G89.2223 – Sensation & Perception

Fall 2006

Taught by: Michael Landy, 998-7857, 6 Washington Place #961, landy@nyu.edu, Mailbox outside of room 862.

Class meets: Monday/Wednesday, 12:00-1:50PM, Room 878, 6 Washington Place, EXCEPT as specified below.

Web content: http://www.cns.nyu.edu/~msl/courses/2223

Grading: Occasional homework - 10%, Midterm - 40%, Final - 50%. Both exams will be take-home.

Tentative Course Outline

Sept 6	Organizational Meeting
Sept 11-13	Psychophysical Method (Sept. 11 class: 3:30-5PM, Room 851)
Sept 18-20	Physical and Physiological Optics
Sept 25-27	Example: Hecht, Shlaer & Pirenne (Sept. 25 class: 3:30-5PM, Room 851)
Oct 2-11	Vision: LST approach - Flicker, Spatial Frequency Channels
Oct 23-25	Vision: SDT and Ideal Observer approaches
Oct 30-Nov 1	Vision: Spatial Acuity, Detection and Discrimination, More on Channels
Nov 6-8	Vision: Motion
Nov 13-15	Vision: Stereopsis and Depth Perception
Nov 20-22	Vision: Segmentation, Texture, Search, Form
Nov 27-29	Vision: Color
Dec 4-6	Audition: Basics, Frequency/Pitch/Masking, Intensity/Loudness
Dec 11-13	Audition: Spatial Localization, Perceptual Organization, Speech Perception (Dec. 11 class: 3:30-5PM, Room 851)

General References and some recent collections:

Vision:

Barlow, H. B., Blakemore, C. & Weston-Smith, M. (Eds.) (1990). *Images and Understanding*. New York: Cambridge University Press.

Barlow. H. B. & Mollon, J. D., Eds. (1982). *The Senses*, New York: Cambridge University Press.

Blakemore, C. (1990). *Vision: Coding and Efficiency*. New York: Cambridge University Press.

Boff, K. R., Kaufman, L. & Thomas, J. P. (Eds.) (1986). *Handbook of Perception and Human Performance*. New York: Wiley.

Braddick, O. J. & Sleigh, A. C. (1983). *Physical and Biological Processing of Images*. New York: Springer-Verlag.

Bruce, V. & Green, P. R. (1990). *Visual Perception: Physiology, Psychology, Ecology*. Hillsdale, NJ: Erlbaum.

Carpenter, R. H. S. & Robson, J. G. (Eds.) (1999). *Vision Research: A Practical Guide to Laboratory Methods*. New York: Oxford University Press.

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

De Valois, K. K. (Ed.) (2000). *Seeing*. New York: Academic Press.

De Valois, R. L. & De Valois, K. K. (1988). *Spatial Vision*. New York: Oxford University Press.

Falmagne, J.-C. (1985). *Elements of Psychophysical Theory*, Oxford: Oxford University Press.

Frisby, J. P. (1980). *Seeing: Illusion, Brain and Mind*, Oxford: Oxford University Press.

Gordon, I. E. (1989). *Theories of Visual Perception*. New York: Wiley.

Gorea, A. (1991). *Representations of Vision*. New York: Cambridge University Press.

Graham, N. (1989). *Visual Pattern Analyzers*. New York: Oxford University Press.

Gulick, W. L. (1989). *Hearing: Physiological Acoustics, Neural Coding, and Psychoacoustics*. New York: Oxford University Press.

Humphreys, G. W., Ed. (1992). *Understanding Vision*. Cambridge, MA: Blackwell.

Kaufman, L. (1974). *Sight and Mind: An Introduction to Visual Perception*, New York: Oxford University Press.

Levine, M. W. & Shefner, J. M. (1991). *Fundamentals of Sensation and Perception, 2nd Ed.*, Pacific Grove, CA: Brooks/Cole.

Landy, M. S. & Movshon, J. A. (1991). *Computational Models of Visual Processing*. Cambridge, MA: MIT Press.

LeGrand, Y. (1957). *Light, Colour and Vision*. New York: John Wiley & Sons Inc.

Marr, D. (1982). *Vision*, San Francisco, CA: W. H. Freeman.

Palmer, S. E. (1999). *Vision Science*. Cambridge, Massachusetts: The MIT Press.

Spillmann, L. & Werner, J. S. (1990). *Visual Perception: The Neurophysiological Foundations*. New York: Academic Press.

Wandell, B. (1995). *Foundations of Vision*. Sunderland, Mass.: Sinauer Associates.

Watt, R. (1991). *Understanding Vision*. New York: Academic Press.

Zeki, S. (1993). *A Vision of the Brain*. Oxford: Blackwell Scientific.

Audition:

van Bergeijck, W. A. M., Pierce, J. R. & David, E. E., Jr. (1960). *Waves and the Ear*. Garden City, NY: Anchor Books.

Edelman, G. M., Gall, W. E., & Cowan, W. M., Eds. (1988). *Auditory Function: Neurobiological Bases of Hearing*. New York: Wiley.

Green, D. M. (1976). *An Introduction to Hearing*. Hillsdale, NJ: Erlbaum.

Houtsma, A. J. M., Rossing, T. D. & Wagenaars, W. M. (1987). Auditory demonstrations booklet and CD. Philips 1126-061.

Moore, B. C. J. (1989). *An Introduction to the Psychology of Hearing*, 3rd Edition. New York: Academic Press.

Pickles, J. O. (1988) *An Introduction to the Physiology of Hearing*. San Diego, CA: Academic Press.

Scharf, B. & Buus, S. (1986). Audition I. Stimulus, physiology, threshold. In Boff, K. R., Kaufman, L. & Thomas, J. P. (Eds.), *Handbook of Perception and Human Performance. Volume I. Sensory Processes and Perception* (pp. 14-1 - 14-71). New York: John Wiley and Sons.

Scharf, B. & Houtsma, A. J. M. (1986). Audition II. Loudness, pitch, aural distortion, pathology. In Boff, K. R., Kaufman, L. & Thomas, J. P. (Eds.), *Handbook of Perception and Human Performance. Volume I. Sensory Processes and Perception* (pp. 15-1 - 15-60). New York: John Wiley and Sons.

Schubert, E. D. (1980). *Hearing, its Function and Dysfunction*. New York: Springer-Verlag.

Stevens, S. S. & Davis, H. (1938). *Hearing, Its Psychology and Physiology*. New York: Wiley.

Tobias, J. V. (Ed.) (1972). *Foundations of Modern Auditory Theory*, Volumes I and II. New York: Academic Press.

Yost, W. A. (1994). *Fundamentals of Hearing*. New York: Academic Press.

Yost, W. A., Popper, A. N. & Fay, R. R., Eds. (1993). *Human Psychophysics*. New York: Springer-Verlag.

Psychophysical Method, Scaling

Required Reading

Brindley, G. S. (1970). *Physiology of the Retina and Visual Pathway*, 2nd Edition. London: Edward Arnold, pp. 132-138.

Treutwein, B. (1995). Adaptive psychophysical procedures. *Vision Research, 35*, 2503-2522.

References

Baird, J. C. & E. Noma (1978). *Fundamentals of Scaling and Psychophysics*, New York: Wiley-Interscience.

Cornsweet, T. N. (1962). The staircase method in psychophysics. *American Journal of Psychology*, *75*, 485-491.

Farell, B. & Pelli, D. G. (1998). Psychophysical methods, or how to measure a threshold, and why. In Carpenter, R. H. S. & Robson, J. G. (Eds.), *Vision Research: A Practical Guide to Laboratory Methods* (pp. 129-136). New York: Oxford University Press.

Findlay, J. M. (1978). Estimates on probability functions: A more virulent PEST. *Perception & Psychophysics*, *23*, 181-185.

Hall, J. L. (1981). Hybrid adaptive procedure for estimation of psychometric functions. *The Journal of the Acoustical Society of America*, *69*, 1763-1769.

Levitt, H. (1971). Transformed up-down methods in psychoacoustics. *The Journal of the Acoustical Society of America*, *49*, 467-477.

Pentland, A. (1980). Maximum likelihood estimation: The best PEST. *Perception & Psychophysics*, *28*, 377-379.

Quick, R. F. Jr. (1974). A Vector-Magnitude Model of Contrast Detection. *Kybernetik*, *16*, 65-67.

Taylor, M. M. (1971). On th efficiency of psychophysical measurement. *Journal of the Acoustical Society of America*, *49*, 505-508.

Taylor, M. M. & Creelman, C. D. (1967). PEST: Efficient estimates on probability functions. *Journal of the Acoustical Society of America*, *41*, 782-787.

Watson, A. B. & Pelli, D. G. (1983). QUEST: A Bayesian adaptive psychometric method. *Perception & Psychophysics*, *33*, 113-120.

Watt, R. J. & Andrews, D. P. (1981). APE: Adaptive probit estimation of psychometric functions. *Current Psychological Reviews*, *1*, 205-214.

Wetherill, G. B. & Levitt, H. (1965). Sequential estimation of points on a psychometric function. *British Journal of Mathematical and Statistical Psychology*, *18*, 1-10.

Wetherill, G. B. (1966). Sequential estimation of points on quantal response curves. In *Sequential Methods in Statistics* (pp. 171-227). London: Methuen.

Wichmann, F. A. & Hill, N. J. (2001). The psychometric function: I. Fitting, sampling, and goodness of fit. *Perception & Psychophysics*, *63*, 1293-1313.

Wichmann, F. A. & Hill, N. J. (2001). The psychometric function: II. Bootstrap-based confidence intervals and sampling. *Perception & Psychophysics*, *63*, 1314-1329.

Physical and Physiological Optics, Monitor Calibration

Required Reading

Riggs, L. A. (1965). Light as a stimulus for vision. In Graham, C. H. (Ed.), *Vision and Visual Perception* (pp. 1-38). New York: Wiley.

LeGrand, Y. (1957). *Light, Colour and Vision*. New York: John Wiley & Sons Inc, pp. 3-104. [Note: concentrate on the following pages and scan the rest: 3-18, 49, 58-59, 63-77, 102-103.]

References

Brainard, D. H. (1989). Calibration of a computer controlled color monitor. *Color Research and Application*, *14*, 23-34.

Brainard, D. H. & Wandell, B. A. (1990). Calibrated processing of image color. *Color Research and Application*, *15*, 266-271.

Cowan, W. (1987). Colorimetric properties of video monitors. Short Course, Annual Meeting of the OSA, Rochester, N.Y..

Cowan, W. B. & Rowell, N. (1986). On the gun independence and phosphor constancy of colour video monitors. *Color Research and Application*, *11* (Supplement), S33-S38.

Klein, S. A., Hu, Q. J. & Carney, T. (1996). The adjacent pixel nonlinearity: Problems and solutions. *Vision Research*, *36*, 3167-3181.

Landy, M. S. & Brainard, D. H. (1990). Graphic Systems for Psychophysicists. Short Course, Annual Meeting of the OSA.

Makous, W. (1998). Optics and photometry. In Carpenter, R. H. S. & Robson, J. G. (Eds.), *Vision Research: A Practical Guide to Laboratory Methods* (pp. 1-49). New York: Oxford University Press.

Maloney, L. T. & Koh, K. (1988). A method for calibrating the spatial coordinates of a visual display to high accuracy. *Behavior Research Methods, Instruments, & Computers*, *20*, 372-389.

Mulligan, J. B. & Stone, L. S. (1989). Halftoning method for the generation of motion stimuli. *Journal of the Optical Society of America A*, *6*, 1217-1227.

Pelli, D. G. & Zhang, L. (1991). Accurate control of contrast on microcomputer displays. *Vision Research*, *31*, 1337-1350.

Post, D. L. & Colhoun, C. S. (1989). An evaluation of methods for producing desired colors on CRT monitors. *Color Research and Application*, *14*, 172-186 .

Savoy, R. L. (1986). Making quantized images appear smooth: Tricks of the trade in vision research. *Behavior Research Methods, Instruments, & Computers*, *18*, 507-517.

Sperling, G. (1971). The description and luminous calibration of cathode ray oscilloscope visual displays. *Behavior Research Methods & Instruments*, *3*, 148-151.

Sperling, G. (1971). Flicker in computer-generated visual displays: Selecting a CRT phosphor and other problems. *Behavior Research Methods & Instruments, 3*, 151-153.

Sperling, G. (1971). Stereoscopic visual displays: Principles, viewing devices, alignment procedures. *Behavavior Research Methods & Instruments, 3*, 154-158.

Sperling, G. (1976). Movement perception in computer-driven visual displays. *Behavior Research Methods & Instrumentation, 8*, 144-151.

Stanislaw, H. & Olzak, L. A. (1990). Parametric methods for gamma and inverse gamma correction, with extensions to halftoning. *Behavior Research Methods, Instruments, & Computers, 22*, 402-408.

Strasburger, H., Ed. (1997). Special issue on the use of cathode-ray-tube displays in visual psychophysics. *Spatial Vision, 10(4)*.

Wandell, B. A. (1987). The synthesis and analysis of color images. *IEEE Transactions on Pattern Analysis & Machine Intelligence, PAMI-9*, 2-13.

Watson, A. B., Nielson, K. R. K., Poirson, A., Fitzhugh, A., Bilson, A., Nguyen, K. & Ahumada, A. J., Jr. (1986). Use of a raster framebuffer in vision research. *Behavior Research Methods, Instruments, & Computers, 18*, 587-594.

Wyszecki, G. & Stiles, W. S. (1982). *Color Science: Concepts and Methods, Quantitative Data and Formulae*. New York: Wiley.

Example: Hecht, Shlaer & Pirenne

Required Reading

Cornsweet, T. N. (1970). *Visual Perception*, New York: Academic Press, pp. 6-89.

References

Hecht, S., Shlaer, S. & Pirenne, M. H. (1942). Energy, quanta, and vision. *Journal of General Physiology*, *25*, 819-840.

Krauskopf, J. (1978). On identifying detectors. In Armington, J. C., Krauskopf, J. K. & Wooten, B. R. (Eds.), *Visual Psychophysics and Physiology* (pp. 283-295).

Krauskopf, J. & Srebro, R. (1965). Spectral sensitivity of color mechanisms: Derivation from fluctuations of color appearance near threshold. *Science*, *150*, 1477-1479.

Vision: LST approach - Flicker, Spatial Frequency Channels

Required Reading

Robson, J. G. (1980). Neural images: The physiological basis of spatial vision. In Harris, C. (Ed.), *Visual Coding and Adaptability* (pp. 177-214). Hillsdale, NJ: Erlbaum.

Sperling, G. (1964). Linear theory and the psychophysics of flicker. *Documenta Ophthalmologica, 18,* 3-15.

Watson, A. B., Ahumada, Jr., A. J. & Farrell, J. E. (1986). Window of visibility: a psychophysical theory of fidelity in time-sampled visual motion displays. *Journal of the Optical Society of America A, 3,* 300-307.

Laboratory Assignment: Transforms, receptive fields, filtering, spectra and phase of natural images. Image processing using HIPS or MATLAB.

References

Anderson, S. J. & Hess, R. F. (1990). Post-receptoral undersampling in normal human peripheral vision. *Vision Research, 30,* 1507-1515.

Blakemore, C. & Sutton, P. (1969). Size adaptation: A new aftereffect. *Science, 166,* 245-247.

Blakemore, C. & Campbell, F. W. (1969). On the existence of neurones in the human visual system selectively sensitive to the orientation and size of retinal images. *Journal of Physiology, 203,* 237-260.

Bracewell, R. N. (1978). *The Fourier Transform and its Applications, Vol. 2.* New York: McGraw-Hill.

Burt, P. J. (1981). Fast filter transforms for image processing. *Computer Graphics and Image Processing, 16,* 20-51.

Burt, P. J. & Adelson, E. H. (1983). The Laplacian pyramid as a compact image code. *IEEE Transactions on Communications, 31,* 532-540.

Campbell, F. W. & Robson, J. G. (1968). Application of Fourier analysis to the visibility of gratings. *Journal of Physiology, 197,* 551-566.

Carlson, C. R. & Klopfenstein, R. W. (1985). Spatial-frequency model for hyperacuity. *Journal of the Optical Society of America A, 2,* 1747-1751.

Coletta, N. J., Williams, D. R. & Tiana, C. L. M. (1990). Consequences of spatial sampling for human motion perception. *Vision Research, 30,* 1631-1648.

Daugman, J.G. (1983). Six formal properties of two-dimensional anisotropic visual filters: structural principles and frequency/orientation selectivity. *IEEE Transactions on Systems, Man and Cybernetics, SMC-13,* 882-887.

Daugman, J.G. (1984). Spatial visual channels in the fourier plane. *Vision Research, 24,* 891-910.

Daugman, J. G. (1985). Uncertainty relation for resolution in space, spatial frequency, and orientation optimized by two-dimensional visual cortical filters. *Journal of Optical Society of America A, 2*, 1160-1169.

Dudgeon, D. E. & Mersereau, R. M. (1984). *Multidimensional Digital Signal Processing*. Englewood Cliffs, NJ: Prentice Hall.

Robson, J. G. (1983). Frequency domain visual processing. In Braddick, O. J. & Sleigh, A. C. (Eds.), *Physical and Biological Processing of Images* (pp. 73-87). New York: Springer-Verlag.

Smith, R. A. & Cass, P. F. (1987). Aliasing in the parafovea with incoherent light. *Journal of the Optical Society of America A, 4*, 1530-1534.

Sperling, G. (1965). Temporal and spatial visual masking I. Masking by impulse flashes. *Journal of the Optical Society of America, 55*, 541-559.

Sperling, G. & Sondhi, M. M. (1968). Model for visual luminance discrimination and flicker detection. *Journal of the Optical Society of America, 58*, 1133-1145.

Watson, A. B. (1983). Detection and recognition of simple spatial forms. In Braddick, O. J. & Sleigh, A. C. (Eds.), *Physical and Biological Processing of Images* (pp. 100-114). New York: Springer-Verlag.

Watson, A. B. (1987). The Cortex transform: Rapid computation of simulated neural images. *Computer Vision, Graphics, and Image Processing, 38*, 311-327.

Watson, A. B. (1987). Efficiency of a model human image code. *Journal of the Optical Society of America A, 4*, 2401-2417.

Watson, A. B. (1987). Estimation of local spatial scale. *Journal of the Optical Society of America A, 4*, 1579-1582.

Williams, D. R. & Collier, R. (1983). Consequences of spatial sampling by a human photoreceptor mosaic. *Science, 221*, 385-387.

Yellott, J. I. Jr. (1982). Spectral analysis of spatial sampling by photoreceptors: topological disorder prevents aliasing. *Vision Research, 22*, 1205-1210.

Yellott, J. I. Jr. (1983). Spectral consequences of photoreception sampling in the rhesus retina. *Science, 221*, 382-385.

Yellott, J. I. Jr., Wandell, B. A. & Cornsweet, T. N. (1984). The Beginnings of Visual Perception: The Retinal Image and Its Initial Encoding. In *Handbook of Physiology - The Nervous System* (pp. 257-316). Bethesda, MD: American Physiological Society.

Vision: SDT and Ideal Observer approaches

Required Reading

Newsome, W. T., Britten, K. H. & Movshon, J. A. (1989). Neuronal correlates of a perceptual decision. *Nature, 341*, 52-54.

Coombs, C. H., Dawes, R. M. & Tversky, A. (1970). *Mathematical Psychology, An Elementary Introduction* (Chapter 6). Englewood Cliffs, NJ: Prentice-Hall.

References

Barlow, H. B. (1978). The efficiency of detecting changes in density in random dot patterns. *Vision Research, 18*, 637-650.

Barlow, H. B. & Levick, W. R. (1969). Three factors limiting the reliable detection of light by retinal ganglion cells of the cat. *Journal of Physiology, 200*, 1-24.

Britten, K. H., Shadlen, M. N., Newsome, W. T. & Movshon, J. A. (1992). The analysis of visual motion: a comparison of neuronal and psychophysical performance. *Journal of Neuroscience, 12*, 4745-4765.

Burgess, A. E. (1985). Visual signal detection III. On Bayesian use of prior knowledge of cross correlation. *Journal of the Optical Society of America A, 2*, 1498-1507.

Burgess, A. E. & Barlow, H. B. (1983). The efficiency of numerosity discrimination in random dot images. *Vision Research, 23*, 811-829.

Burgess, A. E. & Ghandeharian, H. (1984). Visual signal detection I. Phase sensitive detection. *Journal of the Optical Society of America A, 1*, 900-905.

Burgess, A. E. & Ghandeharian, H. (1984). Visual signal detection II. Effect of signal-location identification. *Journal of the Optical Society of America A, 1*, 906-910.

Burgess, A. E., Wagner, R. F., Jennings, R. J. & Barlow, H. B. (1981). Efficiency of human visual signal detection. *Science*, 214 , 93-94.

Duda, R. O. & Hart, P. E. (1973). *Pattern Classification and Scene Analysis*. New York: Wiley.

Falmagne, J.-C. (1985). *Elements of Psychophysical Theory* (chapter 10, pp. 231-257). New York: Oxford University Press.

Geisler, W. S. (1989). Sequential ideal-observer analysis of visual discrimation. *Psychological Review, 96*, 1-7l.

Green, D. M. & Luce, R. D. (1975). Parallel psychometric functions from a set of independent detectors. *Psychological Review, 82*, 483-486.

Green, D. M. & Swets, J. A. (1974). *Signal Detection Theory and Psychophysics*. Huntington, NY: Robert E. Krieger.

Knill, D. C. & Richards, W. (Eds.) (1996). *Perception as Bayesian Inference*. New York: Cambridge University Press.

Macmillan, N. A. & Creelman, C. D. (1991). *Detection Theory: A User's Guide*. New York: Cambridge.

Maloney, L. T. (2002). Statistical decision theory and biological vision. In D. Heyer & R. Mausfeld (Eds.), *Perception and the Physical World: Psychological and Philosophical Issues in Perception* (pp. 145-189). New York: Wiley.

Mamassian, P., Landy, M. S. & Maloney, L. T. (2002). Bayesian modelling of visual perception. In Rao, R. P. N., Olshausen, B. A. & Lewicki, M. S. (Eds.), *Probabilistic Models of the Brain* (pp. 13-36). Cambridge, Massachusetts: MIT Press.

Pelli, D. G. (1985). Uncertainty explains many aspects of visual contrast detection and discrimination. *Journal of the Optical Society of America A, 2*, 1508-1531.

Pelli, D. G. (1990). The quantum efficiency of vision. In Blakemore, C. (Ed.), *Vision: Coding and Efficiency* (pp. 3-24). New York: Cambridge University Press.

Rao, R. P. N., Olshausen, B. A. & Lewicki, M. S. (Eds.) (2002). *Probabilistic Models of the Brain*. Cambridge, Massachusetts: MIT Press.

Quick, R. F. Jr. (1974). A Vector-Magnitude Model of Contrast Detection. *Kybernetik, 16*, 65-67.

Sperling, G. & Dosher, B. A. (1986). Strategy and optimization in human information processing. In Boff, K. R., Kaufman, L. & Thomas, J. P. (Eds.), *Handbook of Perception and Human Performance, Volume I, Processes and Perception*. New York: Wiley.

Swets, J. A. (Ed.) (1964). *Signal Detection and Recognition by Human Observers.* New York: Wiley.

Tanner, W. P. & Birdsall, T. G. (1958). Definitions of d' and η as psychophysical measures. *Journal of the Acoustical Society of America, 30*, 922-928.

Thurstone, L. L. (1927). A law of comparative judgment. *Psychological Review, 34*, 273-286.

Vision: Spatial Acuity, Detection and Discrimination, More on Channels

Required Reading

Graham, N. (1980). Spatial-frequency channels in human vision: Detecting edges without edge detectors. In Harris, C. (Ed.), *Visual Coding and Adaptability* (pp. 215-252). Hillsdale, NJ: Erlbaum.

Watson, A. B. & Robson, J. G. (1981). Discrimination at threshold: Labelled detectors in human vision. *Vision Research, 21*, 1115-1122.

References

Ahumada, A. J., Jr. & Beard, B. L. (1997). Image discrimination models predict detection in fixed but not random noise. *Journal of the Optical Society of America A, 14*, 2471-2476.

Ahumada, A. J., Jr. & Lovell, J. (1971). Stimulus features in signal detection. *Journal of the Acoustical Society of America, 49*, 1751-1756.

Ahumada, A. J. & Watson, A. B. (1985). Equivalent-noise model for contrast detection and discrimination, *Journal of the Optical Society of America A, 7*, 1133-1139.

Badcock, D. R. & Derrington, A. M. (1985). Detecting the displacement of periodic patterns. *Vision Research, 25*, 1253-1258.

Badcock, D. R. & Derrington, A. M. (1989). Detecting the displacements of spatial beats: No role for distortion products. *Vision Research, 29*, 731-739.

Bergen, J. R., Wilson, H. R. & Cowan, J. D. (1979). Further evidence for four mechanisms mediating vision at threshold: Sensitivities to complex gratings and aperiodic stimuli. *Journal of the Optical Society of America, 69*, 1580-1587.

Blake, R. & Martens, W. (1981). Critical bands in cat spatial vision. *Journal of Physiology, 314*, 175-187.

Blakemore, C. & Campbell, F. W. (1969). On the existence of neurones in the human visual system selectively sensitive to the orientation and size of retinal images. *Journal of Physiology, 203*, 237-260.

Blakemore, C. & Sutton, P. (1969). Size adaptation: A new aftereffect. *Science, 166*, 245-247.

Burr, D. C., Morrone, M. C. & Spinelli, D. (1989). Evidence for edge and bar detectors in human vision. *Vision Research, 29*, 419-431.

Burr, D. C., Ross, D. & Morrone, M. C. (1985). Local regulation of luminance gain. *Vision Research, 25*, 717-727.

Campbell, F. W. & Robson, J. G. (1968). Application of Fourier analysis to the visibility of gratings. *Journal of Physiology, 197*, 551-566.

Carlson, C. R. & Klopfenstein, R. W. (1985). Spatial-frequency model for hyperacuity. *Journal of the Optical Society of America A, 2*, 1747-1751.

Cohn, T. E. & Makous, W. (Eds.) (1985). Detection and identification. Special issue of *Journal of the Optical Society of America A, 2*, 1453-1610.

Derrington, A. M. & Badcock, D. R. (1985). Separate detectors for simple and complex grating patterns? *Vision Research, 12*, 1869-1878.

De Valois, R. L. & De Valois, K. K. (1988). *Spatial Vision*. New York: Oxford University Press.

Field, D. J. & Nachmias, J. (1984). Phase reversal discrimination. *Vision Research, 4*, 333-340.

Foley, J. M. & Legge, G. E. (1981). Contrast detection and near-threshold discrimination in human vision. *Vision Research, 21*, 1041-1053.

Gold, J. M., Murray, R. F., Bennett, P. J. & Sekuler, A. B. (2000). Deriving behavioural receptive fields for visually completed contours. *Current Biology, 10*, 663-666.

Gold, J. M., Sekuler, A. B. & Bennett, P. J. (2004). Characterizing perceptual learning with external noise. *Cognitive Science, 28*, 167-207.

Gottesman, J., Rubin, G. S. & Legge, G. E. (1981). A power law for perceived contrast in human vision. *Vision Research, 21*, 791-799.

Graham, N. (1977). Visual detection of aperiodic spatial stimuli by probability summation among narrowband channels. *Vision Research, 17*, 637-652.

Graham, N. (1985). Detection and identification of near-threshold visual patterns. *Journal of the Optical Society of America A, 2*, 1468-1482.

Graham, N. (1989). *Visual Pattern Analyzers*. New York: Oxford University Press.

Graham, N. & Nachmias, J. (1971). Detection of grating patterns containing two spatial frequencies: A comparison of single-channel and multiple-channels models. *Vision Research, 11*, 251-259.

Graham, N., Robson, J. G. & Nachmias, J. (1978). Grating summation in fovea and periphery. *Vision Research, 18*, 815-825.

Graham, N. & Rogowitz, B. E. (1976). Spatial pooling properties deduced from the detectability of FM and quasi-AM gratings: A reanalysis. *Vision Research, 16*, 1021-1026.

Henning, G. B. & Hertz, B. G. (1977). The influence of bandwidth and temporal properties of spatial noise on binocular masking-level differences. *Vision Research, 17*, 399-402.

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