Psych211 Winter 2020 George Sperling
Attention & Perception
Course materials will be made available for registered participants at the first class meeting. For unprotected course materials visit
http://www.cogsci.uci.edu/˜whipl/Psych211/
All required reading will become available under Class_Materials

This course deals as much as possible with basic concepts in visual and auditory perception and in attention that can be and have been expressed in terms of physical or mathematical theories or computational models. It covers a lot of material that is taught in Psych 210 which is not offered in the academic year 2019-2020.

The outline here is in terms of the concepts covered rather than in terms of lectures because the precise selection of concepts and the order presentation depends on the interests and background of the students. However, to talk intelligently about concepts, familiarity with the basic structure and function of the visual and auditory systems is a prerequisite, so that comes first.

The emphasis is on basic science although a good understanding of the basics usually suggests practical applications.

First 5 or 6 lectures: basic principles of the organization of the visual and auditory systems (anatomically and functionally), visual and auditory receptive fields and their linear systems representation.

Second half deals with a selection of theories of perception and attention that are of greatest interest to the instructor and to the students, especially those that utilize the tools developed in the first half of the course.

Textbooks: Visual system, many possible. Relevant excerpts will be available for download from:
Palmer, S. E. (1999). Vision Science. Photons to Phenomenology. Cambridge, MA: MIT Press.
Denes, P. B., and Pinson, E. N. (2015). The Speech Chain. The Physics and Biology of Spoken Language. Long Grove, IL: Waveland Press, Inc.
This is a short book elementary book, the entire book is required reading.

Example of 14 topics covered in this course most of which are rarely if ever covered in psychology textbooks:

1. How to accurately measure your own blind spots (HW, Lecture 1).
2. What to measure and how for an accurate description of visual and auditory stimuli that you might use in experiments.
3. How receptive field properties are determined by principles of neural economy.
4. Pyramid structure, tiling, the consequences for what can and cannot be observed by single neuron recording.
5. A nonmathematical graphical approach to linear systems theory that enables quite accurate judgments of the responses of linear systems (HW 2,3)
6. How to infer V1 and A1 impulse responses from psychophysical measurements:
7. Examples of how to derive computational models of brain processes from simple non-invasive measurements.
8. One-line matrix representation of the transformation of receptor (cone) response to R,G,B color space and vs vs.

9. How to produce stimuli that excite only one receptor class (In fact, #8,9 are covered in specialized books on vision science).
10. Analogous processing: vision spatial frequency channels--auditory critical bands
    second-order vision and auditory periodotopy (e.g., B.Berg colloquium: "Envelope discrimination")
11. Reverse correlation: Used to judge hockey and basketball players, also used to derive V1 spatio-temporal receptive fields, mental templates in human (and animal) discrimination judgments
12. Signal Detection Theory: (Initially used only for detection experiments.)
    Equivalence to macro-economic theory (swords vs plowshares) and to divided attention theory.
    HW: Examples to show SDT representation of psychophysical thresholds is equivalent to the representation of how courtroom decisions depend on the quality of the legal representation, and to how health outcomes depend on income.
    Now widely used to judge quality of computer models of bottom-up attention ("salience").

13. Computational models of human spatial, temporal, and feature attention. Review in www.cogsci.uci.edu/˜whipl/staff/sperling/PDFs/Sperling_in_Lachmann.pdf
14. Optional: A mathematical derivation of the number of neurons that coordinate to generate a facial recognition response in temporal lobe (typically >1,000) Uses the same principles as in describing the word frequency vs word length in natural languages, neural representation in fruit fly olfactory system, etc.

Useful sources for 2nd half of course:
40 chapters in

Nober, A. C., and Kastner, S. (Eds). 2014. The Oxford Handbook of Attention. Oxford, UK: Oxford University Press. Pp. 1,242.

Sperling, G., & Dosher, B. A. (1986). Strategy and optimization in human information processing. In K. Boff, L. Kaufman, & J. Thomas (Eds.), Handbook of perception and human performance: Vol. 1. Sensory processes and perception New York: Wiley. (pp. 2-1 to 2-65). www.cogsci.uci.edu/˜whipl/staff/sperling/PDFs/Sperling+Dosher_HBK_1986.pdf

The topics listed here are taken from the annotated course slides of the first few lectures, available to course participants as downloadable pdfs and movies.

Lectures 1,2,3
Overview of the overall brain organization of visual processing.
Physics of light, Snellâs Law (Princicple of Minimum Effort),
wavelength and speed of light (how to measure), waves of light and of surf,
Digression into contemporary 2 slit quantum paradox
Digression rant: Basic science is usually not very profitable,
if it’s not fascinating, switch to something more profitable ASAP!
visible spectrum, range of light intensities, photomultiplier
quantum versus wave (mouse, rabbit, dog),
parts of the eye, image formation in the retina, visual angles
(how to compute them w/o trigonometry), the blind spot, filling in.
HW. Accurately measure your two blind spots
Digression: How visual angles enabled Eristothenes before 200 bce

to calculate (and you could, too) the diameter of the earth, the size of the moon, and the distance of the moon from earth all quite accurately. Demonstration of visual angles re solar eclipse and the consequences of applying that same scale to the Universe beyond the Milky Way (the name of our galaxy).

Overall brain organization of the visual system, levels of neural processing: brain lobes (occipital, temporal, parietal, frontal; receptors, bipolar cells, ganglion cells, LGN, V1, V2, V3, V3a, V4, V8, FFA, MT, IT, optic nerve, optic tract. Broadmann areas. Sereno lateral unfolding (algorithm, demonstration), Van Essen brain areas, topographical representation of retina-to-V1 mapping (conformal map), Mercator projection, complex representation, how to measure V1 topography.

V1 organization: Occular dominance, hypercolumn, Hubel-Wiesel movie, the Mississippi River analogy to a neuron, world vs model; basic neuron principles (cell body, dendrites, axon, dendrites, synapses, EPSP, IPSP (biophysical mechanisms), Hodgkin Huxley (Na, K, Cl), resting potential, action potential, spikes, conduction speed (Helmholtz), myelin sheath, nodes, saltatory conduction, chemical transmission, Kuffler-GABA, transmitters, linear+nonlinear neural model.

Kuffler receptive fields, fullwave and halfwave rectification. Resume Hubel-Wiesel receptive fields, simple & complex cells, modern measurement by reverse correlation (Hockey, basketball use of reverse correlation), psychophysics reverse correlation, the 2000+ of types V1 receptive fields, optimal stimuli, pyramid structure, tiling,

Simple paper & pencil computation of 1D receptive field processing=> Linear system defined, examples, impulse response as the "mirror image" of the receptive field, pinwheel architecture, how receptive fields are created on successive processing levels by necessarily nonlinear processes (a linear, nonlinear, linear sandwich), bandpass filtering, Blakemore+Campbell 1969 demonstration of human spatial frequency channels, how to derive the channel impulse response from their data requires sine waves and Fourier analysis, developed by examples.

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The above description is much too detailed. The remainer of the perception component of the course, in brief:

The material in Denes & Pinson with additional emphasis on the following:
The production and basic measurement of visual and auditory stimuli (including musical instruments and speech).
Physical measurement of intensity, e.g.,
Luminance (candelas per square meter), sound pressure level, SPL, (dynes per cm)ˆ2, dB, logarithms.

Motion perception as a model visual system illustrating 3 parallel levels of processing that exist in other sensory systems but have not been as extensively studied, and the convergence of different models to yield almost identical predictions.

Then attention:

Required readings in two reviews:
First 9 pages in
Sperling, G., & Dosher, B. A. (1986). Strategy and optimization in human information processing. In K. Boff, L. Kaufman, & J. Thomas (Eds.), Handbook of perception and human performance: Vol. 1. Sensory processes and perception New York: Wiley. (pp. 2-1 to 2-65).

Sperling, G. (2018). A brief overview of computational models of spatial, temporal, and feature visual attention. In T. Lachmann and T. Weis (eds). Invariances in Human Information Processing. New York, N.Y: Routledge, Taylor and Francis Group. Pp. 143-182.

Selections from the classical articles below and/or newer (but potentially more difficult) recent articles:

Wundt, W. An introduction to psychology. (R. Pintner, translator, from the Second German e

1. Pylyshyn, Z. W. & Strom, R. W. (1988).
Tracking multiple independent targets: Evidence for a parallel tracking mechanism.
Spatial Vision, 3 (3), 179-197.

2. Schneider, W. & Shiffrin, R. M. (1977).
Controlled and automatic human information processing: I. Detection, search, and attention.
Psychological Review, 84 (1) 1-66.

3. Link, S. W. The relative judgment theory of two-choice response time. (1975). J. Math. Psych. 12, 144-135.

4a. Sternberg, S. (1964). High-speeed scanning in human memory. Science, 153, 652-654.
4b. McElree, B. and Dosher, B. A. (1990).
Serial position and set size in short-term memory: The time course of recognition. Journal of Experimental Psychology: General, 118, 346-373.

5. Treisman, A. M., and Gelade, G. (1980).
A feature-integration theory of attention. Cognitive Psychology 12 97-136.

6. Wolfe, J. M. (2007). Guided Search 4.0: Current Progress with a model of visual search.

7a. Datta, R. and E. A. DeYoe (2009). "I know where you are secretly attending! The topography of human visual attention revealed with fMRI." Vision Res 49(10): 1037-1044.
1b. bkgd/details
Brefczynski-Lewis, J. A., R. Datta, J. W. Lewis and E. A. DeYoe (2009). "The topography of visuospatial attention as revealed by a novel visual field mapping technique." J Cogn Neurosci 21(7): 1447-1460.

8. Shulman, G. L., Remington, R. W., & McLean, J. P. (1979).
Moving attention through visual space.
Journal of Experimental Psychology:
Human Perception and Performance, 5, 522-526.
