

Bibliography: Psychophysics of Image Evaluation

A Contribution from the SMPTE Working Group on High Definition Electronic Production

Frederick J. Kolb, Jr., Editor

Comparative subjective judgments of image quality from carefully structured tests provide one essential criterion for evaluating the many possible procedures for achieving electronic or electronic-assisted production and post-production. With the many systems of image processing involved, and with the need for comparison with the appropriate photographic systems, each variant offers the potential for its own type of defects, aliasings, and distortions of the "original." While subjective judgments may also be employed for studies within a single system, this bibliography concentrates upon procedures found applicable for the broader case when images from a diversity of processes are to be compared.

A Task Group on Psychophysics was established by the Working Group on High Definition Electronic Production (WGHDEP) in 1982 to assist a group of scientists in the field in focusing upon the problems specific to the WGHDEP. Similar study groups have been formed by the FCC, ATSC, EBU, and CCIR. While the members of the WGHDEP Task Group are now continuing their work as members of the other groups, this bibliography reflects their work and concentrates upon the objectives of concern to the WGHDEP. It documents the most relevant published presentations of the techniques and procedures for developing, conducting, and evaluating subjective tests of the quality parameters for diverse image presentations. It is thus concerned with comparative evaluations of im-

ages produced by alternate or differing technologies. Rather than searching for optimization among minute variations, it assumes that significant differences may exist, and that confidence in the magnitude and worth of such differences is important data in arriving at value judgments and supportable decisions.

This bibliography is organized into four parts, and a description of each reference and its scope is provided for guidance of the extended spectrum of potential users — from one who wishes to know merely enough to understand a presentation and report, to one responsible for organizing and conducting a credible test. It is divided as follows:

Part I: Introduction to Image Evaluation: An overview of basic good practice in image evaluation, for those starting to confront the problems.

Part II: Selected References on Image Evaluation: Reports and examples of test design and results in evaluating image quality under conditions similar to those of interest to the WGHDEP.

Part III: Selected References on Visual Perception: An approach to the problem from the other direction, psychophysical studies such as these are particularly relevant to understanding how viewers react to and judge images.

Part IV: Resource Bookshelf of Reference Texts: Mostly the selection by C. J. Bartleson, with his annotations, of references for the serious practitioner, to elaborate and support the fundamental theory.

Part I: Introduction to Image Evaluation

These three references provide a friendly and manageable introduction, useful to those who are begin-

ning to consider the need for comparative testing, or are reviewing such test results.

Jackson, J.E., "Scaling Techniques for Subjective Judgments of Image Quality," *SMPTE J.*, 83: 891-894, Nov. 1974.

Jackson provides one of the clearest (also most direct and succinct) explanations of how to develop and interpret value judgments. When it is important to know the value of differences in an image quality — just how much better than *A* is *B*? — current studies recommend quantitative evaluation by interval judgment or by ratio-scaling. Jackson provides a particularly lucid explanation of what such numerical judgments really mean. This tutorial introduction emphasizes the various ways in which scaling methods may be classified, some of the judgment techniques which may be employed, and the advantages and disadvantages of these techniques for studying specific problems in the judgment of motion-picture and television image quality.

Jones, B.L., and Marks, E.E., "Picture Quality Assessment: A Comparison of Ratio and Ordinal Scales," *SMPTE J.*, 94:1244-1248, Dec. 1985.

This paper reports on the study of quality for a set of images produced through different systems and processes — typical of the problems faced by the WGHDEP. It could be considered an algorithm for evaluating the magnitude of such differences so that corresponding costs can be related to perceived values. The applications of quantitative ratio-scaling and interval judgment are beautifully illustrated. The advantages of this quantitative approach over merely ranking on a qualitative ordinal scale are shown. The improvements in consistent evaluation and reduced vari-

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ance for value judgments are demonstrated. This paper provides a teaching example for analyzing the problems faced by the WGHDEP.

Grum, F., and Bartleson, C.J. (eds.), *Optical Radiation Measurements: Visual Measurements*, Academic Press: New York, 1984.

Skimming through the contents of Part II, "Psychophysical Methods" (pp. 335-562), is excellent preparation for appreciating the complexities of useful visual judgments. (Later reading with greater care is strongly recommended!) This volume addresses responses of the human visual mechanism. (As a supplement to the references of Part III in this bibliography, "Selected References on Visual Perception," note also Part I of Grum and Bartleson, "Characteristics of the Visual Mechanism," pp. 12-331.) The text covers introductory psychophysics, practical guidelines for measuring matches, thresholds, differences, ratios, and for performing multidimensional scaling. It is the best presentation of the theoretical basis for approaching the problems under study and consideration by the WGHDEP.

Part II: Selected References on Image Evaluation

Concentrating upon presentations of the techniques and procedures, this portion of the bibliography includes selected exemplary papers chosen from the large number of published accounts of image-quality judgments conducted over a wide variety of systems and objectives.

A significant proportion of the most current literature is addressing the specific problems of image quality for images displayed in discontinuous, scanned, and sampled formats. While the basics of psychophysical understanding are common, the differing emphasis between these presentations and continuous (or quasi-continuous) format presentations are recognized, and obviously both cases have relevance in the WGHDEP's production environment.

In reviewing these references, one should be reminded that no single subjective evaluation procedure will be best for all situations. Each experimenter must first carefully define the question that he or she is asking, and then determine the appropriate evaluation methodology. If one only needs to determine how large a modification

is needed in a parameter to produce a visible change, then a threshold or just-noticeable-difference (JND) measurement is all that is required. Or if one needs to determine just the ordering of some characteristic, then an ordinal scale would suffice. However, if the task requires a determination of the sizes or magnitudes of the differences between test images, then some interval or ratio-scale method will be required. Ratio-scales become particularly important when one needs to compare many different systems, to correlate comparisons made over periods of time, or to interpret results from different observers. Finally, the measurement of the effect on quality of a communication channel can be treated as an impairment problem, and that specific question leads to other possible approaches.

In a review of the questions posed in the WGHDEP, the planning of committee-sponsored comparative studies structured to permit determination of a quantitative value judgment is being accorded high priority.

ANSI PH22.133-R1969 (withdrawn 1979): "Screen Luminance and Viewing Conditions for 35mm Review Rooms," *SMPTE J.*, 72:495, June 1963.

Controlled luminance levels and colorimetry, along with controlled illuminance and well-defined viewing conditions, are specified and recommended to achieve the image presentation comparable to that expected from the same print in a theater conforming to centerline theatrical specifications.

ANSI/SMPTE RP41-1983: "Evaluation of Color Films Intended for Television," *SMPTE J.*, 93:543-544, May 1984.

Controlled projection and viewing conditions are specified and recommended for review of motion-picture films intended for subsequent television release, in order that their resultant image quality on the television receivers may be predicted.

Allnatt, J.W., *Transmitted-Picture Assessment*, J. Wiley & Sons, Ltd.: London, 1983.

This book presents, discusses, and evaluates the results of over 30 years of study on the impairments of television images in the British Telecom Research Laboratories and in the BBC. Expositions of the science of design-

ing tests with minimum bias, the evaluation of data with minimum uncertainty, and above all the problems of coping with subjective decisions made through imperfectly-known human algorithms, provide an excellent reference. The somewhat differing valuation procedures employed around the world are described, and the attempts by the CCIR to evolve commonality are reviewed. Inasmuch as the emphasis is upon "impairments" and their tolerance thresholds, all judgments reported and considered are defined only by an ordinal or impairment scale.

Bartleson, C.J., "Annotated Bibliography on Psychophysical Methods," *CIE J.*, 4: 1-13, 1985.

The CIE TC-1.3 (Colorimetry) constituted a Task Force at its committee meeting in Tokyo, Japan, on the occasion of the 19th session of the CIE, for the purpose of preparing a report on "Guidelines for Measuring Color." In 1981 in Berlin, at its meeting at the AIC Conference COLOR '81, the committee redefined the objective of that Task Force as the preparation of an annotated bibliography relating to the application of psychophysical methods to the measurement of color.

This annotated bibliography is the final report of the Task Force. The purpose of the document is to provide a selective, introductory guide to currently available literature that can serve to help those who are not already familiar with psychophysical methods to learn more about the subject. The document has been prepared by the chairman of the Task Force on "Guidelines for Color Measurement." (All entries are textbooks.)

Carlson, C.R., and Bergen, J.R., "Perceptual Considerations for High-Definition Television Systems," *SMPTE J.*, 93:1121-1126, Dec. 1984.

The perceptual impact of various HDTV systems is evaluated using just-noticeable-difference (JND) analysis. The major conclusion of this analysis is that foreseeable cameras and displays will not permit effective use of luminance bandwidths beyond roughly 10 MHz in a 4:3 aspect ratio format. Current work, however, is showing that psychophysical functions derived from JND can be imprecise when applied to subjective evaluations of images spanning a significant range of quality.

CCIR Recommendation 500-3 (1986): "Method for the Subjective Assessment of the Quality of Television Pictures," *Rec. and Reports of the CCIR 1986, XI-Part 1*:165-173.

Emphasis by the CCIR has been on identifying impairments to image quality, and especially upon identifying the maximum impairment that can be judged acceptable. An ordinal scale is employed. Guidance is offered on test content, viewing conditions, and test procedures through Annexes and subsidiary reports.

CCIR Report 313-6 (1986): "Assessment of the Quality of Television Pictures — A Bibliography," *Rec. and Reports of the CCIR 1986, XI-Part 1*:220-223.

Seventy-one papers are listed by author and title, plus 41 CCIR documents. Although grouped within the category of "Image Evaluation," the purposes and scopes of these papers are highly divergent and only a small number will be relevant to any specific question.

CCIR Report 405-5 (1986): "Subjective Assessment of the Quality of Television Pictures," *Rec. and Reports of the CCIR 1986, XI-Part 1*:174-201.

In a series of Annexes, the procedures for developing ordinal evaluations among the CCIR administrations are summarized and explained. Five additional Annexes provide examples of some applications.

CCIR Report 959-1 (1986): "Experimental Results Relating Picture Quality to Objective Magnitude of Impairment," *Rec. and Reports of the CCIR 1986, XI-Part 1*:201-203.

The numerous sources of impairment observed in television display are enumerated, and the maximum acceptable tolerance levels are tabulated and discussed.

CCIR Report 1082 (1986): "Methods for Measuring the Intrinsic Picture Quality of Current and New Television Systems," *Rec. and Reports of the CCIR 1986, XI-Part 1*:208-213.

This report is concerned with the methods for assessing and comparing the intrinsic quality of television systems as opposed to evaluating the degradations to quality within a given

system; i.e., concerned with the application of interval and ratio-scaling as opposed to ordinal scaling. A test methodology for ratio-scaling is described, followed by an illustrative example of the comparison of picture-quality assessments by category rating and by magnitude estimation. The method is applicable to identifying the perceived values of systems and images spanning a range of image quality, such as comparing HDTV with systems conforming to CCIR Rec. 601. (cf. B.L. Jones and L. E. Marks).

CCIR Report 1083 (1986): "Advanced Statistical Processing of Subjective Test Results," *Rec. and Reports of the CCIR 1986, XI-Part 1*:214-215.

An advanced statistical treatment is proposed for application to impairment data on systems of widely differing quality, in order to identify the most probable boundary line in the representation plane for a given percentile from the population. The proposed statistical processing attempts to extract more quantitative rankings from the qualitative impairment data. (The conclusions are controversial.)

CCIR Recommendation 654 (1986): "Subjective Quality of Television Pictures in Relation to the Main Impairments of the Analogue Composite Television Signal," *Rec. and Reports of the CCIR 1986, XI-Part 1*:223-230.

For each of eight of the common impairments observable in current composite color television, this recommendation presents a proposed correlation of impairment scale with objective measurement of the television signal waveform.

Jackson, J.E., "Scaling Techniques for Subjective Judgments of Image Quality," *SMPTE J.*, 83:891-894, Nov. 1974.

Subjective scaling relative to the judgment of motion-picture or television images is discussed with the aim of arriving at a criterion (or criteria). This is an excellent tutorial introduction, the primary emphasis being on the various ways in which scaling methods may be classified, some of the judgment techniques which may be employed in obtaining the different scales, and the advantages and disadvantages of these techniques for studying specific problems. The ad-

vantages of interval scales are emphasized, since they provide a quantitative value-measure for decision guidance among multiple choices.

Jones, B.L., and Marks, L.E., "Picture Quality Assessment: A Comparison of Ratio and Ordinal Scales," *SMPTE J.*, 94: 1244-1248, Dec. 1985.

Two picture-quality experiments were conducted using ratio (quantitative) and ordinal (rank-ordered) scaling methods. The ratio-scales were generated by instructing observers to assign a magnitude to the quality parameter studied and normalizing the results. The ordinal scales were generated by rank-ordering within pre-established category scales. The purpose was to compare the methods to see if one method would outperform the other. Two stimulus ranges were employed on otherwise equivalent stimulus material and observers. The ratio-scale results showed much smaller context effects and have the additional virtue of providing meaningful ratios and intervals in the numerical responses, facilitating a quantitative interpretation of perceived values. (cf. CCIR Report 1082 [1986])

Jones, B.L., and McManus, P.R., "Graphic Scaling of Qualitative Terms," *SMPTE J.*, 95:1166-1171, Nov. 1986.

The article describes an investigation carried out to determine the perceived intervals between the successive descriptive terms on subjective picture and sound quality, i.e., 4 or 5-point and multiple-point category scales. This study involved participants in five geographical areas of the U.S., and also participants in Rome, Italy (conducted in the Italian language). The intervals were found to be irregular and compressed at the end points. The meanings of the words showed some regional and cultural dependence. It was concluded that these category scales are ordinal (qualitatively rank-ordered) and not interval (quantitative measures of magnitudes), and that interval or ratio-scales should be used when the "distances" between test stimuli are under examination.

Schreiber, W.F., "Psychophysics and the Improvement of Television Image Quality," *SMPTE J.*, 93:717-724, Aug. 1984.

Basic studies of vision are applied to an analysis of television systems, with emphasis upon how known psychophysical functions governing image evaluation explain observer response to scanned images displayed on a cathode ray tube. The differences between continuous and sampled images are emphasized. A hypothetical television system — from capture through to CRT display — is developed to take maximum advantage of the psychophysics reviewed herein.

Wendland, B., and Schröder, H., "On Picture Quality of Some Television Signal Processing Techniques," *SMPTE J.*, 93:915-922, Oct. 1984.

Potential quality improvements in CRT displays through VLSI signal processing permit the advantages of filtration of the television signal, progressive scan, and higher line-number systems. Image quality is evaluated by rank-ordering and compared with electrical measurement of the signal. The significance of the channel characteristics is emphasized.

Part III: Selected References on Visual Perception

Visual psychophysics, as described by Bartleson, "attempts to build a descriptive bridge between stimulus and response." Just as Part II of this bibliography concentrates upon method, this section includes references that concentrate upon substance, more concerned with understanding the visual reaction than selecting an imaging system. Since the results obtained in any subjectively evaluated experiment depend significantly upon the conditions under which the experiment is carried out (and nominally parallel but procedurally different experiments may not even agree), visual psychophysics has an essential part in planning experiments most likely to be relevant.

Biberman, L.M. (ed.), *Perception of Displayed Information*, Plenum Press: New York, 1973.

This book discusses the transfer of information from a visual source to a receiver, especially a CRT. Image quality parameters are reviewed in the context of physical and psychophysical understandings, to provide a basis for correlation of quality judgments with objective measurements. Image quality and observer perfor-

mance, and image reproduction by a line raster system are treated in detail. A prediction of quality in sampled images by consideration of signal-to-noise ratios is shown to have a high probability of correlation with judgments of human observers. The text was developed in conjunction with studies in the Institute for Defense Analyses, and the preparation of a graduate course on special topics in electrical engineering.

Cornsweet, T.N., *Visual Perception*, Academic Press: New York, 1970.

The manner in which an organism selects external information to register and act upon, Cornsweet points out, is a property of the organism itself. The study of visual perception is the study of the human organism. The areas discussed most intensively are those related to the perceptions of brightness and color, and include both aspects that are well understood and problems that have not yet been solved. The book builds upon material from courses taught by the author at Yale and at the University of California, Berkeley.

Graham, C.H. (ed.), *Vision and Visual Perception*, Wiley: New York, 1965.

The main point of difference from other treatises on vision and visual perception is that the authors attempt to say something about the broadest concepts and definitions of visual perception — from electrophysiology through flicker and afterimages, and many further topics, for example. Some of the subjects' earlier roots are reviewed for better understanding of ensuing developments.

Holoch, G., "Resolving Power of the Human Eye in the Diagonal Direction," contribution from IRT to the EBU, (GT V1/HDTV 376).

If the resolution is to remain adapted to the eye response for all spatial directions, the limiting resolution in the diagonal direction must not be reduced by more than roughly 10% from that provided in the horizontal and vertical directions. This sets up more strict criteria than previous studies, which have concluded that diagonal spatial frequencies may be reduced by as much as 30% without the change being detected.

Lucas, F.X.J., and Burdrikis, Z.L., "Picture Quality Predictions Based on a Visual Model," *IEEE Trans.*

Communications, 30:1674-1692, July 1982.

A comprehensive model of the visual process is proposed, incorporating visual filtering, adaptation, and masking. The model is applied to evaluation of bit-rate reduction concepts in digital encoding of moving monochrome images. Quantitative ratio-scaling subjective judgments showed encouraging correlation with values predicted by the model when both filtering and local masking were included. It is concluded that observers base their judgment on the worst areas in the image.

Part IV: Resource Bookshelf of Reference Texts

Reference texts taken directly from recommendations and annotations by Bartleson, C.J., *CIE J.*, 4:1-13, 1985, combined with a few appropriate supplements.

Box, G.E.P., Hunter, W.G., and Hunter, J.S., *Statistics for Experimenters*, J. Wiley: New York, 1978.

This text comes close to being a standard for application of statistical methods to experimental design, analysis, and model-building. It is not a simple book, but it is down-to-earth and rich in practical hints as well as straightforward explanations. It is divided into four sections: (1) comparing two treatments (paired comparisons, sampling, significance, etc.); (2) comparing more than two treatments (analysis of variance, factorial and other designs, etc.); (3) measuring the effects of variables; and (4) building and using mathematical models (a section that should be of particular interest to those who attempt to draw inferences of system from their data). It is predicated and written on the assertion that "scientific research" is a process of guided learning [and] the object of statistical methods is to make that process as efficient as possible.

Chapanis, A., *Research Techniques in Human Engineering*, The Johns Hopkins University Press: Baltimore, Md., 1959.

Broadly useful text on designing and conducting experiments, by an experienced worker.

Dixon, W.J., and Massey, F.J., Jr., *Introduction to Statistical Analysis*, McGraw-Hill: New York, 1957.

For those who want an introduction to basic statistical methods and theory, it is difficult to find a better text than this one.

Draper, N., and Smith, H., *Applied Regression Analysis (2nd ed.)*, J. Wiley: New York, 1981.

This book does not deal with scaling directly but is one of the best texts for regression analysis, which is the basic data-reduction method for interval scaling. The text is clear and detailed; it also contains many examples.

Gescheider, G. A., *Psychophysics: Method, Theory, and Application (2nd ed.)*, Lawrence Erlbaum Assoc.: Hillsdale, N.J., 1985.

This has become the classic text due to the age and limited availability of Guilford, J.P. (below). The concepts of sensory measurement and of psychophysical theory are treated, along with the conduct of valid experimentation. It is an excellent substitute reference.

Green, P.E., and Rao, V. R., *Applied Multidimensional Scaling: A Comparison of Approaches and Algorithms*, Holt, Rinehart & Winston: New York, 1972.

This is a standard text for multidimensional scaling. It covers most modern methods, treats both theoretical and practical questions, and provides a number of examples.

Grum, F., and Bartleson, C.J. (eds.), *Optical Radiation Measurements, Vol. 5: Visual Measurements*, Academic Press: New York, 1984.

This volume addresses light measurement by methods involving the human visual mechanism. It includes chapters by a number of contributors and covers introductory psychophysics, practical guidelines for measuring matches, thresholds, differences, ratios, and performing multidimensional scaling. The book also contains information on the eye as an optical system and detector of light, on visual pigments and sensitivity, and on both photometry and colorimetry.

Part II (of the three-part text) is recommended as the best presentation of valid, scientifically-directed approaches to the problems in selecting the most valid test procedures. Part III (of the three-part text) is recommended for its exploration of visual perception. This entire volume is most relevant to the questions under

study and consideration by the WGHDEP.

Guilford, J.P., *Psychometric Methods (2nd ed.)*, McGraw-Hill: New York, 1954.

This is the classic text in this field. Despite its age, it still provides useful introductions to concepts of sensory measurement and psychophysical theory. There is a mathematical introduction which is followed by chapters on the methods of constant stimuli, adjustment, and limits (identified by these and other names). In addition, the book deals with paired comparisons, rank order, category scaling, rating scales, factor analysis, and early methods of multidimensional scaling. All have numerous examples worked out. Separate chapters are devoted to principles of judgment, theory of psychological tests and their development, and reliability and validity of measurements. (This book is essentially out of print. See Gescheider, G.A.)

Haug, T.S., and Treliak, O.J. (eds.), "Picture Bandwidth Compression," *Proc. of the 1969 Symposium on Picture Bandwidth Compression*, Gordon & Breach: New York, 1972.

The chapter by Pearson, D.E., "Methods for Scaling Television Picture Quality," is particularly relevant in this volume, which reviews much of the image analysis studies conducted in Bell Laboratories.

Kling, J.W., and Riggs, L.A. (eds.), *Woodworth and Schlosberg's Experimental Psychology (3rd ed.)*, Holt, Rinehart & Winston: New York, 1971.

Woodworth and Schlosberg has been a classic source for experimental psychologists for many years (~1938). It is an excellent source of theory and application of experimental technique with many guidelines and sensible suggestions for good practice.

Marks, L.E., *Sensory Processes, The New Psychophysics*, Academic Press: New York, 1974.

This was written by a prominent worker in the field of direct scaling (and a former student of Stevens, the leading modern proponent of this method). It is thorough and clear and contains numerous examples from the author's own research, examples that are used to illustrate the application

of the method with step-by-step exemplifications.

Mosteller, F., and Tukey, J.W., *Data Analysis and Regression*, Addison-Wesley: Reading, Mass., 1977.

Although this text does not deal directly with experimental methods (it is mainly a book on statistical inference), it provides a wealth of practical information about how to handle experimental data and how to assess their reliability and robustness.

Schiffman, S.S., Reynolds, M.L., and Young, F.W., *Introduction to Multidimensional Scaling Theory, Methods, and Applications*, Academic Press: New York, 1981.

An excellent book that is divided into three sections: (1) basic concepts and a data bank that is common to all examples throughout the book; (2) a description of seven commonly used computer programs and their applications (including comparisons of their outputs); (3) a section on theory that includes detailed descriptions of the ways in which each of the seven computer algorithms work. This book helps to understand what the various multidimensional programs can do and how they can be used effectively. A directory of programs is included.

Shepard, R.N., Romney, A.K., and Nerlove, S.B. (eds.), *Multidimensional Scaling: Theory and Applications in the Behavioral Sciences*, Seminar Press: New York, 1972.

This two-volume work provides a thorough coverage of the theory and methodology of multidimensional scaling. The first volume contains primarily theory and tutorial sections. The second volume provides many examples illustrating the subjects discussed in the first volume. It is an unusual and very useful publication.

Sidowski, J.B. (ed.), *Experimental Methods and Instrumentation in Psychology*, McGraw-Hill: New York, 1966.

A number of chapters, by various authors, deal with many aspects of experimental design, including discussions of the "nuts and bolts" of setting up instruments and collecting data.

Stevens, S.S., *Psychophysics, Introduction to its Perceptual, Neural, and Social Prospects*, J. Wiley: New York, 1975.

This volume, which was published posthumously, is the final summary of

a corpus of work and proposals spanning more than a quarter of a century during which the author raised the status of magnitude scaling to the level of an accepted technique in psychophysics. The book is a model of clarity of prose and tutorial exposition. It is understandably biased toward what has been called "the new psychophysics," i.e., direct estimation methods (as opposed to methods based on discrimination) and, especially, the magnitude or ratio estimation approaches to scaling. At the time that the book was written, there probably was no other person who had conducted more direct scaling experiments than Stevens, and his wealth of practical exper-

ience is reflected in the many suggestions he offers for good experimental practice. It is more of a tutorial than a "cookbook."

Torgerson, W.S., *Theory and Methods of Scaling*, J. Wiley: New York, 1958.

In many ways, this book is similar to Guilford's. However, it tends to be more theoretical and provides fewer tutorial examples. Some of the treatments are more up-to-date in Torgerson and the author takes more cognizance of the labor savings that can be realized with the aid of computers.

Wyszecki, G. and Stiles, W.S., *Color*

Science: Concepts and Methods, Quantitative Data and Formulae (2nd ed.), J. Wiley: New York, 1982.

This is the premier reference for detailed information about physical data for characterizing stimuli, geometrical optical properties of the eye, colorimetry, photometry, matching of colors, so-called uniform color-scales, thresholds, and theories and models of color vision. The emphasis is heavy on physics, colorimetry, and photometry; it is not a textbook on vision nor on scaling. However, it is a virtually indispensable reference for color psychophysics where the emphasis is on the word "color."

24th Annual SMPTE Television Conference

January 26-27, 1990, Orlando, Fla.

Call for Papers

A call for papers for the 24th Annual SMPTE Television Conference has been formally announced by Editorial Vice-President Frank J. Haney, Capital Cities/ABC, Inc. Program Chairman Clyde D. Smith, Lockheed Space Operations Co., anticipates that papers on the theme "Television — Merging Multiple Technologies" will examine how multiple technologies are merging together, making it difficult to know what is television and what is not.

Clyde Smith and Program Vice-Chairman Paul Montgomery, Tasp Group, Inc., are planning four sessions, one morning and one afternoon session each day. They are especially interested in papers on the practical applications of other technologies merging into television, such as robotics in studios and how television is expanding into nontraditional fields like flight simulation.

To have a paper considered, the author should send his name, address, telephone number, and a 100-word abstract of the proposed paper on an author form to SMPTE, Att.: Marilyn Waldman, Program Coordinator, 595 W. Hartsdale Ave., White Plains, NY 10607, by September 15, 1989. Author forms are available from headquarters at this address. Addi-

tional details about the program can be obtained by writing to the SMPTE or by calling (914) 761-1100.

The television conference will be held Friday, January 26, and Saturday, January 27, 1990, at Disney's Contemporary Resort in Lake Buena Vista, Fla. In addition to a full technical program, there will be a Get-Together Luncheon on Saturday, a

Spouses Program, and Coffee Club. The Contemporary's location in the Walt Disney World® resort assures there will be plenty to do for attendees and their families before and after the conference.

As more information is available on the 24th Annual SMPTE Television Conference, updates will be published in the *Journal*. — Nancy T. Engel



Disney's Contemporary Resort, site of the 24th Annual SMPTE Television Conference. Photo © 1989 the Walt Disney Co.