Psychology 599 - Special Topics

Methods in Visual Psychophysics

Bosco S. Tjan, Ph.D.
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Visual psychophysics refers to a large class of empirical techniques where a subject's performance in a specific task is measured as a function of certain physical properties of the visual stimuli. Results are used to construct functional models that describe the neurocomputations underlying visual perception. As a major source of empirical data and theories in the field, visual psychophysics has always been an important tool in vision science.

This hands-on class will provide a comprehensive overview of the core empirical techniques and analytical methods in visual psychophysics. Students will gain both practical and theoretical understanding of the subject matters. The course is suitable for graduate students of all levels in all disciplines of vision science (psychology, biology, engineering). Students with programming experience and general competency in at least one of the following areas will benefit most from the class: linear algebra, probability theory, statistics.

Reading materials: selected research articles
Exams: three random quizzes, no final
Final project, presented on 5/2 2-6pm, may be either an implementation of a psychophysical procedure, or a concrete proposal of an experiment.
Grades based on: class presentation - 25%, quizzes - 15%, homework and programming assignments - 30%, final project - 30%.

Class will meet once a week for 2 hours, followed by 1.5 hours of lab.

Lecture Plan:

Week 1: Overview of visual system, methods and apparatus; Matlab tutorial
Week 2: Computer-based stimulus presentation, monitor calibration I: luminance & contrast control
Week 3: Linear system analysis, Fourier analysis, and a very brief introduction to image processing
Week 4: Signal-detection theory, internal noise, nonlinearities, and psychometric functions
Week 5: Method of constant stimuli, adaptive methods, and the human contrast sensitivity function
Week 6: Human color perception, monitor calibration II: color
Week 7: Presentation of motion stimuli, monitor calibration III: timing and phosphor delay rate, human spatiotemporal sensitivity function
Week 8: Spatial resolution of a monitor, aliasing and anti-aliasing, achieving subpixel resolution, and alignment threshold measurements
Week 9: Pattern recognition, signal-in-noise method, and ideal-observer analysis
Week 10: High-level visual-cognition experiments, counter-balancing, methods for measuring response time, computer-based event timing, speed-accuracy trade-off methods
Week 11: Perception of 3D shape, and Bayesian analysis of cue combination

Week 12: Eye/Head-tracking, virtual reality setups, psychophysical issues with video projectors

Suggested Readings (listed in the order of relevancy to the lectures) **[presenter]**

General

Carpenter, R. H. S., & Robson, J. G. e. (1999). *Vision Research: a practical guide to laboratory methods*. Oxford: Oxford University Press.

Week 1: Overview of visual system, methods and apparatus; Matlab tutorial

Matlab Tutorial and Documentations(2002). Available: http://www.mathworks.com/access/helpdesk/help/techdoc/matlab.shtml.

Livingstone, M., & Hubel, D. (1988). Segregation of form, color, movement, and depth: anatomy, physiology, and perception. *Science, 240*(4853), 740-749.

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

Week 2: Computer-based stimulus presentation, monitor calibration I: luminance & contrast control

Pelli, D. G., & Zhang, L. (1991). Accurate control of contrast on microcomputer displays. *Vision Res, 31*(7-8), 1337-1350.

Tyler, C. W. (1997). Colour bit-stealing to enhance the luminance resolution of digital displays on a single pixel basis. *Spat Vis, 10*(4), 369-377.

Week 3: Linear system analysis, Fourier analysis, and a very brief introduction to image processing

Campbell, F. W., & Robson, J. G. (1968). Application of Fourier analysis to the visibility of gratings. *J Physiol, 197*(3), 551-566.

Regan, D. (1991). A brief review of some of the simuli and analysis menthods used in spatiotemporal vision research. In D. Regan (Ed.), *Spatial Vision* (pp. 1-42). Boca Raton, FL: CRC Press.

Week 4: Signal-detection theory, internal noise, nonlinearities, and psychometric functions

Legge, G. E., Kersten, D., & Burgess, A. E. (1987). Contrast discrimination in noise. *J Opt Soc Am A, 4*(2), 391-404.

Klein, S. A. (2001). Measuring, estimating, and understanding the psychometric function: a commentary. *Percept Psychophys, 63*(8), 1421-1455.

Pelli, D. G. (1990). The quantum efficiency of vision. In C. Blakemore (Ed.), *Vision: coding and efficiency*. Cambridge: Cambridge University Press.

[Debbie] Lu, Z. L., & Dosher, B. A. (1999). Characterizing human perceptual inefficiencies with equivalent internal noise. *J Opt Soc Am A Opt Image Sci Vis, 16*(3), 764-778.

Burgess, A. E., & Colborne, B. (1988). Visual signal detection. IV. Observer inconsistency. *J Opt Soc Am A, 5*(4), 617-627.

Laming, D. (1991). Signal detection theory. In J. J. Kulikowski & V. Walsh & I. J. Murray (Eds.), *Limits of Vision* (pp. 15-22). Boca Raton, FL: CRC Press.

Green, D. M., & Swets, J. A. (1974). *Signal detection theory and psychophysics*. Huntington, N.Y.: R. E. Krieger Pub. Co.

Wichmann, F. A., & Hill, N. J. (2001). The psychometric function: I. Fitting, sampling, and goodness of fit. *Percept Psychophys, 63*(8), 1293-1313.

Wichmann, F. A., & Hill, N. J. (2001). The psychometric function: II. Bootstrap-based confidence intervals and sampling. *Percept Psychophys, 63*(8), 1314-1329.

Week 5: Method of constant stimuli, adaptive methods, and the human contrast sensitivity function

[Simon] Dai, H. (1995). On measuring psychometric functions: a comparison of the constant-stimulus and adaptive up-down methods. *J Acoust Soc Am, 98*(6), 3135-3139.

Treutwein, B. (1995). Adaptive psychophysical procedures. *Vision Res, 35*(17), 2503-2522.

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

Watson, A. B., & Pelli, D. G. (1983). QUEST: a Bayesian adaptive psychometric method. *Percept Psychophys, 33*(2), 113-120.

[Wilson] Laming, D. (1991). Contrast sensitivity. In J. J. Kulikowski & V. Walsh & I. J. Murray (Eds.), *Limits of Vision* (pp. 35-43). Boca Raton, FL: CRC Press.

Laming, D. (1991). Theoretical basis of the processing of simple visual stimuli. In J. J. Kulikowski & V. Walsh & I. J. Murray (Eds.), *Limits of Vision* (pp. 23-34). Boca Raton, FL: CRC Press.

Week 6: Human color perception, monitor calibration II: color

Kulikowski, J. J., & Walsh, V. (1991). On the limits of colour detection and discrimination. In J. J. Kulikowski & V. Walsh & I. J. Murray (Eds.), *Limits of Vision* (pp. 202-220). Boca Raton, FL: CRC Press.

Brainard, D. (1996). Cone contrast and opponent modulation color spaces. In P. K. Kaiser & R. M. Boynton (Eds.), *Human Color Vision*. Optical Society of America.

Brainard, D. (1995). Colorimetry. In M. Bass (Ed.), *Handbook of Optics: Vol. 1. Fundamentals, Techniques, and Design* (pp. 26.21-26.54). New York: McGraw-Hill.

Tjan, B. S. (1996). *Color Spaces for Human Observer*. Available: http://external.nj.nec.com/homepages/tjan/colorspace/color.html.

Lu, Z. L., Lesmes, L. A., & Sperling, G. (1999). Perceptual motion standstill in rapidly moving chromatic displays. *Proc Natl Acad Sci U S A, 96*(26), 15374-15379.

[Luis] Lu, Z. L., Lesmes, L. A., & Sperling, G. (1999). The mechanism of isoluminant chromatic motion perception. *Proc Natl Acad Sci U S A, 96*, 8289-8294.

[Luis] Lu, Z. L. & Sperling, G. (2001). Sensitive calibration and measurement procedures based on the amplification principle in motion perception. *Vision Research, 41*, 2355-2374.

Week 7: Presentation of motion stimuli, monitor calibration III: timing and phosphor delay rate, human spatiotemporal sensitivity function

[Carlos] Adelson, E. H., & Bergen, J. R. (1985). Spatiotemporal energy models for the perception of motion. *J Opt Soc Am A, 2*(2), 284-299.

[Rosemary] Lu, Z. L., & Sperling, G. (2001). Three-systems theory of human visual motion perception: review and update. *J Opt Soc Am A Opt Image Sci Vis, 18*(9), 2331-2370.

Crowell, J. A., & Banks, M. S. (1993). Perceiving heading with different retinal regions and types of optic flow. *Percept Psychophys, 53*(3), 325-337.

Week 8: Spatial resolution of a monitor, aliasing and anti-aliasing, achieving subpixel resolution, and alignment threshold measurements

[Jeff] McKee, S. P. (1991). The physical constraints on visual hyperacuity. In J. J. Kulikowski & V. Walsh & I. J. Murray (Eds.), *Limits of Vision* (pp. 221-233). Boca Raton, FL: CRC Press.

Morgan, M. F. (1991). Hyperacuity. In D. Regan (Ed.), *Spatial Vision* (pp. 87-135). Boca Raton, FL: CRC Press.

Wilson, H. R. (1989). Psychophysical models of spatial vision and hyperacuity. In D. Regan (Ed.), *Spatial Vision* (pp. 64-86). Boca Raton, FL: CRC Press.

Week 9: Pattern recognition, signal-in-noise method, and ideal-observer analysis

[Michelle] Schrater, P., & Kersten, D. (2002). Vision, psychophyscis and Bayes. In R. P. N. Rao & B. A. Olshausen & M. S. Lewicki (Eds.), *Probabilistic Models of the Brain* (pp. 37-60). Cambridge, Massachusetts: MIT Press.

[Noah] Geisler, W. S. (1989). Sequential ideal-observer analysis of visual discriminations. *Psychol Rev, 96*(2), 267-314.

Liu, Z., & Kersten, D. (1998). 2D observers for human 3D object recognition? *Vision Res, 38*(15-16), 2507-2519.

Eckstein, M. P., Thomas, J. P., Palmer, J., & Shimozaki, S. S. (2000). A signal detection model predicts the effects of set size on visual search accuracy for feature, conjunction, triple conjunction, and disjunction displays. *Percept Psychophys, 62*(3), 425-451.

Tjan, B. S., & Legge, G. E. (1998). The viewpoint complexity of an object-recognition task. *Vision Res, 38*(15-16), 2335-2350.

Week 10: High-level visual-cognition experiments, counter-balancing, methods for measuring response time, computer-based event timing, speed-accuracy trade-off methods

[Guest lecturer: Prof. Irving Biederman]

Cooper 1991

Biederman, I., & Cooper, E. E. (1992). Size invariance in visual object priming. *J. of Experiment Psychology - Human Perception & Performance, 18*(1), 121-133.

Sutter, A., & Graham, N. (1995). Investigating simple and complex mechanisms in texture segregation using the speed-accuracy tradeoff method. *Vision Res, 35*(20), 2825-2843.

[Xiaomin] Burock, M. A., Buckner, R. L., Woldorff, M. G., Rosen, B. R., & Dale, A. M. (1998). Randomized event-related experimental designs allow for extremely rapid presentation rates using functional MRI. *Neuroreport, 9*(16), 3735-3739.

Dosher, B. A., Han, S., & Lu Z. L. (preprint) Parallel Processing in Visual Search Asymmetry.

Week 11: Perception of 3D shape, and Bayesian analysis of cue combination

Ernst, M. O., & Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. *Nature, 415*(6870), 429-433.

Hillis, J. M., Ernst, M. O., Banks, M. S., & Landy, M. S. (2002). Combining sensory information: Mandatory fusion within, but not between, senses. *Science, 298*(5598), 1627-1630.

[Bosco]Knill, D. C. (1998). Ideal observer perturbation analysis reveals human strategies for inferring surface orientation from texture. *Vision Research, 38*(17), 2635-2656.

Landy, M. S., Maloney, L. T., Johnston, E. B., & Young, M. (1995). Measurement and Modeling of Depth Cue Combination - in Defense of Weak Fusion. *Vision Research, 35*(3), 389-412.

Week 12: Eye/Head-tracking, virtual reality setups, psychophysical issues with video projectors

Crane, H. D., & Steele, C. M. (1985). Generation-V Dual-Purkinje-Image Eyetracker. *Applied Optics, 24*, 527–537.

Young, L. R., & Sheena, D. (1975). Survey of Eye Movement Recording Methods. *Behavior*

Research Methods & Instrumentation, 7(5), 397–439.
Loomis, J. M., & Knapp, J. M. (2003). Visual perception of egocentric distance in real and virtual environments. In L. J. Hettinger & M. W. Haas (Eds.), *Virtual & Adaptive Environments: Applications, Implications, and Human Performance Issues*. Hillsdale NJ: Erlbaum.
Burdea, G., & Coiffet, P. (2003). *Virtual Reality Technology* (2nd ed.). New York: John Wiley & Sons.