{ijkr})^x}{N} \tag{4}$$

For each observer, i, find P_i and Q_i, i.e.:

for j, k, r = 1,1,1 to J, K, R

if $2 \le \beta_{2jkr} \le 4$ then

if $u_{ijkr} \ge \bar{u}_{jkr} + 2\,S_{jkr}$ then $P_i = P_i + 1$

if $u_{ijkr} \le \bar{u}_{jkr} - 2\,S_{jkr}$ then $Q_i = Q_i + 1$

else

if $u_{ijkr} \ge \bar{u}_{jkr} + \sqrt{20}\,S_{jkr}$ then $P_i = P_i + 1$

if $u_{ijkr} \le \bar{u}_{jkr} - \sqrt{20}\,S_{jkr}$ then $Q_i = Q_i + 1$

$$\text{If } \frac{P_i + Q_i}{J \bullet K \bullet R} > 0.05 \text{ and } \left|\frac{P_i - Q_i}{P_i + Q_i}\right| < 0.3 \text{ then reject observer } i.$$

N : number of observers

J : number of test conditions including the reference

K : number of test pictures or sequences

R : number of repetitions

L : number of test presentations (in most cases the number of presentations will be equal to $J \bullet K \bullet R$, however it is noted that some assessments may be conducted with unequal numbers of sequences for each test condition).

2.3.2 Screening for SSCQE method

For specific observer screening when using SSCQE test procedure, the application domain is not anymore one of the test configurations (combination of a test condition and a test sequence) but a time window (e.g. 10 s vote segment) of a test configuration. There is a two step filtering, the first one is devoted to detection and discarding of observers exhibiting a strong shift of votes compared to the average behaviour, the second one is made for detection and screening of inconsistent observers without any consideration of systematic shift.

– *Step 1*: Detection of local vote inversions

Here also, it must be first ascertained whether this distribution of scores for each time window of each test configuration is "normal", or not, using the β_2 test. If β_2 is between 2 and 4, the distribution may be considered as "normal". Then, the process applies for each time window of each test configuration as mathematically expressed hereafter.

For each time window of each test configuration and using the votes u_{ijkr} of each observer, the mean, $\bar{u}_{jklr}$, standard deviation, S_{jklr}, and the coefficient, $\beta_{2\,jklr}$, are calculated. $\beta_{2\,jklr}$ is given by:

$$\beta_{2\,jklr} = \frac{m_4}{(m_2)^2} \text{ with } m_x = \frac{\sum_{n=1}^{N} (u_{\ njklr} - \bar{u})^x}{N}$$

For each observer, i, find P_i and Q_i, i.e.:

for j, k, l, r = 1, 1, 1, 1 to J, K, L, R

if $2 \leq \beta_{2jklr} \leq 4$ then

if $u_{njklr} \geq \bar{u}_{jklr} + 2\, S_{jklr}$ then $P_i = P_i + 1$

if $u_{njklr} \leq \bar{u}_{jklr} - 2\, S_{jklr}$ then $Q_i = Q_i + 1$

else

if $u_{njklr} \geq \bar{u}_{jklr} + \sqrt{20}\, S_{jklr}$ then $P_i = P_i + 1$

if $u_{njklr} \leq \bar{u}_{jklr} - \sqrt{20}\, S_{jklr}$ then $Q_i = Q_i + 1$

$$\text{If } \frac{P_i}{J \bullet K \bullet L \bullet R} > \text{X\% or } \frac{Q_i}{J \bullet K \bullet L \bullet R} > \text{X\% then reject observer } i.$$

N : number of observers

J : number of time windows within a test combination of test condition and sequence

K : number of test conditions

L : number of sequences

R : number of repetitions.

This process allows to discard observers who have produced votes significantly distant from the average scores. Graph 1 shows two examples (the two extreme curves exhibiting important shifts).

Nevertheless, this rejection criteria does not allow to detect possible inversions which is another important source of bias. For that reason a second process step is proposed.

– *Step 2*: Detection of local vote inversions

For Step 2, the detection is also based on the screening formulae given in Annex 2 of the present Recommendation. A slight modification concerning the application domain is introduced. The input data set is again constituted by the scores of all the time windows (e.g. 10 s) of all the test configurations. But this time the scores are preliminary centred around the overall mean to minimise the shift effect which has been already been treated at the first process stage. The usual process is then applied.

It must be first ascertained whether this distribution of scores for each time window of each test configuration is "normal", or not, using the β_2 test. If β_2 is between 2 and 4, the distribution may be taken as "normal". Then, the process applies for each time window of each test configuration as mathematically expressed hereafter.

The first step of the process is the calculation of centred scores for each time window and each observer. The mean score, $\bar{u}_{klr}$, for each of the test configuration being defined as:

$$\bar{u}_{klr} = \frac{1}{N} \bullet \frac{1}{J} \sum_{n=1}^{N} \sum_{j=1}^{J} u_{njklr}$$

Similarly the mean score for each test configuration and each observer is defined as:

$$\bar{u}_{nklr} = \frac{1}{J} \sum_{j=1}^{J} u_{njklr}$$

and u_{njklr} corresponds to the score of observer i for time window j, test condition k, sequence l, repetition r.

For each observer, the centred scores u^*_{njklr} are calculated as follows:

$$u^*_{njklr} = u_{njllr} - \bar{u}_{nklr} + \bar{u}_{klr}$$

For each time window of each test configuration, the mean, $\bar{u}^*_{jklr}$, the standard deviation, S^*_{jklr}, and the coefficient, $\beta_{2^*\,jklr}$, are calculated. $\beta_{2^*\,jklr}$ is given by:

$$\beta^*_{2\,jklr} = \frac{m_4}{(m_2)^2} \text{ with } m_x = \frac{\sum_{n=1}^{N} (u^*_{njklr})^x}{N}$$

For each observer, i, find P^*_i and Q^*_i, i.e.:

for j, k, l, r = 1, 1, 1, 1 to J, K, L, R

if $2 \leq \beta_{2^*jklr} \leq 4$ then

if $u^*_{njklr} \geq \bar{u}^*_{jklr} + 2\, S^*_{jklr}$ then $P^*_i = P^*_i + 1$

if $u^*_{njklr} \leq \bar{u}^*_{jklr} - 2\, S^*_{jklr}$ then $Q^*_i = Q^*_i + 1$

else

if $u^*_{njklr} \geq \bar{u}^*_{jklr} + \sqrt{20}\, S^*_{jklr}$ then $P^*_i = P^*_i + 1$

if $u^*_{njklr} \leq \bar{u}^*_{jklr} - \sqrt{20}\, S^*_{jklr}$ then $Q^*_i = Q^*_i + 1$

$$\text{If } \frac{P^*_i + Q^*_i}{J \bullet K \bullet L \bullet R} > \text{Y and } \left| \frac{P^*_i - Q^*_i}{P^*_i + Q^*_i} \right| < \text{Z then reject observer } i.$$

With:

N : number of observers

J : number of time windows within a test combination of test condition and sequence

K : number of test conditions

L : number of sequences

R : number of repetitions.

Proposed values for parameters (X, Y, Z) experienced as adapted to this method are 0.2, 0.1, 0.3.

3 Processing to find a relationship between the mean score and the objective measure of a picture distortion

If subjective tests were carried out in order to investigate the relation between the objective measure of a distortion and the mean scores $\bar{u}$ ($\bar{u}$ calculated according to Chapter 2.1), the following process can be useful, which consists of finding a simple continuous relationship between $\bar{u}$ and the impairment parameter.

3.1 Approximation by a symmetrical logistic function

The approximation of this experimental relationship by a logistic function is particularly interesting.

The processing of the data $\bar{u}$ can be made as follows:

The scale of values $\bar{u}$ is normalized by taking a continuous variable p so that,

$$p = (\bar{u} - u_{min}) / (u_{max} - u_{min}) \quad (5)$$

with u_{min} = minimum score available on the u -scale for the worst quality

u_{max} = maximum score available on the u -scale for the best quality.

Graphical representation of the relationship between p and D shows that the curve tends to be a skew-symmetrical sigmoid shape provided that the natural limits to the values of D extend far enough from the region in which u varies rapidly.

The function $p = f(D)$ can now be approximated by a judiciously chosen logistic function, as given by the general relation:

$$p = 1/[1+\exp(D- D_M)G] \tag{6}$$

where D_M and G are constants and G may be positive or negative.

The value p obtained from the optimum logistic function approximation is used to provide a deduced numerical value I according to the relation:

$$I = (1/p - 1) \tag{7}$$

The values of D_M and G can be derived from the experimental data after the following transformation:

$$I = \exp (D - D_M)G \tag{8}$$

This yields a linear relation by the use of a logarithmic scale for I:

$$\log_e I = (D - D_M)G \tag{9}$$

Interpolation by a straight line is simple and in some cases of an accuracy which is sufficient for the straight line to be considered as representing the impairment due to the effect measured by D.

The slope of the characteristic is then expressed by:

$$S = \frac{D_M - D}{\log_e I} = \frac{1}{G} \tag{10}$$

which yields the optimum value of G. D_M is the value of D for $I = 1$.

The straight line may be termed the impairment characteristic associated with the particular impairment being considered. It will be noted that the straight line can be defined by the characteristic values D_M and G of the logistic function.

3.2 Approximation by a non-symmetrical function

3.2.1 Description of the function

The approximation of the relationship between the experimental scores and the objective measure of a picture distortion by a symmetrical logistic function is mostly successful in the case that the distortion parameter D can be measured in a related unit, e.g. the SNR (dB). If the distortion parameter was measured in a physical unit d, e.g. a time delay (ms), the relation (8) has to be replaced by:

$$I = (d / d_M)^{1/G} \tag{11}$$

and therefore (6) becomes:

$$p = 1 / [1 + (d / d_M)^{1/G}] \tag{12}$$

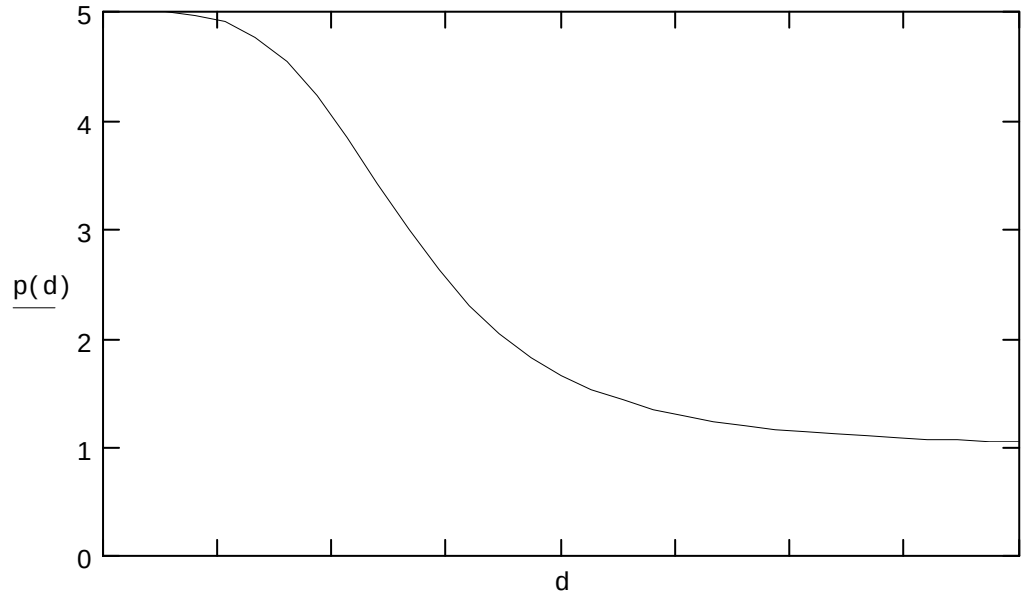
This function approximates the logistic one in a non-symmetrical way.

3.2.2 Estimation of the parameters of the approximation

The estimation of the optimal parameters of the function that provides the minimum residual errors between the actual data and the function may be obtained with any recursive estimation algorithm. Fig. 12 shows an example of the use of the non-symmetrical function to represent actual subjective data. This representation allows the estimation of specific objective measures corresponding to interesting subjective value: 4.5 on the five-grade scale, for instance.

FIGURE 12

Non-symmetrical approximation



3.3 Correction of the residual impairment/enhancement and the scale boundary effect

In practice, the use of a logistic function sometimes cannot avoid some differences between experimental data and approximation. These discrepancies may be due to the end of scale effects or simultaneous presence of several impairments in the test which may influence the statistical model and deform the theoretical logistic function.

A kind of scale boundary effect has been identified in which observers tend not to use the extreme values of the judgement scale, in particular for high quality scores. This may arise from a number of factors, including a psychological reluctance to make extreme judgements. Moreover the use of the arithmetical mean of judgements according to equation (1) near the scale boundaries may cause biased results because of the non-Gaussian distribution of votes in these areas.

Frequently an "residual impairment" (even in reference pictures the mean score only reaches a value $\overline{u}_0 < u_{max}$) is stated in the tests.

There are some useful approaches to correct the raw data of assessments for processing valid conclusions (see Table 5).

TABLE 5

Comparison of methods of correction of the scale boundary effects

Boundary effects compensation methods	Features			
	Residual impairment compensation	Residual enhancement compensation	Shift in the centre of the scale	Reference
No compensation	No	No	No	-
Linear scale transformation	Yes	May be significant error	No	[1,2]
Non-linear scale transformation (1)	Yes	Yes	No	[2]
Imps addition based method	Yes	No	Yes	
Multiplicative method	Yes	No	Yes	

(1) According to the non-linear scale transformation the corrected votes have to be calculated:

$$u_{corr} = C(\overline{u} - u_{mid}) + u_{mid}$$

$$C = \frac{\overline{u} - u_{0\,\min}}{u_{0\,\max} - u_{0\,\min}} \frac{u_{\max} - u_{mid}}{u_{0\,\max} - u_{mid}} + \frac{u_{0\,\max} - \overline{u}}{u_{0\,\max} - u_{0\,\min}} \frac{u_{\min} - u_{mid}}{u_{0\,\min} - u_{mid}}$$

with:

u_{corr}: corrected score

$\overline{u}$: uncorrected experimental score

u_{min}, u_{max}: boundaries of the voting scale

u_{mid}: middle of the voting scale

u_{0min}, u_{0max}: lower and upper boundaries of the tendency of experimental scores.

The correction of boundary effects if they exist in experimental data is a part of data processing of great importance. So, choice of procedure must be done with great accuracy. Note that these correction procedures involve special assumptions, so caution is advised in using them; their use should be reported in the presentation of the results.

For novel users the following references further explain the procedure for the correction of votes:

[1] Krivosheev M.I. Osnovy televisonnych izmerenij (Fundamentals of TV metrology), Moscow, “Radio i svias”, 1989.

[2] Gofaizen O.V. Algorithms of statistic analysis of data of subjective assessment of TV images quality. “Voprosy radioelectronycy” (Questions of Radioelectronics), Ser. “Obshchie voprosy radioelectronycy” (General questions of radioelectronics), 1990, issue 19, p. 97-110.

3.4 Incorporation of the reliability aspect in the graphs

From the mean grades for each impairment tested and the associated 95% confidence intervals, three series of grades are constructed:

– minimum grade series (means - confidence intervals);

– mean grade series;

– maximum grade series (means + confidence intervals).

The estimation parameters for the three series are then estimated independently. The three functions obtained can then be drawn on the same graph, the two from the maximum and minimum series as dotted lines and the mean estimate as a solid line. The experimental values are also plotted on this graph (see Fig. 13). We thus get an estimate of the 95% continuous confidence region.

For the grade 4.5 (threshold of visibility for the method) we can thus read off directly from the graph an estimated 95% confidence interval that can be used to determine a tolerance range.

The space between the maximum and minimum curves is not a 95% interval, but a mean estimate thereof.

At least 95% of the experimental values should lie within the confidential region; otherwise it may be concluded that there was a problem in carrying out the test or that the function model chosen was not the optimum one.

4 Conclusions

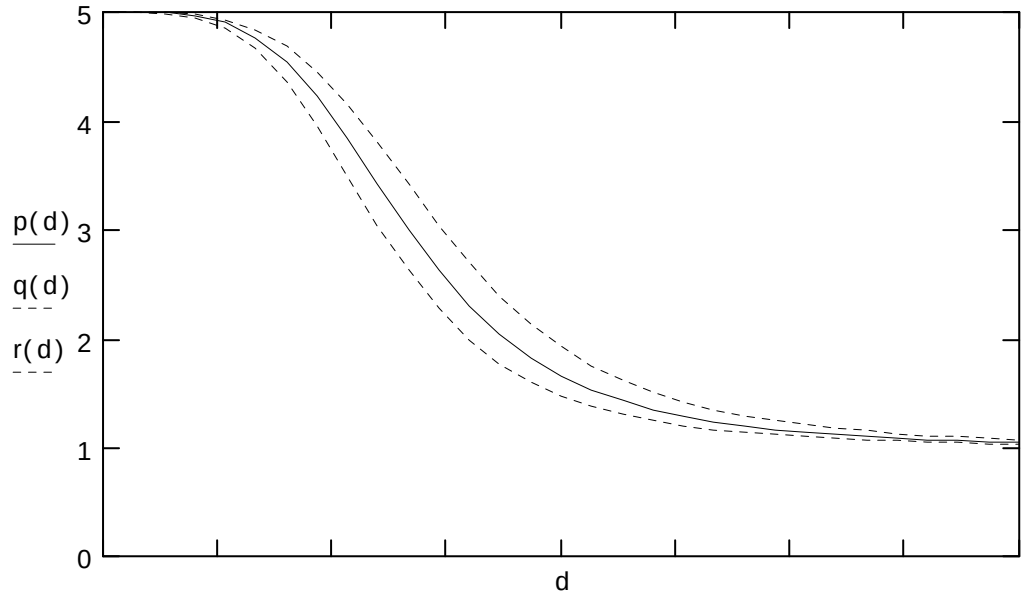
A procedure for the evaluation of the confidence intervals, i.e. the accuracys of a set of subjective assessment tests, has been described.

The procedure also leads to the estimation of mean general quantities that are relevant not only to the particular experiment under consideration, but also to other experiments carried out with the same methodology.

Therefore, such quantities may be used to draw diagrams of the confidence interval behaviour which are helpful for the subjective assessments, as well as for planning future experiments.

FIGURE 13

Case of a non-symmetrical impairment characteristic



p(*d*): mean grade series

q(*d*): minimum grade series

r(*d*): maximum grade series

d: objective impairment measurement

ANNEX 3

Description of a common inter-change datafile format

The purpose of a common inter-change data file format is to facilitate exchange of data between laboratories taking part in a collaborative international subjective evaluation campaign.

Any subjective evaluation assessment is developed according to five successive and dependent phases: test preparation, test performing, data processing, results presentation and interpretation. It is usually the case that, in large international campaigns, the work is distributed between the different laboratories participating:

– A laboratory has the responsibility to setup the test, in collaboration with other parties, by identifying the quality parameters to be assessed, the test material to be used (currently critical but not unduly so), the test framework (e.g. methodology, viewing distances, session arrangement, sequence of test item presentation) and the test environment (e.g. viewing conditions, introductory speech).

– Volunteering laboratories are asked to provide the test material processed according to the appropriate techniques representative of the quality parameter to be assessed (simulation or hardware based).

– A different partner is responsible for editing the test tape.

– Different volunteering laboratories are performing the test using the preliminary edited tape. The test can be a “blind test”. In this case, the laboratory will carry out the test by gathering the assessors’ votes without necessarily knowing the quality parameters under evaluation.

– Another participant is generally requested to co-ordinate the collection of the resulting raw data for processing and edition of results., which can also be done blindly.

– Finally, the results are interpreted from a text/table or graphic representation, and a final report is published.

The format proposed allows the gathering of results delivered according to the test procedures defined during the test definition phase.

The format is compliant with the evaluation methods described in Recommendation ITU-R BT.500.

It is made of text files with a structure which is shown in Tables 6 and 7. Its syntax is built around "labels" and "fields" in addition to a limited set of reserved symbols (e.g. "**[**", "**]**", " ", "↵" and "=").

There is no intrinsic limitation in terms of capacity (e.g. the number of participating laboratories, observers, test sequences and quality parameters, voting scale boundaries or the type of voting peripheral).

TABLE 6

Identification "Results" text file format

Identification file format and syntax	Comments
[Test framework]↵	[Section identifier]
Type= *"DSCQS" or "DSIS I", "DSIS II", etc.*↵	Identification of Rec. ITU-R BT.500 methodology used
Number of sessions = *1 ≤ integer ≤ x*↵	Number of sessions(1) in which a test has been distributed
Scale minimum = *integer*↵	Definition of the scale (see methodology specific requirements, if any)
Scale maximum = *integer*↵	Display diagonal (in)
Monitor size = *integer*↵	
Monitor make and model = *chain of characters*↵	
[RESULTS] ↵	[Section identifier]
Number of results= *1 ≤ integer ≤ y*↵	Number of "Results"(1) files being considered
Result(*j*). Filename(s) = *character string*.DAT↵	Full .DAT (see Table 7) filename including the path
....	
Result(*j*).Name= *character string*↵	Custom "Results" file name
Result(*j*).Laboratory= *character string*↵	Identification of the test performing laboratory
Result(*j*).Number of observers= *1 ≤ integer ≤ N*↵	Total number of observers
Result(*j*).Training= *"Yes" or "No"* ↵	Indicates if the votes gathered during the training are included the DAT file attached
[Result(*j*).Session(*i*).Observers] ↵	[Section identifier]
O(*k*).First Name= *character string*↵	Observer identification
O(*k*).Last Name= *character string*↵	
O(*k*).Sex= *"F" or "M"* ↵	Optional
O(*k*).Age= *integer*↵	Optional
O(*k*). Occupation = *character string*↵	Main socio-economic groups (e.g. worker, student)
O(*k*).Distance= *integer*↵	Viewing distance in display heights (e.g. 3H, 4H, 6H)

(1) Session: A test can be divided in a number of different sessions to cope with the maximum test duration requirement. The same or different observers can attend different sessions during which they will be asked to assess different test items. The merging of votes gathered from different sessions gives a complete set of test "Results" (number of presentations x number of votes per presentation). "Results" can be attached in different .DAT files which would be delivered for each performance.

TABLE 7

“Results” .DAT raw data text file format

filename.DAT File Format and Syntax	Comments
integer integer integer.....↲ integer integer integer.....↲ integer integer integer.....↲	A DAT raw data file is made of vote values separated by a space. One line should be used per observer Raw data is stored in the order of entry Data can be distributed in different DAT files identified in Table 6 by “Result(j). Filename(s)”[(1)].

(1) See (1) to Table 6.