BASIC RESEARCH IN PRECISE MEASUREMENT

PHASE II

APPENDIX D1

FINAL REPORT

for

TASK 3 - VIEWING ILLUMINATION

BIBLIOGRAPHY ON VIEWING ILLUMINATION

MAY 1972

Prepared by

STATINTL

[redacted]

ABSTRACT

This document contains a bibliography of selected references on the subject of viewing illumination. The bibliography contains 582 references which are listed alphabetically and cross-indexed. Selected summaries of the more pertinent references are provided.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

ILLUMINATION STUDY BIBLIOGRAPHY

INTRODUCTION

This document contains a bibliography of selected references pertinent to the general subject of illumination and human visual behavior in the context of mensuration performance. The bibliography was prepared by [redacted] under a contract sponsored by the U.S. Government. The bibliography has been arranged in such a manner to allow ready access by subject or author. Collateral data has been provided as fully as possible to permit acquisition of documents when desired. A companion item to this bibliography is a summary of selected references.

STATINTL

SCOPE

The open literature search is summarized in Figure 1. The collection of references was directed towards full coverage of readily available documents (1960--1971) concerning illumination and human visual performance pertinent to the Center's mensuration mission. Sources utilized were the Defense Documentation Center, Clearing House for Technical and Scientific Information, Boeing Co. Imagery Interpretation Bibliography, professional journals, previously published technical bibliographies, symposium and annual meeting papers, and manufacturing brochures and publications.

ACCESS

The bibliography is arranged alphabetically by author. Two groupings will be found, with the second beginning at entry 0554. Access by subject is provided by a subject index file (see Figure 2). Figure 3 demonstrates access procedures.

ENTRY DESCRIPTION

Each entry will contain author or corporate name, title, source of publication, and pertinent recovery data. Certain listings will be followed by a document number or code which refers to its accessibility:

AD XXX XXX	DDC Document
GXXXXX	Boeing Imagery Interpretation Bibliography

ABBREVIATIONS

Abbreviations were not generally used in compiling the bibliography. However, the following list is provided for use if needed.

AMER. J. PSYCHOL	American Journal of Psychology
J. EXP. PSYCH	Journal of Experimental Psychology
J. GEN. PHYSIOL	Journal of General Physiology
JOSA	Journal of the Optical Society of America
JOURNAL SMPTE	Journal of Society of Motion Picture and Television Engineers
PHOTO. ENGR	Photogrammetric Engineering
PSE	Photographic Science and Engineering

FIGURE 1.

SEARCH TERMS

DDC/NASA SEARCH

SUBJECT: ILLUMINATION/HUMAN FACTORS (BROAD COVERAGE)

KEY WORDS

A. Color Photography
   1. Color Film
B. Color Temperature
   1. Blackbody Radiation
   2. Emissivity
   3. Spectral Emmittance
C. Color Vision
D. Lamps
   1. Arc Lamps
   2. Electroluminescent Lamps
   3. Fluorescent Lamps
   4. Gas Lamps
   5. Glow Lamps
   6. Incandescent Lamps
   7. Infrared Lamps
   8. Mercury Lamps
   9. Neon Lamps
   10. Neon Tubes
   11. Sodium Lamps
   12. Ultraviolet Lamps
   13. Xenon Lamps
E. Brightness
   1. Color
   2. Glare
   3. Human Factors Engineering
   4. Incandescence
   5. Radiance
   6. Reflectance
F. Color
   1. Chroma
   2. Color Codes
   3. Color Matching
   4. Color Temperature
   5. Comprehension
   6. Contrast
G. Color Vision/Visual Defects
H. Color Vision/Visual Reception
I. Colorimeters
   1. Color
   2. Colorimetric Analysis
   3. Colorimetry
J. Human Factors Engineering
   1. Comfort
   2. Performance
   3. Psychological Effects
K. Light (Visible Radiation)
L. Visibility
   1. Contrast
   2. Light
   3. Resolution
M. Visible Spectrum
N. Visual Perception
   1. Flicker
   2. Critical Flicker Fusion
O. Illuminance

The open literature search included the broad categories of illumination, illuminants, human visual behavior, color science, color

vision, viewing and display systems. Document search was generally for the period 1960-1971.

Reference sources most widely quoted are Applied Optics, Illuminating Engineering, Journal of Experimental Psychology, Journal of Society of Motion Picture and Television Engineers, Journal of the Optical Society of America, Photographic Science and Engineering, Vision Research.

FIGURE 2

SUBJECT HEADINGS

I. COLOR
   1. Color (General)
   2. Colorimetry
   3. Color Matching
   4. Color Photography
   5. Color Specification
   6. Color Theory

II. COLOR VISION
   1. Chromatic Adaptation
   2. Color Contrast
   3. Color Discrimination
   4. Color Vision (General)
   5. Color Vision Theory
   6. Visual Mechanism

III. ILLUMINANTS
   1. Arc Lamps
   2. Color Rendering
   3. Color Temperature
   4. Discharge Lamps
   5. Electroluminescent Lamps
   6. Fluorescent Lamps
   7. Incandescent Lamps
   8. Spectral Distribution

IV. ILLUMINATION

1. Design Guides/Standards
2. Flicker
3. Glare
4. Illumination (General)
5. Luminance
6. Photometry
7. Visual Performance

V. VIEWING SYSTEMS

1. Design Guides
2. Direct Viewing/Stereoscopic
3. Other
4. Projection

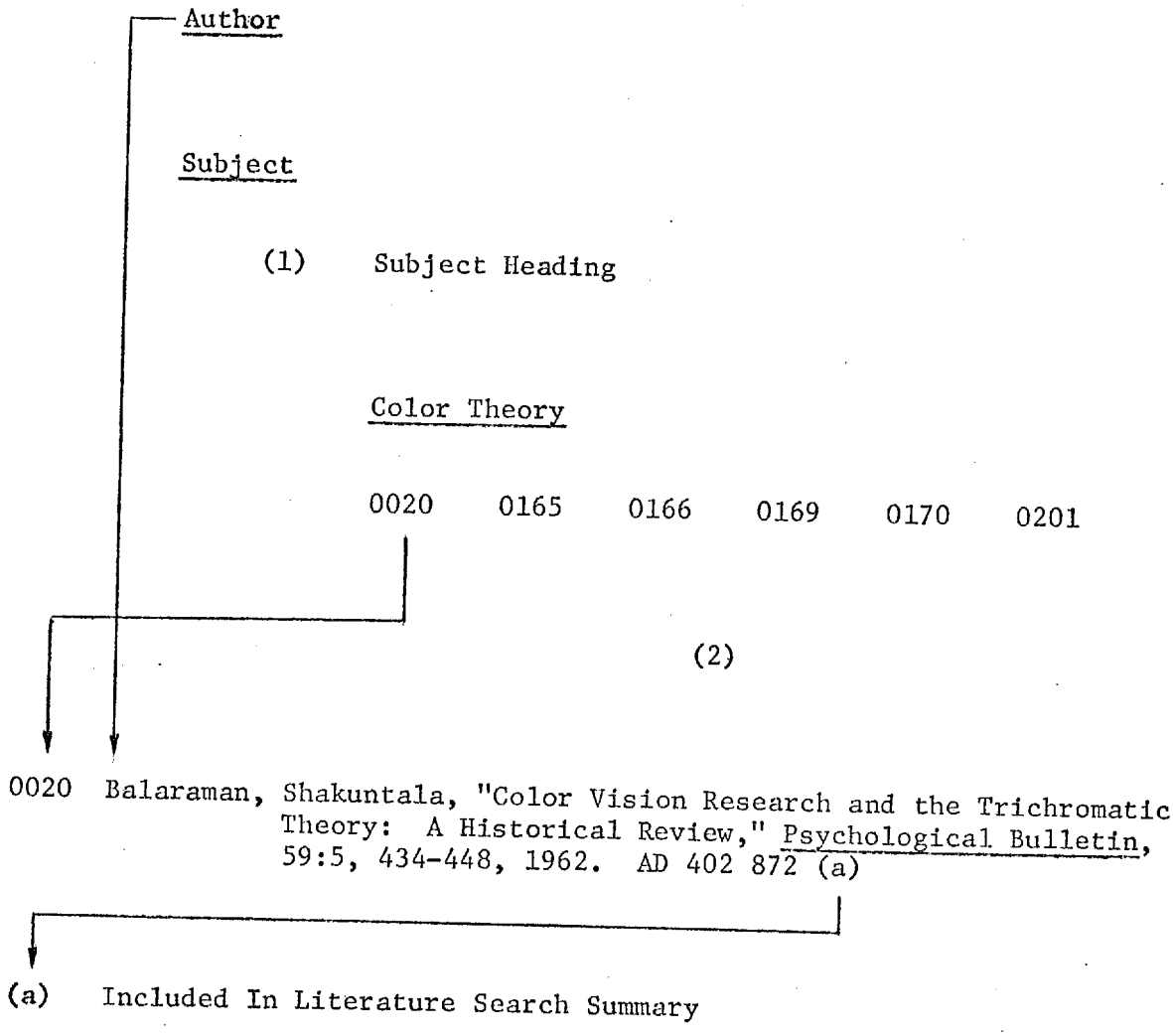
VI. VISION

1. Accommodation
2. Acuity
3. Adaptation
4. Brightness
5. Contrast
6. Interpretation Performance
7. Physiological Factors
8. Psychological Factors
9. Spectral Sensitivity
10. Vision (General)

FIGURE 3.

BIBLIOGRAPHY ENTRY

ACCESS: Bibliography May Be Entered By Author Or Subject.



I. COLOR

1. Color (General)

0044 0089 0116 0164 0294 0353
0366 0388 0500 0547 0566

2. Colorimetry

0022 0041 0042 0043 0121 0199
0228 0241 0242 0290 0291 0293
0299 0300 0301 0308 0309 0314
0317 0328 0340 0354 0355 0356
0357 0373 0425 0426 0451 0531
0532 0544 0545 0546 0558 0559
0560 0561 0562 0563 0564 0565
0567 0568 0579

3. Color Matching

0074 0212 0223 0248 0308 0309
0359 0373 0376 0377 0494

4. Color Photography

0012 0013 0028 0029 0094 0134
0149 0168 0171 0172 0175 0200
0272 0300 0301 0305 0313 0334
0353 0361 0394 0415 0473 0478
0499 0509 0530 0536 0537 0555
0556 0557 0569 0574

5. Color Specification

0010 0011 0105 0110 0173 0174
0176 0204 0205 0222 0224 0271
0289 0293 0303 0304 0340 0384
0385 0388 0389 0393

6. Color Theory

0020 0165 0166 0169 0170 0201
0292 0362 0445 0488 0515

II. COLOR VISION

1. Chromatic Adaptation

0068 0101 0150 0172 0231 0302
0306 0349 0351 0444

2. Color Contrast

0077 0268 0277 0278 0279 0286
0288 0297 0364 0485 0512 0551

3. Color Discrimination

0003 0004 0066 0067 0074 0080
0081 0102 0103 0105 0108 0111
0140 0185 0202 0258 0338 0347
0348 0352 0435 0453 0458 0459
0460 0461 0462 0549

4. Color Vision (General)

0016 0023 0071 0115 0201 0236
0237 0238 0239 0240 0255 0259
0287 0327 0369 0548 0580

5. Color Vision Theory

0037 0039 0040 0067 0071 0092
0110 0126 0141 0143 0144 0152
0178 0254 0263 0295 0323 0324
0325 0326 0406 0407 0522 0542
0543

6. Visual Mechanism

0040	0045	0068	0072	0087	0097
0099	0100	0103	0102	0122	0123
0124	0128	0129	0131	0154	0167
0171	0207	0221	0225	0232	0256
0257	0260	0263	0272	0276	0331
0335	0358	0360	0386	0393	0401
0403	0406	0407	0417	0425	0430
0432	0434	0436	0437	0438	0439
0443	0446	0451	0452	0474	0475
0485	0491	0495	0498	0503	0514
0522	0529	0532	0538	0548	0555
0567	0573	0576			

III ILLUMINANTS

1. Arc Lamps

0065	0106	0120	0196	0371	0505
0581					

2. Color Rendering

0022	0025	0088	0090	0091	0107
0135	0137	0212	0243	0283	0298
0390	0391	0392	0441	0455	0493
0563					

3. Color Temperature

0096	0134	0229	0312	0539	0540

4. Discharge Lamps

0191	0273	0282	0322	0404	0510

5. Electroluminescent Lamps

0230	0274	0275	0321	0405	0411
0421	0490				

6. Fluorescent Lamps

0136 0160 0243 0251 0285 0339
0342 0413 0531 0553

7. Incandescent Lamps

0001 0312 0333 0398 0483 0511
0582

8. Spectral Distribution

0031 0065 0195 0465 0466 0482

IV. ILLUMINATION

1. Design Guides and Standards

0009 0050 0055 0057 0059 0061
0113 0114 0117 0157 0318 0343
0380 0463 0489 0507 0525 0526
0571 0572

2. Flicker

0030 0063 0177 0318 0553

3. Glare

0052 0147 0148 0159 0189 0466
0467 0502 0535

4. Illumination (General)

0130 0133 0153 0155 0244 0265
0269 0379

5. Luminance

0049 0050 0058 0060 0062 0073
0109 0122 0123 0124 0197 0220
0332 0554 0570

6. Photometry

0118	0119	0120	0158	0184	0246
0250	0251	0274	0284	0290	0339
0370	0404	0517	0531	0533	0541
0560	0565				

7. Visual Performance

0064	0078	0159	0198	0211	0215
0221	0233	0249	0281	0296	0315
0316	0336	0346	0372	0378	0398
0399	0402	0408	0422	0431	0454
0456	0465	0468	0482	0527	0528
0532	0570	0571			

V. VIEWING SYSTEMS

1. Design Guides

0017	0157	0350	0419	0427	0428
0457	0464				

2. Direct Viewing/Stereoscopic

0009	0014	0179	0232	0286	0381
0412	0531				

3. Other

0021	0048	0130	0226	0394	0427
0449	0471	0479	0577		

4. Projection

0015	0083	0109	0112	0139	0145
0163	0192	0210	0311	0330	0363
0374	0375	0447	0448	0464	0469
0472	0536	0554	0575	0580	

VI. VISION

1. Accommodation

0005 0006 0095

2. Acuity

0019 0075 0076 0078 0079 0097
0098 0101 0131 0161 0177 0233
0268 0328 0329 0349 0378 0577

3. Adaptation

0018 0046 0070 0075 0076 0078
0227 0234 0252 0523 0409 0410
0416 0467 0486

4. Brightness

0027 0033 0034 0035 0036 0084
0085 0104 0132 0142 0146 0151
0162 0182 0183 0187 0189 0190
0216 0217 0219 0234 0235 0245
0247 0264 0270 0320 0341 0344
0368 0387 0399 0400 0401 0429
0496 0497 0504 0520 0521

5. Contrast

0082 0161 0187 0245 0367 0396
0397 0492

6. Interpretation Performance

0062 0138 0420 0442 0476 0477
0513 0518 0519

7. Physiological Factors

0002	0008	0046	0082	0093	0180
0186	0193	0194	0213	0337	0395
0410	0423	0424	0450	0501	0516
0524	0534	0578			

8. Psychological Factors

0038	0056	0063	0069	0193	0206
0208	0214	0267	0310	0365	0433
0434	0449	0470	0484	0491	0506
0508					

9. Spectral Sensitivity

0007	0070	0079	0086	0098	0111
0125	0126	0127	0156	0209	0218
0252	0261	0262	0266	0280	0307
0319	0376	0377	0382	0383	0414
0440	0480	0481	0516	0523	

10. Vision (General)

0054	0181	0188	0203	0345	0552
0578					

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LITERATURE SUMMARY:

The following summaries of selected references are, in most cases, abstracts as published in technical journals or DDC Report Bibliographies.

STUDY: Akita, Graham and Hsia, "Maintaining an Absolute Hue in the Presence of Different Background Colors" (0003)

DESCRIPTION: Subjects were instructed to make wavelength settings for various hues by an absolute method in the presence of surround-field colors or darkness. Surround- and test-field colors were equated in luminance. The subject's compensatory shift in setting for the maintenance of a test-color is taken to be the difference between his wavelength setting for the test-color in the presence of the surround-field color and the wavelength setting for the test-color with a dark surround. In general, the compensatory shift in wavelength setting is always in the direction of the background wavelength. A discussion regarding the nature of the shift setting is given.

STUDY: Baker, "Initial Stages of Dark and Light Adaptation" (0018)

DESCRIPTION: Recent changes in theory of visual adaptation and analysis of published experimental data show importance of transient changes at beginning of dark adaptation and light adaptation.

STUDY: Balaraman, "Color Vision Research and the Trichromatic Theory: A Historical Review" (0020)

DESCRIPTION: A historical review of color vision research and the trichromatic theory, color mixture, luminosity, wavelength discrimination, saturation discrimination, anomalous trichromats, classification of color vision types, color-blind vision.

STUDY: Bartleson, "Color in Memory in Relation to Photographic Reproduction" (0024)

DESCRIPTION: A recent determination of the mean memory-colors that are associated with certain familiar objects which are frequently photographed has indicated that color shifts occur in all three dimensions of hue, saturation, and brightness. One other experiment in which memory-colors were determined also showed such color shifts. However, all experiments in which the general ability to remember colors was tested by successive color matching show that apparently only saturation and brightness are changed significantly in memory, and that remembered hues are essentially the same as those of the originals.

An experiment has been performed which verifies the results of both types of memory experiments and clearly shows that such differences do exist, depending upon the type of memory experiment involved. The two tasks involve dissimilar frames of reference for the choices of remembered colors and, therefore, lead to the choice of colors which may have different chromaticities.

STUDY: Bartleson, "Interrelations Among Screen Luminance, Camera Exposure, and Quality of Projected Color Transparencies" (0025)

DESCRIPTION: Experiments have indicated that (1) the optimum camera exposure of color-transparency materials is a function of the screen luminance at which the transparency is projected, (2) exposure latitude passes through a maximum as a function of screen luminance. The conclusion is reached that screen luminance is an important primary factor affecting reproduction quality for projected transparencies.

STUDY: Bartleson, and Bray, "On the Preferred Reproduction of Flesh, Blue-Sky, and Green-Grass Colors" (0028)

DESCRIPTION: The preferred color for reproduced complexions is found to be the same chromaticness as the mean memory-color for flesh. This color is perceptually and statistically different from that of the average for natural Caucasion flesh. However, the preferred repdocution-colors for blue sky and green grass appear to have the same hues as the average natural objects and are perceptually and statistically different from the corresponding mean memory-colors. It is concluded that memory-colors do not represent an adequate criterion for determining preferred color reproduction. Apparently, it is necessary to consider colors and their reproductions only with respect to the frames of reference in which they are perceived in order to draw any useful inferences about reproduction qualities.

STUDY: Bartley and Nelson, "Further Study of Pulse-To-Cycle Fraction And Critical Flicker Frequency, Decisive Theoretical Test" (0030)

DESCRIPTION: Experimental confirmation of hypothesis that various ranges of pulse-to-cycle fractions between 0.02 and 0.98 are not linearly related to conditions of flicker and fusion; in given repetitive cycle, short pulses produce flicker, longer pulses produce fusion; still longer ones flicker, and longest pulses fusion.

STUDY: Beck, Jacob, "Apparent Spatial Position and the Perception of Lightness" (0033)

DESCRIPTION: Two studies investigated the relation of lightness perception to the perception of spatial position. The results confirm earlier findings that lightness perception may be affected by how an O perceives the surface to be oriented with respect to the illumination. The results fail to support the hypothesis, however, that the apparent position of a surface relative to the illumination is used as a basis for computing the albedo of a surface. Rather, the general hypothesis the studies appear to support is that processes of percceptual organization come into play as a result of the cue properties of stimuli which affect whether a variation in luminance will be seen as a difference in the illumination of the surface or as a difference in the lightness of the surface. Thus, an area of reduced surface luminance seen in one position as a shadow is, in another, seen as a gray surface color, in each case consistent with the apparent position of the surface.

STUDY: Berman, Phyllis W., and Leibowitz, H.W., "Some Effects of Contour on Simultaneous Brightness Contrast" (0038)

DESCRIPTION: Simultaneous brightness contrast was measured as a function of: (a) the orientation of a test object, shaped as a figure 8, on a half light, half black surround, (b) type and width of a contour separating the figure halves on the divided background. 48 adult Ss matched the brightness of the figure half on the dark background with that on the light surround. Subjective contrast was significantly greater: (a) when the figure 8 was presented with its rings on backgrounds of different brightness than when each ring lay on both backgrounds, (b) when figure halves were moved apart, each into its own surround, rather than when a dividing line separated the halves, (c) as width of the contour between halves was increased. The results are discussed in terms of the contribution of the border to subjective contrast obtained with complex stimulus configuration.

STUDY: Biernson, "Spectral Scanning as Mechanism of Color Vision" (0039)

DESCRIPTION: Postulate that eye employs scanning discrimination to perceive color; wavelength-dependent effect within cone causes different wavelengths to produce different spatial distributions of energy in photodetector region; electrical scan across this region produces modulated waveform defining color information; dc value gives white information; first harmonic gives blue-yellow information; second gives green-red; phase determines difference between blue and yellow and green and red; waveform is demodulated in retina to generate separate dc voltages producing white-black, blue-yellow, and green-red sensations.

STUDY: Biernson and Snyder, "A Theoretical Model for Color Vision" (0040)

DESCRIPTION: This report covers the development of a model of color vision based on feedback control principles, which provides an explanation for the wide dynamic range, high accuracy of spectral discrimination, and invariance to changing illumination that we experience in color vision. The model is consistent with physiological and psychological evidence. Analysis is presented of waveguide modes in the retinal receptors which are assumed to be the means of spectral discrimination.

STUDY: Bittini, "Fluctuations of Physiological Nature, as Revealed by Differential Threshold Determinations, at Various Luminances of the Adapting Field" (0046)

DESCRIPTION: Detection probability curves, as functions of log luminance of the background were obtained for a green light stimulus (12 minutes of arc, in angular aperture, located at 7 degrees nasal) superimposed upon a green field. In some experiments the contrast of the patch relatively to its background was kept constant, for all the curves obtained, while each curve corresponds to a different exposure time; in other experiments the exposure time was fixed, while the contrast was varied from curve to curve. The comparison between the forms of the curves of a same family or between those of two different families was made. The main result is that a range of the luminance of the adapting field exists where a source of fluctuations affects the threshold data, which does not occur beyond that range. Such a range is tested to coincide with the mesopic range. These fluctuations are supposed to be of physiological nature and due to the particular level of the luminance of the adapting field, involving the transition from rod to cone dominance.

STUDY: Bixel, "The Visibility of Non-Uniform Target-Background Complexes: II Further Experiments" (0049)

DESCRIPTION: Further studies have been made of targets of uniform luminance presented against background of non-uniform luminance. Experiments were conducted in which the overall contrast of the target-background complex was systematically varied until the target was at the visibility threshold.

STUDY: Blackwell, "Optics and Vision" (0054)

DESCRIPTION: This report describes the progress of the Optics and Vision Program of Project MICHIGAN for the period 1 August 1956 to 31 January 1957. It describes the study, development, and tests of illumination, optical, electro-optical, and physiological aids to visual surveillance. It also describes the study, development, and tests of improved visual and photographic surveillance procedures, and improved battle-area illumination techniques. Finally, it describes studies leading to the construction of visibility-forecasting charts. These studies involve the three basic aspects of visual surveillance: target and background characteristics; optical properties of the atmosphere; and operating characteristics of the eye.

STUDY: Blackwell, "The Visibility of Non-Uniform Target-Background Complexes' (0058)

DESCRIPTION: Experimental studies are reported which involved measuring "detection" thresholds for targets presented against a pictorial background of complexly variably luminance.

STUDY: Blackwell and Kristofferson, "Effects of Target Size And Shape On Visual Detection - Continuous Foveal Target At Moderate Background Luminance" (0060)

DESCRIPTION: Target contrast for detection determined by the temporal forced-choice method has been measured for each of 60 continuous targets of uniform luminance at a background luminance of 9.52 foot-lamberts, an exposure duration of 0.010 second, and with foveal-target presentation. Targets varied in size from what were effectively point sources up to targets extending to the limits of the central force. Four general classes of target shape are included: circular, rectangular, multiple-legged, and regular geometrical forms.

STUDY: Bliss, "Visual Simulation and Image Interpretation" (0062)

DESCRIPTION: This report summarizes the available data on parameters affecting target recognition in dynamic image forming systems. The various alternative ways in which visual systems can be simulated and the relative merits of each approach are discussed. Seventy-one research reports which purport to relate to the effect upon operator performance of variations in the parameters of image forming systems are analyzed.

STUDY: Blunt and Schmeling, "Study of Psychophysical Factors of Vision and Pyrotechnic Light Sources" (0063)

DESCRIPTION: A detailed survey of the open and classified literature on pyrotechnics and vision has been made. A limited amount of experimentation was done to investigate the effectiveness of flickering colored light sources on target detection. The physical data on the composition of, and radiation from, green, red, blue, yellow and white flare compositions have been presented in summary tabulations. A bibliography of the reports and journal articles that were included in this is presented. The index lists the 461 entries by category; vision and visibility, pyrotechnic light sources, targets and background psychological factors. A large number of tables and graphs are presented which are useful in determining visibility and illumination parameters.

STUDY: Brown and Ranken, "Luminance, Purity and Wavelength Matches of Contrast Colors" (0077)

DESCRIPTION: Contrast colors induced in a central "white" area by surrounding inducing colors were matched in the contralateral eye. Results are presented in terms of luminance, wavelength of a spectral component, and colorimetric purity of the match as well as in C. I. E. Values. A relation between colorimetric purity of the match and saturation of the inducing color is indicated. A neutral region in C. I. E. color space is roughly defined which differs from the locus of the "white" component employed in the experiment.

STUDY: Calkin, Hunt, and Letzer, "Filtering and Monitoring Systems for Color Printing" (0094)

DESCRIPTION: By adjusting the positions of cyan, magenta, and yellow filters over the entrance to a light-integrating device, a convenient form of filtration can be provided for color printing and enlarging; the color and intensity of the light can be monitored by means of photocells filtered with red, green, and blue filters. Light is wasted if more than two of the three colors, cyan, magenta, and yellow, are used together in the filtration, and it is therefore desirable to devise systems which provide continuous adjustment of the color of the light, in any direction from the unfiltered color, by means of combinations of only two of the three colors at any one time. Several arrangements are described for both sequential and simultaneous adjustment of the two color-balance controls, together with the electronic monitoring system required for each.

STUDY: Cavonius, "Human Visual Acuity Measured with Colored Stimuli" (0097)

DESCRIPTION: Previous studies of visual acuity have dealt almost exclusively with achromatic brightness differences. The present study measures acuity under conditions in which the target and surround are equated in brightness but differ in wavelength. It has been suggested that acuity should always be less under these conditions, such monochromatic stimuli may stimulate fewer foveal color sensitive receptors than white stimuli. Light from two monochromators illuminated alternate bars of a grating target. The resulting stimuli were presented in modified Maxwellian view and appeared to the observer as a 1 degree grating of colored lines in a neutral surround. A zoom system varied the angular subtense of the lines, when the grating consisted of alternate colored and black lines acuity was fairly constant (about 1.30) from 430 NM to 670 NM. Equally good acuity could be obtained when alternate lines were matched for brightness, provided that the wavelength separation between adjacent lines was adequate. This separation is minimum in the blue and increases toward the red; it does not appear to be simply related to wavelength discrimination. When maximum acuity has been reached by wavelength separation no further improvement can be made by introducing a brightness difference. It is concluded that wavelength difference can be a sufficient condition for good visual acuity.

STUDY: Cavonius, "The Effect of Wavelength on Visual Acuity" (0098)

DESCRIPTION: Visual acuity was measured in monochromatic light at wavelengths between 440 and 660 NM. The test objects were gratings which filled a 1.5 degree circular field centered in a 30 degree neutral surround. Luminance contrast between adjacent bars was adjustable, and acuity thresholds were determined for different contrasts. It was found that acuity depends primarily on luminance contrast and only slightly on wavelength, so that the same luminance contrast yields similar acuity thresholds at all wavelengths provided that the test objects are equated in luminance. It is suggested that the dominant wavelength of a visual display system (such as a cathode ray screen) is relatively unimportant in the perception of fine detail. Instead, criteria such as grain size and available luminance are more important.

STUDY: Cavonius, Hilz and Kravitz, "Chromaticity and Luminance Effects on Visual Detection" (0100)

DESCRIPTION: Wavelength discrimination functions were measured with square-wave grating test objects in which alternate sets of bars were illuminated with two different wavelengths. When both wavelengths are made equal in brightness, the wavelength difference required to detect the grating increases monotonically with grating spatial frequency. Since this relation is approximately constant across the visible spectrum, the shape of the wavelength discrimination function tends to be preserved at high spatial frequencies, although much higher wavelength differences are needed to detect the high frequency gratings. Introducing a detectable brightness mismatch between the two wavelengths results in (1) a reduction of the wavelength difference needed to detect a hue difference between adjacent grating bars and (2) a minimum in the threshold wavelength difference versus spatial frequency function. Under these conditions, wavelength difference no longer increases monotonically with spatial frequency. The resulting functions resemble those previously reported for threshold luminance contrast versus spatial frequency. The relation of these results to form detection and to lateral inhibition is discussed.

STUDY: Clark, "Recognition Characteristics Study for Buoys" (0108)

DESCRIPTION: By determining the present day required buoy significances, both lateral and non-lateral, to be provided as distinctive daymark qualities to the mariner, the present system of buoy color and shape coding is shown to have some shortcomings. The basis of these shortcomings stems from numerous additions to the original two-color, two-shape, two-signal system. A system is presented to provide a far more distinctive twelve-signal system utilizing four shapes and six colors. A review of the present day state-of-the-art of vision science yields some expectation as to which colors and shapes may be good. Experimentation is proposed to determine an optimal set of colors and shapes for the presented system.

STUDY: Connors and Kinney, "Relative Red-Green Sensitivity as a Function of Retinal Position" (0125)

DESCRIPTION: Hue cancellation was employed to obtain sensitivity curves for red and for green by the method of constant stimuli. Data were taken at the fovea, and at points every 2 deg along the lower vertical meridian of the visual field. The results show that sensitivity to red, relative to green, is highest at the fovea, and decreases as the peripheral angle is increased. The relative sensitivity to green is highest in the near periphery, from 2 to 10 deg from the fovea. Beyond this point it falls rapidly, and is no longer measurable at positions where red responses are still obtained.

STUDY: Connors and Siegel, "Differential Color Sensitivity in the Purple Region" (0127)

DESCRIPTION: Color discrimination was measured by the method of constant stimuli at eight points along a blue to red continuum. The standard deviations of judgments of color difference were used as the measure of discrimination. In terms of ratios of luminances of the components, the sensitivity throughout most of the purple region is relatively constant. There is some decrease in sensitivity at the blue extreme and a larger decrease at the red end. The results are plotted on a CIE X, Y chromaticity diagram and compared with similar data of other authors.

STUDY: Crawford, "Colour Rendering Properties of Illuminats-Application Of Psychophysical Measurements To Their Evaluation" (0135)

DESCRIPTION: Nature and importance of color rendering from standpoint of illumination; color-shift (as compared to daylight) method of appraisal is shown to be not yet sufficiently developed for practical application; "spectral band" method, however, has been fully investigated experimentally and provides practical system of color-rendering assessment; tolerances found by laboratory experiment by full-scale tests are very nearly correct for general application.

STUDY: Devalois and Walraven, "Monocular and Binocular Aftereffects of Chromatic Adaptation" (0150)

DESCRIPTION: Supersatured greens seen after long-wavelength adaptation depend upon contrast from the continuing afterdischarge of bleached red receptors in the surround, rather than upon inactivation from bleaching of red receptors in the test spot area. When test spot and bleach field coincide spatially, supersatured greens are not seen. When the test field is presented in the other eye at a corresponding place, the green looks unsaturated. Here, however, no influence of the size of the bleaching field is found. This means that the color contrast effect does not occur binocularly. Color contrast must therefore be a retinal phenomenon.

STUDY: Diamond, "Brightness of Field as a Function of Its Area" (0151)

DESCRIPTION: Brightness of test field as function of its area studied in fovea at different luminance levels, only at threshold were there systematic differences in test luminance as function of test area; and theory based on inhibitory interaction in retina of "on" by "off" nerve fibers.

STUDY: Dimmick, "The Psychological Dimensions of Color" (0152)

DESCRIPTION: Clarification of all aspects of color requires an adequate systematization of the psychological data of color relationships, as well as their physical stimulus correlates and their physiological substrate. Such data must be based on the operational procedures of psychological methodology. Experimental results can be expressed as an equation of the form U+V+W+X=C. Quantification of the equation must be in terms of psychological units, such as just noticeable differences and equal intervals. The dimensions defined by the equation may be related to orthogonal co-ordinate systems. The multi-dimensional figure thus generated emphasizes essential interrelationships among colors.

STUDY: Fenton, "Application of the Land Color-Vision Effect to Television Systems (A Feasibility Study)" (0178)

DESCRIPTION: The findings of Edwin H. Land in his experiments on the color-vision process in man indicate that the human eye can distinguish practically all the colors of the spectrum in an image that has been constructed using only two discrete colors of light, whereas the conventional theories of color vision maintained that a minimum of three colors was necessary. A study was undertaken, therefore, to test the feasibility of displaying the land-effect on a closed-circuit television system. Land's experimental arrangements were duplicated, using photographic film, to ensure a familiarity with the techniques and type of results to be expected. The method was then adapted to the television system, and it was found that the results so obtained were equal. If not superior, to those obtained with photographs, although images produced by this two-color method lacked some of the fine distinguishability of hue and saturation available in a three-color system. It was concluded that the use of the land-effect in electronic display devices would be advantageous in situations where a true rendition of the colors of a scene is not required but where a variety of colors is helpful in increasing clarity or in presenting information that could not be rendered in black and white. It should also be of interest in cases where the picture does not have to be of standard commercial broadcast quality.

STUDY: Fiorentini and Ronchi, "Basic Research in the Field of Vision" (0181)

DESCRIPTION: The results are summarized of various investigations on some basic characteristics of vision. The subjects of the investigations are the following: (1) disappearance of a stabilized image with intermittent illumination; (2) influence of a vibrating movement on the vision of an image with fuzzy contours; (3) some methods for improving the perception of signals in extrafoveal vision; (4) is the pulsating illumination actually advantageous, in practice, with respect to steady illumination; (5) blue-green interaction at mesopic levels; (6) blue-green electroretinographic responses; and (7) the perception of size in ambients of different color and by correcting the chromatic aberration of the eye.

STUDY: Geffcken, "Christiansen Dispersion Filters for High-Intensity and Selective Monochromators" (0195)

DESCRIPTION: It is well known that there are two basically different possibilities for separating certain wavelength regions from the radiation of a light source: (1) light filters which preferentially weaken by true absorption a part of the light; and (2) so-called "monochromators" which by variously intense refraction of the individual colors (dispersion) make possible a filtering by masking out undesired wavelength regions. The first method has the advantage of greater simplicity and economy. In addition, the efficacy of the filters is practically independent of the ray path. It is not possible in most cases, however, to make up filters or filter combinations which separate a very narrow wavelength region with sufficient sharpness without greatly reducing the transmittance at the same time. The second method must be chosen for these purposes, using a monochromator which makes possible a very complete and selective separation. If it is a prism monochromator, however, it will possess all of the disadvantages of a complicated mechanical apparatus. Discussed in this paper is one type of monochromator, first described by Christiansen, which possesses these disadvantages to a far lesser extent.

STUDY: Graham, "Simple Discriminatory Functions - Review, Summary, And Discussion" (0202)

DESCRIPTION: Critical review of literature on neural-visual effects; discussion includes light and dark adaptation, brightness contrast, brightness and color discrimination in terms of fluctuation theory, and recent neural theories of visual functions.

STUDY: Hanes and Hansen, "Learning Curves for Color Identification" (0225)

DESCRIPTION: Observers can learn to identify 65 different color chips with less than 5 percent error in 40 to 55 hours of study when the chips are presented singly. With the stimulus materials used in the study (chips from the Munsell student set), two different distributions of the chips within the set produced essentially equivalent results. Presentation of more than one chip simultaneously, after prolonged study with single-chip presentation, had little effect on some observers but seemed to make the identification problem much more difficult for others.

STUDY: Ikeda and Boynton, "Effect of Test-Flash Duration Upon Spectral Sensitivity Of Eye" (0266)

DESCRIPTION: Experiments on effect of duration of test stimulus on color-vision threshold; two sensitivity curves obtained with test durations of 100 and 12.5 milliseconds; difference in shape is attributed to change in contribution of responsible sensitivity mechanisms.

STUDY: Imai, "Classification of Sets of Stimuli with Different Stimulus Characteristics and Numerical Properties" (0267)

DESCRIPTION: The purpose of the experiment was to determine the effects of stimulus characteristics and numerical properties of sets of stimuli on classification. Sets contained 12 stimuli which were all identical, had different categories defined by color, or had different categories defined by attributes of color and size. Number of categories and numerical distribution of stimuli in categories were varied. For each set is made a free classification and several restricted classifications in which the number of classes was specified. The results show: sets of identical stimuli are classified into equal sized groups. Categorically defined stimuli are classified by category insofar as possible, but the tendency to numerical balance affects classifications with unbalanced numerical distributions or when the task restriction is incompatible with category classification. Stimuli defined by attributes are classified so as to maintain the attribute structure, although both category classification and numerical balance tendencies are evident with unbalanced numerical distributions and incompatible classification restrictions.

STUDY: Anonymous, "Influence of Color Contrast on Visual Acuity" (0268)

DESCRIPTION: The effect of chromatic contrast on visual acuity and visibility is investigated. Various brightnesses and qualities of light in the visual field of the observer have been employed, primarily for the study of their effect on the relative contribution of chromatic contrast to visual acuity and to visibility as compared to the contribution of luminous contrast. The variation of visibility as a function of chromatic contrast and adaptation level is studied.

STUDY: Hanson and Anderson, "Studies on Dark Adaptation--7. Effect Of Pre-exposure Color On Foveal Dark Adaptation" (0277)

DESCRIPTION: Effects on foveal sensitivity of white, red, green, and blue pre-exposure were measured with white, red, green, and blue test patches; effects of pre-exposure color were slight.

STUDY: Kaswan, Jaques, and Young, Stephen, "Effect of Luminance, Exposure Duration, and Task Complexity on Reaction Time" (0296)

DESCRIPTION: Reaction time to a pattern-discrimination task was found to be about equally affected by variation in exposure duration (4-512 msec.) and luminance (09.-11.84 mL.). In a supplementary study of figure-ground detection, it was found that luminance affected RT to a greater extent than exposure duration. Further, it was found that luminance and exposure duration determined different RT functions in the two experiments. In the discrimination task there was a gradual shift in the relation of luminance and exposure duration to RT, from inverse at bright and long exposures, to direct at dim and brief exposures. In the detection task, RT was always inversely related to changes in luminance and exposure duration, to the extent to which RT was affected by these variables.

STUDY: Kinney, "Effect of Exposure Time on Induced Color" (0308)

DESCRIPTION: The colors induced into neutral fields of either illuminant A or C by four surround colors (red, green, yellow, or blue) were determined for various exposure durations, ranging from 50 to 400 MSec. The induced color was compared, using a binocular septum technique, with a field of colored light that could be varied in hue, saturation, and brightness. The effects of exposure time differed for the four inducing colors; red and blue have the most different effects. As the exposure time was lengthened, increasing saturations of green were induced by red while decreasing saturations of yellow were induced by blue.

STUDY: Krauskopf, "Experiments in Human Color Vision" (0318)

DESCRIPTION: Flicker photometry produces highly reliable data on the spectral sensitivity of the human photopic system. Experiments are being conducted to determine the spectral sensitivity of the turtle by analogous procedures. Progress to date includes (1) the construction of suitable apparatus, (2) the development of adequate behavioral techniques, (3) the demonstration that white lights may be photometered by these techniques, (4) the collection of preliminary data with spectral lights. Sufficient data have been obtained to suggest that sensitivity can be measured within a few tenths of a log unit.

STUDY: Krauskopf, "Spectral Sensitivity of Small Retinal Areas" (0319)

DESCRIPTION: The measurement of the image forming properties of the human visual system by means of a photoelectric ophthalmoscope and retinal light distributions for bright bar targets 1.6 ft wide for pupil diameter ranging from 3-8 MM. are presented. Spatial frequency response functions for these pupil diameters are also given. These functions, which are independent of the target used to measure them, describe the image formation properties of the optics. The color appearance of small briefly presented monochromatic stimuli vary in color from flash to flash. The color mixer uses monochromatic stimuli obtained by selecting portions of a spectrum produced by passing white light through a replica grating. A model suitable for student use has been constructed.

STUDY: Kristofferson and O'Connell, "The Detectability of Targets Containing Interval Luminance Gradients" (0320)

DESCRIPTION: Detection thresholds were measured for 13 non-uniform targets consisting of circular area approximately 60 minutes in diameter, on the center of which a circular luminance increment approximately 4 minutes in diameter was super-imposed. The ratio of center to annular luminance ranged between 1.0 and infinity. Predictions of the luminance of the center area required for the entire target to be at detection threshold were made from the values of threshold luminance of the center and annulus presented singly, on the basis of several varients of the element-contribution hypothesis.

STUDY: Lakowski, "Theory and Practice of Colour Vision Testing: A Review, Part 1" (0326)

DESCRIPTION: It is the concern of this paper to examine not only the effectiveness of tests for detecting colour confusion but also their usefulness in assessing colour vision generally. In Part 1, problems of administration and age and the question of the basic elements of such tests are discussed. The existing theory of colour vision and colour defect is outlined and the principle of objective colour specification, which is believed to be valuable for understanding these tests, is introduced.

STUDY: Lennox-Buchthal, "Some findings on Central Nervous System Organization with Respect to Color" (0331)

DESCRIPTION: Evidence is reviewed that reorganization of visual messages with respect to color occurs in the central nervous system. In man, catfish and cats, blue and red stimuli of equal brightness appear to undergo temporal differentiation in that red stimuli are transmitted more rapidly than blue. This has not so far been confirmed for monkey. In monkey cortex (the eye light adapted) more than half the single units responding to light did so with narrow spectral responsiveness. Different units responded to flashes through only one of four broad pass filters peaked at 450, 515, 587 or 600 millimicrons. All single units with narrow spectral responsiveness to 560 millimicrons responded as well to one or two adjacent filters. The response of the same cells to optic nerve stimulation suggested that they lay on a one to one pathway from optic nerve to cortex. The different experimental conditions from those used in studies of monkey geniculate do not appear sufficient to explain the difference in results. It seems likely that the information available to single cortical cells is different from that at geniculate and that it is simpler.

STUDY: Lipkin and Sacks, "Monocular Flicker Discrimination As Function Of Luminance And Area Of Contralateral Steady Light" (0336).

DESCRIPTION: Experimental study of effects of steady light in one eye on flicker-fusion threshold of intermittent flashes of light in other eye; inhibitory effect is shown to depend in part on relative luminances; relation between field size and decrease in critical rate of flickering field stereoscopically superimposed on contralateral steady image.

STUDY: Lit, "Depth-Discrimination Thresholds as a Function Of Binocular Differences Of Retinal Illuminance At Scotopic and Photopic Levels" (0337)

DESCRIPTION: The precision of depth discrimination has been measured in a two-rod test apparatus involving real-depth cues. The effects of two variables have been studied: (a) the level of equal retinal illuminance presented to the two eyes; and (b) the difference in the level of the retinal illuminance presented to the two eyes. It has been found that depth discrimination in this test varies as a function of the level of equal retinal illuminance presented to the two eyes in much the same way that acuity or intensity discrimination vary with luminance. Stereoscopic threshold angles vary more than 19:1 over some five log units of variation in illuminance. Unequal retinal illuminance presented to the two eyes at any given illuminance level has a comparatively small deleterious effect upon the precision of depth discrimination.

STUDY: Luria, "Color-Name as a Function of Stimulus-Intensity and Duration" (0347)

DESCRIPTION: The study is concerned with the question of whether or not wavelengths of light chosen for optimum color-coding for panel or signal lights at one light level or flash duration can be used at other light levels and durations. The results show that there is considerable stability of color-naming over a wide range of conditions. Nevertheless, certain marked changes occur, more as a result of changes in light level than flash duration. As the light dims and the flash duration gets shorter, the observers seem to make some of the errors that color blind persons do. They begin to confuse yellow with red, and green with blue; the violets seem much redder to them. Therefore, when dim or short signal flashes must be used, operators should not be called upon to make distinctions between red and yellow, or between green and blue. The best colors for use through a wide range of conditions are those reds, yellows, greens, and blues which do not, at reasonably bright light levels, appear to have any other colors "mixed" in with them.

STUDY: McCamy, "A Nomograph for Selecting Light Balancing Filters for Camera Exposure of Color Films" (0361)

DESCRIPTION: A nomograph has been designed for rapid selection of filters to adjust the spectral quality of the illumination to the spectral sensitivity of the film for color photography. The nomograph provides for a very large number of combinations of films and light sources in a simple form, permits the easy interpolation of new films, light sources, or filters, indicates which filters would nearly satisfy when an ideal filter is not available, indicates the general nature of abnormal combinations for special effects, and provides a convenient conversion from color temperature to reciprocal color temperature. The nomograph is based on the assumption that the color balance of color films, the chromaticity of the illumination, and the effect of filters can be characterized adequately on a scale of reciprocal color temperature and that the change of reciprocal color temperature by a given filter is a constant.

STUDY: Mackavey, Bartley, and Casella, "Disinhibition in Human Visual System" (0365)

DESCRIPTION: Experiment using binocular photometry shows how observer's exposure to second inducing target may lead to decrease in level of simultaneous brightness contrast; relation to Hartline's inhibition of primitive eye; and inadequacy of stray-illumination hypothesis for brightness contrast.

STUDY: Marimont, "Model for Visual Response to Contrast" (0367)

DESCRIPTION: Simple steady-state model proposed to explain apparent increase in contrast of scene when illuminance is increased; both reference level and gain of system depend on average illumination.

STUDY: Matteson and Luria, "Color-Mixture Functions with a White Desaturant" (0373)

DESCRIPTION: Color-mixture functions were obtained (A) with the traditional method of using one of the three primaries to desaturate the test wavelength, and (B) by desaturating with a broadband white light. Three normal trichromats made monocular, foveal color matches to wavenumbers from 2300 to 1500/MM in 50/MM increments using primaries of 2177/MM (459.3 MU), 1900 (526.3), and 1550 (645.2), with a 2 degree field at a luminance of about 1.0 ML. The most prominent differences were that the amounts of all three primaries needed to match test stimuli below the blue primary (2200-2300/MM) were less with the white desaturant, as was the negative-red lobe between the blue and green primaries. The dominant wavelengths of the test stimuli at the match points were compared for the two conditions, and comparisons were made between the changes under these conditions and the differences in the CIE 2 deg. and 10 deg. CMFS, foveal and parafoveal CMFS, and changes resulting from reduction in luminance.

STUDY: Myers, "Accommodation Effects in Multi-Color Displays" (0386)

DESCRIPTION: The study sought to investigate accommodation effects with simultaneous exposure of two colors in a single display. Combinations of red and blue color were used for the Landolt C-Ring stimuli and the portion of the screen surrounding the stimuli. Definite visual effects were reflected by significant differences in performance (i.e., number of correct responses to C-Ring aperture position). Decrement in performance appears to be a function of the particular color employed rather than the result of a re-accommodation problem between two colors. Myopia with exposure to the blue colored stimuli resulted in fewer number of correct responses for these conditions. A significant interaction was noted. Size of the C-Ring aperture was shown to be of significant consequence in affecting performance differences between color combinations. Larger aperture size tended to compensate for the induced myopia with the blue stimuli. This was evidenced by the fact that performance with the blue stimuli improved at the larger sizes and approached that with the red stimuli at the smaller sizes. The significance of these findings is discussed in terms of practical applications. Note is also made regarding the relevancy of the study as a guide of factors to be considered in future studies involving visual effects with the use of multi-color displays.

STUDY: Novakova, "Certain Physical Problems of Physiological Optics" (0395)

DESCRIPTION: The author discusses several physical problems involved in physiological optics, specifically the function of transmission of contrast by the eye, the visual capacity of the eye, the problem of color vision, and the visual capacity of the eye in twilight. The article is based on the German literature, particularly the works of O. Bryngdahl (Die Naturwissenschaften, 1964, 51, 177), and describes the current level of research in physiological optics. These problems are important in the manufacture of optical instruments. The author concentrates primarily on the problem of the function of the transmission of contrast in the visual system and methods of measurements. The methods of measuring the modulation function of transmission and the threshold modulations on the retina of the eye are described, as is the method used by A. Arnulf (Abbilden Und Sehen, Munchen, 1962, V. Internationaler Kongress Fur Optik, 11-15) and those used by Bryngdahl. The contrast test is explained by means of diagrams. The author points out that the article does not cover all the problems involved. The original article has four figures.

STUDY: Ogle, "Blurring of Retinal Image and Contrast Thresholds In Fovea" (0396)

DESCRIPTION: Experimental study of extent to which retinal image of test object is blurred before it cannot be seen against its background; data for contrast thresholds for point-light source seen against white background of 12 millilambert luminance; derivation of equation to fit data for out-of-focus images.

STUDY: Ogle, "Foveal Contrast Thresholds with Blurring of Retinal Image And Increasing Size Of Test Stimulus" (0397)

DESCRIPTION: Experiment showing influence of blurring of retinal image on luminous-contrast thresholds for foveal perception of circular-stimulus test objects of different sizes seen against background luminance of 12 millilambert; contrast threshold rises with increase of blurring theoretical equation for effects of blurring.

STUDY: Olesen, "Color Investigation, White Lighting" (0398)

DESCRIPTION: The addition of filters to small incandescent lamps for integral lighting does not decisively reduce shift of color coding and is a questionable improvement when compared to the disadvantages associated with filter incorporation.

STUDY: Onley, "Light Adaptation and Brightness of Brief Foveal Stimuli" (0399)

DESCRIPTION: Experimental study of changes in brightness scale as function of light adaptation; determination of relations among scales derived independently for differing adaptive states; procedure for determining generalizable set to brightness scales.

STUDY: Oyama, Tadasu, and Hsia, Yun, "Compensatory Hue Shift in Simultaneous Color Contrast as a Function of Separation between Inducing and Test Fields" (0403)

DESCRIPTION: Each of 2 color-normal Ss was instructed to adjust a monochromator illuminating a foveally fixated 4 degree circular test field to give a "best" blue, green, and yellow in ascending and descending determinations; a red setting was obtained only in an ascending sequence, i.e., in order of increasing wavelength. Settings were made in the presence and absence of a 30 degree circular surround (inducing field) of each of the same four colors. A compensatory shift in wavelength setting for the contrast-induced tinge occurred almost always in the direction of the inducing color; this trend was observed under varying conditions of separation between the inducing and test fields, ranging from 0 degrees to 8 degrees. Over this entire range of separation, another trend was observed that the amount of shift decreased as the separation increased.

STUDY: Powers and Miller, "Pitfalls of Color Densitometry" (0415)

DESCRIPTION: This paper points out a number of false notions about the design, operation, maintenance, and control of a color densitometer, and the utilization of its measurements. The basic optical principles of a typical color densitometer are described. The relationships between these color density measurements and any other set of reliable color density measurements is discussed. The common pitfalls are discussed in detail. These are classified into operational, control, and maintenance errors.

STUDY: Reilly and Teichner, "Effects of Shape and Degree Of Structure Of Visual Field On Target Detection And Location" (0420)

DESCRIPTION: Effects of degree of structuring and form of visual field on target detection and target location, studies for three different search times; targets were more accurately reported under intermediate levels of structure, with square rather than round fields, and with longer search times.

STUDY: Richards and Luria, "Color-Mixture Functions at Low Luminance Levels" (0424)

DESCRIPTION: Color-mixture and luminosity functions for a 2-degree test field with a 10-degree surround were obtained from three observers at three luminance levels in the mesopic region using both foveal and 3-degrees 20' parafoveal fixations. For the fovea, the luminosity functions remained constant as the luminance was decreased, but there were large changes in the color-mixture functions. In spite of these changes, however, photometric additivity expressed in the form of Abney's Law appears to be approximately valid at all luminance levels. In the parafovea, both the color-mixture and luminosity functions changed with luminance, and the changes in the color-mixture functions were almost identical with those occurring in the fovea. All the results are shown to be in accord with the hypothesis that, as luminance is reduced, there is an increasing concentration of rhodopsin which is localized primarily in one type of receptor whose response function is also partially responsible for the photopic color sensitivity at short wavelengths. It appears therefore, that one type of receptor is active at all luminance levels and undergoes a change from a photopic to a scotopic function in the mesopic region as a result of a conversion from a photopic "blue" pigment to rhodopsin.

STUDY: Rizy, "Color Specification for Additive Color Group Displays" (0427)

DESCRIPTION: Nine pairs of dichroic filters were used in a xenonsource additive color projector to determine their effects upon observer performance in a search-and-discrimination task with seven color codes. The objective was to define performance parameters preliminary to setting filter specifications. Results indicated that a blue filter, reflecting wavelengths well into the green region, facilitated performance in the majority of color codes. A red filter, close to the infrared in reflectance, reduced performance in most codes. The most efficient color code, regardless of filter, was red. Green, blue and cyan were least efficient. Recommendations were made suggesting a blue filter of approximately 516 millimicrons cutoff and a red filter with a cutoff between 581 and 595 millimicrons, for optimum observer performance in the context of a seven color code. Performance criteria were compared and an alternate filter option was described. Further examination of the areas around the most adequate cutoff points and alternate filter arrangements were proposed as the next step toward setting firm specifications.

STUDY: Roehler, "Some Relationships Between the Average Energy of the Quanta in a Visual Stimulus and the Color Response" (0430)

DESCRIPTION: It is shown that the ratio of the number of light quanta absorbed by the retina to the absorbed light energy is an important parameter in the elaboration of colour information by the visual sense. For this ratio, thus the number of quanta absorbed per unit of absorbed energy, the term "specific quantum number" (SQN) is introduced. By measuring the SQN for various spectral regions it can be shown, on the basis of Grassmann's Laws, that all light stimuli which occupy the same locus in colour space, independently of their colour composition (metamers), also have equal SQN's. The colour loci, for equal SQN in the colour triangle, lie along lines which coincide exactly with the tritanopic colour confusion lines. One component of the colour discriminating function of the visual sense derives from the ability to gauge differences in the specific quantum number. With the help of a simple model, the dependency of opponent-colour experience upon receptor excitation can be qualitatively described.

STUDY: Rogers, Detambel and Bien, "Shared Spectrum Display Enhancement" (0431)

DESCRIPTION: An illumination system is described which utilizes for display, portions of the visible spectrum which have been excluded from the ambient light. The resulting tinted illumination is matched in brightness to a standard white light by experimental subjects, and stimulus threshold measurements made as a function of display intensity for various stimulus and ambient spectra. Certain combinations are found to lower the threshold of detection, indicating enhanced stimulus brightness, whereas others are found to raise the threshold. A close relationship is found between experimental data and results predicted on the basis of previously published increment-threshold measurements.

STUDY: Ronchi, Bittini, and Adachi, "Subjective Sharpness Of Contour As Function Of Luminance And Contrast" (0433)

DESCRIPTION: Some quantitative aspects of blur-to-sharp transition investigated using field containing two uniform fields of different luminance; transition is abrupt in some cases, graded in other cases; experimental evidence shows that at threshold of sharpness, limiting slope of graded zone is higher the greater the difference between luminance of two uniform fields.

STUDY: Ronchi and Tittarelli, "Detection of Circular Light Signals in Relation to Shape and Color Identification" (0434)

DESCRIPTION: A small and brief circular spot was flashed at 7 degrees nasal to the fovea. Absolute threshold, color identification threshold, and threshold of perception of the circle were determined. The number of wrong responses given by the subject when attempting to identify the color of the signal and the degeneration of apparent shape under degraded viewing conditions is presented. The radiation emitted by an incandescent lamp, 2800°K, was filtered by filters. The threshold of circular shape identification was found to be slightly higher than that of color identification. The findings were compared with the data reported in the current literature. Practical recommendations for the use of the data are given.

STUDY: Schroyer, "The Apparent Color of Point Sources" (0446)

DESCRIPTION: Of the two diagrams presently employed in the pyrotechnics lab for colored flare evaluation purposes the more appropriate one was constructed thirty years ago in England for the purpose of specifying colored glasses for railroad signal lights. It rates a colored point source of light for signalling purposes according to its location in the recognition diagram. The location being determined by the light's chromaticity coordinates. According to that recognition diagram, many operational green flares would be seen as white, contrary to the field experience of pyrotechnics laboratory observers. A flare simulator developed in this laboratory was used to produce flare colors and other known test colors at adjustable illumination levels. The simulator consists of a combination of standard source, variable aperture plate, color glass filter combinations, and neutral density filters. Twenty observers were employed to collect data to construct a new recognition diagram emphasizing the requirements for the recognition of green color at a probability level above 90% under the conditions of low illumination level and small subtense (angle subtended at the observer's eye).

STUDY: Sen and Mowbray, "Influence of Size and Brightness Parameters On Differential Sensitivity Of Central Retina To Photic Flicker" (0450)

DESCRIPTION: Measurement of differential thresholds for rate of photic intermittance for 10 rates between 2.5 and 32.5 interruptions per second, 5 luminance levels, and 5 visual angles in central retina; peak thresholds were 15.0 interruptions per second for low luminance and 22.5 for high luminance; stimulus-size effects were small.

STUDY: Sheppard, "A Critical Review of the Experimental Foundation of Human Color Perception" (0451)

DESCRIPTION: A presentation of the minimum material needed for a comprehensive study of normal human color perception. The artificial nature of colorimetry is discussed, with emphasis on the distinction between experimental facts established in the matching experiments and the formalism of colorimetry derived in part from these facts. A representative portion of the available experimental data on individual foveal spectral sensitivity is collected and analyzed. Data on the initial photoreception process and the anatomy, histology, morphology, ontogeny, and electrophysiology of the retinal neurons are analyzed, noting the multiplicity of results indicating a fundamental difference between receptor mechanisms in the rods and cones. A review of data on central neural mechanisms indicates a complex, dynamic role for the lateral geniculate nuclei in human color vision. Considerations of diverse psychophysiological phenomena are summarized. The general conclusion of the study is that the available experimental evidence does not clearly dictate the fundamental physiological processes mediating human color vision. Principal conclusions are discussed in relation to the three distinct fields of colorimetry, visual biophysics, and visual psychophysics, four suggestions are given for psychophysical modeling.

STUDY: Sheppard, "Temporal Factors in Subjective Color" (0452)

DESCRIPTION: The memorandum provides a synopsis of what is known about subjective-color sensations produced by temporal factors in the retinal luminous stimulus. Four principal psychophysical phenomena or effects involved in subjective color are identified and discussed. The Prevost-Fechner-Benham effect refers essentially to the evocation of a color sensation that differs when the visual stimuli are intermittently rather than continuously. The Broca-Sulzer-Pieron effect concerns the variations of color sensations with time. The Brucke-Bartley effect refers to the enhanced brightness of visual stimuli when presented intermittently rather than continuously. The disappearance of visual sensation when the retinal image is artificially stabilized so that it falls continuously on the same receptors is termed the Ditchburn-Ratliff effect. The use of the Prevost-Fechner-Benham effect to obtain colored images on black-and-white television receivers is discussed to illustrate one technological application of subjective color. An unexpected appearance of the Prevost-Fechner-Benham effect in a visual experiment is discussed to emphasize the dangers involved in a failure to consider subjective-color effects during the design of man-machine systems utilizing human visual characteristics.

STUDY: Seigel, "Discrimination of Color, III. Effect of Spectral Bandwidth" (0460)

DESCRIPTION: An experimental investigation of the effect of varying bandwidth on color discrimination was undertaken. No evidence was found for any differences in sensitivity to color differences among the 5-, 10-, 20-, and 80 millimicron bandwidths studied. It was concluded that for psychological research in vision less emphasis should be placed on monochromatic radiation of the stimulus and more on obtaining greater luminance levels.

STUDY: Siegel, "Discrimination of Color: IV. Sensitivity as a Function of Spectral Wavelength, 410 through 500 Mu" (0461)

DESCRIPTION: Color discrimination functions for three observers were plotted in the short-wavelength region of the spectrum. The method of constant stimulus differences was used. Comparisons between the present results and earlier results are reported. Sensitivity proved more variable in this region than elsewhere in the spectrum.

STUDY: Siegel, "The Discrimination of Color: I. Comparison of Three Psychophysical Methods and II. Sensitivity as a Function of Spectral Wavelength, 510 to 630 Milimicrons" (0462)

DESCRIPTION: The comparative inadequacy of the method of limits, the method of constant stimulus differences, and the method of adjustment were studied by using three criteria suggested by Blackwell. It was concluded that the method of constant stimulus differences was the most adequate and the method of adjustment the least adequate for determining sensitivity to color differences. Study II reports the experimental determination of just noticeable differences in color as dependent upon wavelength at differences in color as dependent upon wavelength at 10-milimicrons steps from 510 to 630 milimicrons. The method of constant-stimulus differences was used to produce limens in terms of measures both of central tendency and of dispersion of judgments. The data have been analyzed to determine the different functional relationships between various colors and wavelengths. Peak sensitivity was found in the yellow region of the spectrum.

STUDY: Silver, Landis and Jones, "Development of Criteria for Evaluation of Large-Screen Displays" (0464)

DESCRIPTION: The research was directed toward developing a metric of display quality for evaluation of large-screen displays and toward developing a criterion to validate the metric. Two approaches were used. In the first, multidimensional analysis (MDA) was used to test the hypothesis that, other things being equal, display quality was related to the number of perceived dimensions of information content; the results of the test failed to support the hypothesis, In the second approach, a game situation was used in which the monetary value of the subjects' decisions could be calculated. Several display parameters, including format, information density, and color, were manipulated. The monetary value of the decisions, or "decision value" was found to be a reliable and valid measure of display quality. It is recommended that MDA and decision quality be combined to formulate a predicitive model of display quality. Research to this end should be conducted using a wide range of stimuli and subject proficiency levels.

STUDY: Smith, Sidney L., "Color Coding and Visual Search" (0474)

DESCRIPTION: Twelve Ss each viewed a series of 300 displays, which varied in display density, in number of colors used, in the particular color of the target, with either a white or black background, under conditions where S either knew the color of the target in advance, or did not.

Neither the particular color of the target nor the display background had any significant effect on search time. Search time increased regularly with increasing display density. For multicolored displays, when the color of the target was known in advance, search times were considerably shorter than when the target color was unknown. When the color of the target was unknown, search times were not significantly different than those for single-colored displays.

STUDY: Smith, "Display Color Coding for a Visual Search Task" (0475)

DESCRIPTION: An analysis is presented which describes the results of an experimental study of the effects of display color coding on visual search time. Twelve subjects each viewed a series of 300 displays, which varied in display density, in number of colors used, in the particular color of the target, with either a white or black background, under conditions where the subject either knew the color of the target in advance, or did not. Neither the particular color of the target nor the display background had any significant effect on search time. Search time increased regularly with increasing display density. For multicolored displays, when color of the target was known in advance, search times were considerably shorter than when the target color was unknown. When the color of the target was unknown, search times were not significantly different than those for single-colored displays.

STUDY; Taylor, "Foveal Vision-Dependence of Threshold Energy On Visual Angle Of Circular Target" (0501)

DESCRIPTION: Theoretical study of role of target size of subtended visual angle in determining threshold contrast at constant luminance; circular nonmoving targets, detected at threshold, appear as point source for small target diameters and pass smoothly into subjective annular shape for larger diameters.

STUDY: Thomas, "Relation of Brightness Contrast to Inducing Stimulus Output" (0504)

DESCRIPTION: Measurement of brightness-contrast effects elicited by foveally viewed, briefly exposed point stimuli; relation to psychophysical measure of inducing stimulus output; effects of test-stimulus illuminance; contrast effects summated in nonlinear fashion.

STUDY: Umberger, "Color Reproduction Theory for Subractive Color Films" (0509)

DESCRIPTION: When it is recognized that the blue, green, and red primaries controlled by the yellow, magenta, and cyan dyes, respectively, of color films are unstable and vary from point to point in a color reproduction, it becomes of interest to determine the average primaries over the area of the scene. By area-integration it has been found t that the best average primaries are represented by the ε or dye-extinction curves treated as energy distributions. This result is restricted, however, to systems in which Beer's law applies and in which the scene area-integrates to a neutral gray. Application of the above area-integration methods permits (a) determination of the hypothetical block dyes equivalent to the real dyes, (b) application of existing additive color theory to subtractive color films, and (c) derivation of a relativistic theory of color which appears to account for many of the observed environmental effects on visual perception.

STUDY: Weissman and Kinney, "Relative Yellow-Blue Sensitivity as a Function of Retinal Position and Luminance Level" (0523)

DESCRIPTION: Relative sensitivity for yellow and blue was determined by hue cancellation, using the method of constant stimuli. Measurements were made with a 1-degree stimulus at the fovea, 2 degrees above the fovea, and every 4 degrees along the upper vertical meridian out to 18 degrees at three luminance levels (0.5, 0.1, and 0.01 Ft-L). Relative yellow-blue sensitivity remained much the same from fovea to periphery for the two highest light levels. At the lowest luminance level there was a slight increase in relative blue sensitivity in the near periphery and a progressive decrease in relative yellow sensitivity as the peripheral angle increased. The variability of color discrimination increased greatly as luminance decreased and the peripheral angle increased.

STUDY: Wolf and Zigler, "Some Relationships of Glare and Target Perception" (0535)

DESCRIPTION: This study was carried out to describe quantitatively the relationship between the luminance of a glare source and threshold luminance of a test target when both are varied in angular subtense and distance from each other. The threshold visibility of a test target in the vicinity of a glare source was determined for various sizes and luminances of the glare source, various angular separations between glare source and target, and various exposure times and retinal locations. Thresholds for target perception become lower as glare luminance is decreased, area of glare source is decreased, distance between glare source and test target is increased, and size of test target is increased.

STUDY: Woodbury, "Two Psychophysical Methods for Evaluating the Quality of Projected Color Slides" (0536)

DESCRIPTION: The exposure indexes of reversal color materials for use in miniature cameras are normally based on the results of judgments made of the quality of projected slides which differ only in the exposure given. These slides are presented to the judges in either of two ways -- in the order of increasing or decreasing exposure or in a random order with respect to exposure. Although the results with both methods are identical, the advantage appears to be with the ordered-sequence presentation because of the simpler programming and data-handling processes.

STUDY: Bartleson, "Factors Affecting the Quality of Projected Image: Level of Veiling Illuminance" (0554)

DESCRIPTION: The effect of screen luminance on the quality of projected color transparencies is reviewed briefly and new experimental work on the effect of non-image veiling illuminance is reported. The addition of veiling illuminance to a projected screen image degrades the quality of the image. The amount of degradation depends upon (a) the camera exposure used in producing the transparency, (b) the open-gate screen luminance used for projection, and (c) the amount of veiling luminance relative to the screen luminance. The results illustrate quantitative interrelations among camera exposure, screen luminance, and veiling luminance in determining the quality of projected images.

STUDY: Bartleson, "Influence of Observer Adaptation on the Acceptance of Color Prints" (0555)

DESCRIPTION: A qualitative investigation of the influence of chromatic adaptation on the acceptance of small color prints is described. Under controlled conditions, the acceptance of prints varies with chromatic adaptation. In normal adaptation and viewing situations the prints apparently contribute more to the observer's adaptation. In either case, prints that are optimum under neutral adaptation conditions remain optimum or, at least, highly acceptable under varying conditions of viewing. Off-balance prints tend to cause the largest variation in acceptance when the conditions of observer adaptation vary.

STUDY: Bartleson, and Breneman, "Brightness Reproduction in the Photographic Process" (0556)

DESCRIPTION: Recent data on brightness perception in complex fields are applied to the problem of specifying photographic tone-reproduction objectives. Basically, the objective of both transparency and relfection-print processes is the achievement of 1:1 reproduction of brightness relative to a reference white. In the case of transparencies projected in a darkened room, this reference white may be reproduced at a density level high enough to permit the reproduction of specular highlights at lower densities. Since there are no other reference whites under such viewing conditions, the observer accepts the "image white" as his reference. However, reflection prints typically are viewed with illuminated surrounds which provide the observer with tangible lightness references. Thus, the lightnesses in the print image must be consistent with these environmental references as well as providing relative-brightness reproduction. The luminances of the image highlights should, therefore, be greater than those of the white references in both print and surround. Since this does not normally obtain, a compromise is effected in which the relative brightnesses of these highlights are compressed by utilizing the "toe" of the tone-reproduction function. In viewing conditions where the print image is illuminated to a higher level than the surround, less of the toe region is utilized, with the result that relative brightnesses are reproduced over nearly all of the scale as is the case with transparencies. Similarly, optimum television images are those which closely approach 1:1 reproduction of relative brightnesses. The theoretical predictions derived here compare favorably with experimental data on optimum tone reproduction.

STUDY: Bartleson and Woodbury, "Psychophysical Methods for Evaluating the Quality of Color Transparencies: I. Comparison of Categorical and Comparative-Judgment Data" (0557)

DESCRIPTION: Experiments have been conducted in order to devise an efficient, economical, and precise method of evaluating the quality of projected transparencies. It has been determined that categorical- and comparative-judgment methods yield comparable results in the quality regions of interest, viz., the regions of high quality.

STUDY: Breneman, "A Color Chart for Use in Evaluating Quality of Color Reproduction" (0569)

DESCRIPTION: To facilitate quantitative evaluation of the quality of color reproduction obtained with various photographic processes under given conditions of illumination, a color chart has been constructed. The twenty-four color patches include nine saturated colors, seven achromatic colors, and eight desaturated colors, among which are the familiar colors of flesh, foliage, and blue sky. The patches that represent the colors of natural objects have been matched to them as well as possible in spectral reflectance. Permanent pigments have been used so that the chart can be used repeatedly in direct sunlight without danger of fading or discoloring. The patches have uniform glossy surfaces so that unwanted surface reflections can be eliminated.

STUDY: Breneman, "The Effect of Level of Illuminance and Relative Surround Luminance on the Appearance of Black-and-White Photographs" (0570)

DESCRIPTION: Measurements have been made of changes in the appearance of a black-and-white photograph which occur with changes in the level of illuminance and relative surround luminance. The procedure requires making direct measurements of the perceived brightnesses of scene elements under a variety of viewing conditions. The results indicate that, within a range of about 10-100 ft-c, the level of illuminance has little effect on the relative brightnesses perceived in the reproduction. Only a slight shift in over-all brightness occurs. Changes in the relative luminance of the surround have a considerable effect on the apparent contrast among scene elements, however. When a dark surround is replaced by a light one, contrast is enhanced in the middlestones and highlights and reduced in the shadows. The influence of the surround luminance is greater at the edge than at the center of a picture, and it is greater in dark areas of the scene than in light areas. These changes in appearance can be qualitatively predicted by a consideration of separate adaptive processes of the visual mechanism.

STUDY: Briggs, Farrell, Kraft, and Rowntree. "Illumination and Interpreter Performance" (0571)

DESCRIPTION: This study investigated the effects of two color temperature of illumination (2360 K and 5500 K) on target detection and mensuration performance, lateral phoria, and visual acuity. The target detection task consisted of searching for specific targets found on a target key, in 9- by 9-in. aerial photographs at 1:20,000 scale. The experimental design consisted of two illumination sources (display and ambient) in combination with two color temperatures, resulting in four illumination conditions. Each of the twenty subjects participated in four 4-hr. test sessions, one under each illumination condition. Color temperature of illumination had no overall effect on target detection or mensuration performance, phoria, or visual acuity. Phoria measured at the beginning of each daily session was, on the average, 0.951 diopters more ex$_o$ (greater divergence) for the high color temperature than the low. Fixed spacing between acuity targets resulted in better acuity than ratio spacing. Significant changes occurred over hours for all measures except mensuration error. A significant correlation occurred between acuity and target detection performance for each subject.

STUDY: Brown, "Problems in the Specification of Luminous Efficiency" (0572)

DESCRIPTION: Problems of specifying luminous efficiency are considered in relation to the entire range of visual function from scotopic to photopic. The changing spectral response which accompanies changing adaptation and changing nature of the visual task is taken into account.

STUDY: Daily, "High Efficiency Rear-Projection Screens" (0575)

DESCRIPTION: Using a new type of high efficiency rear-projection screen, a 40-foot wide projected color picture can now be photographed on standard Eastman Color Negative Film, Type 5248, with the camera operating at f/4 at 24 frames/sec. Data are presented on the transmission and reflectance characteristics of this new screen, together with data on several other experimental screens which have wide-angle and high-transmission characteristics.

STUDY: Grether and Reynolds, "Effects of Color of Instrument Lighting on Absolute and Acuity Thresholds with Exposure to a Simulated Instrument Panel" (0576)

DESCRIPTION: Three colors of aircraft instrument illumination (Aviation red, unfiltered white, blue-filtered white) were compared to determine their effects on post-exposure, scotopic absolute and acuity thresholds; and legibility for the reading of instruments. A simulated T-38 instrument panel, illuminated by light from incandescent instrument lamps, was used for light exposure.

STUDY: MacAdam, "A New Look at Colorimetry" (0579)

DESCRIPTION: This is a report on the proceedings of the International Commission on Illumination (CIE) which met in Zurich, Switzerland, from June 13 to June 22. The status of the revision of the standard data for colorimetry is explained and discussed. The present FCC standards for color television are specified in terms of colorimetric data adopted by the CIE in 1931. Most quantitative work on color, during the past 24 years, has been based on the CIE data. The significance of the proposed revisions in relation to that work and to future work and specifications is discussed.

STUDY: MacAdam, "Perceptions of Colors in Projected and Television Pictures" (0580)

DESCRIPTION: Many color photographs are taken in daylight and projected with tungsten lamps. On the other hand, commercial motion pictures made with tungsten studio lamps are almost always projected with arcs that resemble daylight. Color-television receivers produce "white" of daylight quality or even bluer, although most of the scenes televised are tungsten-lighted. Hence the question: "How should a color in one quality of illumination be reproduced for viewing with some other quality?" An investigation undertaken to answer this question will be described, and the results will be discussed.

The simple answer suggested by Von Kries' law of coefficients appears to be only a first approximation. Closer analysis of the behavior of the eye seems to indicate that human color vision is served by at least four, and probably by five or even six, different photosensitive processes, having different spectral sensitivities and different degrees of adaptation to various qualities of illumination.

These findings do not call into question the trichromatic character of color perception, on which color photography and color television are based. Apparently the visual nervous system provides only three channels, capable of handling only three independent responses. But each of these responses appears to be stimulated by a combination of two or more photosensitive processes in the eye.

STUDY: Tyler, De Palma, and Saunders, "Determination of Absolute Values of Total and Spectral Radiant Intensities of Tungsten Lamps" (0582)

DESCRIPTION: Present techniques for measuring the absolute spectral energy of tungsten lamps are difficult in practice. The purpose of this paper is to show that these absolute spectral energy values, up to 1.2 μ, can be computed from published spectral blackbody tables and emissivity data for tungsten, provided experimental determinations are made of the color temperature and the total radiant intensity of the lamp and the transmittance of the lamp envelope. It is demonstrated that the proposed method is valid for a variety of tungsten lamps of differing filament structures.