

AN OPERATING MANUAL

The Vision Laboratory
Volen Center for Complex Systems
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June 7, 2017

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¹This coinage, *labspeak*, was suggested by Orwell's coinage "newspeak" in his novel *1984*. Unlike "newspeak", though, *labspeak* is meant to facilitate and sharpen thought and communication, not subvert them.

1 Purpose of this document.

This document is meant to ease newcomers' integration into the operation of the Vision Laboratory at Brandeis University's Volen Center. The document presents a lot of information, but there may be only one truly essential thing for new lab members to know: "If you are uncertain, ask." To repeat: "If you are uncertain, ask."

Corollaries to this advice? "If you're working on a document and are unsure about how it's progressing, ask someone else to read it." "If you're working on a project and realize that you can use some advice, ask for it."

It's simple: do not hesitate to take advantage of fellow lab members' knowledge, fresh eyes and advice. When you encounter something that you don't know, or are not sure about, and have made a good faith effort to work out on your own, it only makes good sense to ask. (And as you identify things that you think should be added to this document, please share them.)

1.1 Writing a manual may be futile, but reading one is not.

Any written document, including this Lab Manual, has limited capacity to communicate new information. As Plato put it in *Phaedrus* (275d-e),

Then anyone who leaves behind him a written manual, and likewise anyone who takes it over from him, on the supposition that such writing will provide something reliable and permanent, must be exceedingly simple-minded; he must really be ignorant.... if he imagines that written words can do anything more than remind one who knows that which the writing is concerned with.

Plato's cynicism about documents like this lab manual may be justified, or not. The writer of this manual may be, as Plato might put it, "exceedingly simple-minded." However, there is no denying that this Lab Manual can achieve its purpose only if it is read, re-read, and kept near at hand for ready reference. Word up!

1.2 Failure and general advice

Stuart Fierstein's 2016 book *Failure: Why science is so successful* is a great source of advice and ideas for researchers –grizzled veterans and fresh-faced beginners alike. Fierstein reminds us that at "its core, science is all about ignorance and failure, and perhaps the occasional lucky accident." If you are incapable of dealing with failure(s), research is probably not your cup of coffee (or tea). As Fierstein puts it, the smooth "Arc of Discovery" in science is a myth; progress in science actually goes in fits and starts, stumbling and lurching along. So be prepared to stumble, but also be ready to recognize when you've been lucky enough to stumble onto something important/interesting.

2 Research projects.

Current projects include research into

- Sensory memory. How we remember, forget, mis-remember, or distort what we see or hear
- Video games in cognitive neuroscience. How gamified experimental platforms can be exploited.
- Multisensory integration and competition. How correlated visual and auditory inputs influence perception and memory
- EEG/ERP studies. Characterizing the neural circuits and states that participate in cognitive control of sensory memory
- Vision and visual memory in aging

3 Research collaborators

Many projects in the lab are being carried out as part of a collaboration with researchers outside the lab. These research partners include: [Art Wingfield](#) (Psychology Dept., Brandeis), [Allison Sekuler](#) and [Pat Bennett](#) (McMaster University, Hamilton, Ontario), [Tim Hickey](#) (Brandeis, Computer Science), [Jason Gold](#) (Indiana University), [Chad Dubé](#) (Univ South Florida), [Jeremy Wolfe](#) (Harvard Medical School), and [Paul Miller](#) (Brandeis University, Biology).

These people are not only our collaborators and colleagues; they are also a valuable intellectual resource for the laboratory. As a courtesy, all initial contacts with our collaborators should be cleared with the lab director.

4 Current/recent publications

Current versions of lab publications, including some papers that are under review, can be downloaded from the *Publications* link on the lab director's website: <http://www.brandeis.edu/~sekuler>

5 Communication

Most work in the lab is collaborative, which makes free and unfettered communication among lab members crucial. In addition to frequent face-to-face discussions, casual chats and debates, and e-mail, we exploit other means for communication.

5.1 Lab meetings

Lab members usually meet as a group once each week, either to discuss some new, interesting publication, and/or to discuss a project ongoing in the lab. Attendance *and* active participation are mandatory.

6 Transparency and Reproducibility

After data have been collected and are safely stored (including multiple backups), they must be analyzed thoroughly –and with utmost care. Those analyses must be documented in detail so that someone else, in the lab or elsewhere, now or in years in the future,² can repeat what the analysis, modifying or expanding on it as desired. The documentation that is required makes the details of one’s work available to other people. This is a requisite for reproducibility of research, and provides a valuable way for us to review, now or in the future, exactly what we did.

Normally, when we analyze data, we write (and debug) code to do our computations, and then write a narrative, say for publication, explaining what we did. Of course, the narrative is not the actual computational process. In fact, this separation of processes, makes it difficult if not impossible for readers to know precisely what was done. And that separation undermines readers’ access to all the behind-the-scenes operations, for example, the details of data analysis and the code that generated graphs.

To address this difficulty, the pioneering computer scientist, Donald E. Knuth articulated a concept he called “literate programming.” Only half-jokingfully, Knuth suggested that programs be thought of as works of literature³ In a 1984 paper entitled, “Literate Programming,” Knuth suggested:

Let us change our traditional attitude to the construction of programs: Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to human beings what we want a computer to do.

When we do “illiterate” programming, we separate (i) writing program code to do our analysis, from (ii) a narrative that explains what the code does, and what the results mean. That’s illiterate programming, and it is by far the most common and easiest way to commit science. But it’s not the only possible way.

As Yihui Xie⁴ notes, it possible to do literate programming that weaves together (“knits”) the source code, the results from the source code, and a narrative account of the code and the results. **R**’s *knitr* package is one excellent way to do integrated, literate programming (see 9.7.2). Working in Matlab, consider **matlabweb** (<https://www.ctan.org/pkg/matlabweb>) to accomplish pretty much the same end. As Krzysztof and Poldrack note⁵ “using one of those tools not only provides the ability to revisit an interactive analysis performed in the past but also to share an analysis accompanied by plots and narrative text with collabora-

²This is not a mere theoretical scenario. A colleague at another institution recently asked me to send materials that I used over a decade ago to analyze some data. I found the materials and shared them with the colleague.

³Knuth invented *TeX*, the typesetting program on which *LaTeX* is based. Knuth credits his work on *TeX* as the stimulus for developing literate programming.

⁴Xie is the developer of *knitr*, a widely-used tool for literate programming. He is also the author of *Dynamic Documents with R and knitr* (2nd edition, 2015), a copy of which is available in the Vision Lab.

⁵“A Practical Guide for Improving Transparency and Reproducibility in Neuroimaging Research,” *PLoS Biology*, 2016

tors.”

7 Experimental subjects.

The lab draws most of its experimental subjects from three sources. Subjects drawn from special populations, including older adults, are not described here.

7.1 Intro Psych pool

For pilot studies that require >10 subjects, each for a short time, we can use subjects from the Intro Psych pool. They are not paid, but receive course credit instead. Because availability of such subjects is limited, if you anticipate drawing on the pool, this must be arranged at the start of a semester. Note that usually we do *not* use the Psych 1A pool for EEG or studies requiring more than an hour.

7.2 Lab members and friends

For pilot studies requiring a few subjects, it is easiest to entice volunteers from the lab or from the graduate programs. Reciprocity is expected. There’s a distinct downside to taking this easiest path to subject recruitment: For some studies, subjects who are too-well versed in your experiment may generate data that cannot be trusted.

7.3 Paid subjects

For studies that require many hours per subject, it’s preferable to recruit paid subjects. Payment is usually \$10 per hour, occasionally with a performance-based bonus designed to promote good cooperation and effort. Subjects in EEG experiments are paid a higher rate, typically \$15 per hour. Paid subjects are recruited in various ways, notably by means of posted notices in the ”Help Wanted” section of [myBrandeis](#)’ Classified Categories. If you post a notice on *myBrandeis*, be aware that the text will be visible to anyone on the internet anywhere, not just Brandeis students, and this sometimes allows inappropriate individuals to contact us about participating in our research.

7.3.1 Groundrules for paid subjects

Subjects are not to be paid if they do not complete all sessions that were agreed to in advance. Subjects should be informed in advance that missed appointments or lateness will be grounds for termination. This is an important policy: experience teaches that subjects who are late or miss appointments in an experiment’s beginning stages, will continue to do so. Subjects who show up, but are extremely tired or whine and complain or are sick are unlikely to give their ”all” during testing. This wastes money and time, but even worse, it noises up your data.

7.3.2 Verify understanding and agreement to comply.

It is a good idea to verify a subject's understanding and full compliance with instructions as early in an experiment as possible. Some lab members have found it useful to monitor and verify subject compliance online, via a webcam. Whatever means you adopt, do not wait until several sessions have passed, only to discover from a subject's miraculously short response times and/or chance level performance, that the subject was, to put it kindly, taking the experiment far less seriously than you'd like.

7.3.3 Get it in writing.

All arrangements you make with paid subjects must be communicated in writing, and subjects must sign off on their understanding and agreement. This is important in order to avoid misunderstandings, e.g., what happens when a non-compliant subject must be terminated.

7.3.4 Paying subjects.

If you are testing paid subjects, you must maintain a list of all subjects, their dates of service, the amount paid, their social security numbers, and signatures. All cash advances for human subjects must be reconciled on a timely basis. This means that must provide Winnie Huie (grants manager in Psychology office) with documentation of the disbursement of the advance.

7.3.5 Human subjects certification.

Do **not** test any human subject until you have been certified to do so. Certification is obtained by taking an internet-based course/exam, which takes about 90 minutes to complete: <http://cme.nci.nih.gov/>. Certification that you have taken the exam will be sent automatically to Brandeis' Office of Sponsored Programs, where it will be kept on file. Print two copies of your certification; give one to the lab director, and retain the other for your own records.

7.3.6 Mandatory record keeping

The U.S. government requires that we report the gender and ethnic characteristics of all subjects whom we test. The least burdensome way to collect the necessary data is by including two questions at the end of each consent form. Then, at the end of each calendar quarter (March 31, June 30, September 30 and December 31), each lab member who's tested any subjects during that quarter should give his or her consent forms to the Lab Director.

7.4 Copying and lab supplies.

Requests for supplies such as pens, notebooks, dry markers for white boards, file folders, etc. should be directed to Lab Director. Everyone is responsible for insuring that shared equipment is kept in good order –that includes any battery-dependent device, the coffee maker, the microwave oven and the printer.

7.5 Laboratory notebooks.

It is important to keep full, accurate, contemporaneous records of experimental details, plans, ideas, background reading, analyses and research-related discussions. Computer records can be used, of course, for some of these functions, but members of the lab are encouraged to supplement them with bound (not loose leaf) paper Lab notebooks. When you begin a new lab notebook, either paper or electronic, be sure to reserve the first page or two for use as a table of contents. Be sure to date each entry, and, of course, keep the book in a safe place.

8 Equipment.

8.1 EyeTracker.

The lab owns an EyeLink 1000 table-mounted, video-based eye tracker. See <http://www.sr-research.com>. It is located in Testing Room B, and can run experiments with displays generated either on a Windows computer or on a Mac. For Mac-based experiments, most people in the lab use Frans Cornelissen's EyeLink toolbox for Matlab <http://cornelis.med.rug.nl/pub/EyelinkToolbox/> The EyeLink toolbox was described in a paper published in 2002 in *Behavior Research, Methods, Instrumentation & Computers*. A .pdf of this paper is available for download from the EyeLink home page (above). The EyeLink Toolbox makes it possible to measure eye movements and fixations, while also presenting and manipulating stimuli via display routines implemented in the Psychophysics Toolbox. The EyeLink Toolbox's output is an ASCII file. Although such files are easily read into Matlab for analysis, be mindful that the files can be quite large and unwieldy.

8.1.1 Eliminating blink artifacts

If you want to analyze EyeLink output in Matlab, as we often do, rather than using EyeLink's limited, built-in functions, you must deal with format issues. Matlab cannot read files in EyeLink's native output format (.edf), but can read them after they've been transformed to ASCII, which is an option with the EyeLink. Preprocessing of ASCII files should include identification and elimination of peri-blink artifacts, during the brief period when the EyeLink has lost the subject's pupil. Brian Gold, a lab alumnus, wrote a Perl script for this purpose; his code is wicked fast, operating on an entire 30 Mb file in about 5 seconds on a 1.5 MHz CPU. Brian's script is available on one of the lab servers. For a quick online tutorial on Perl, which stands for "Practical Extraction and Report Language", go to <http://archive.ncsa.uiuc.edu/General/Training/PerlIntro/>.

8.2 Electroencephalography.

For EEG/ERP (event-related potential) studies the lab uses powerful EEG system: an EGI dense geodesic array System 250, which uses high impedance electrodes. (EGI, by the way, is Electrical Geodesics, Inc.) With this Macintosh-based system, the time required by an experienced user to set up a subject, and to confirm the impedances for the 128 electrodes, is ~10-12 minutes. Note the word "experienced" in the previous sentence; it's important.

The lab also owns a license for [BESA](#) (Brain Electrical Source Analysis), a powerful software system for analyzing EEG/ERP data. In addition, the lab owns two excellent books that introduce readers to the fine art of recording, analyzing, and making sense of ERPs.: Todd Handy's edited volume [Event Related Potentials: A Methods Handbook](#) (MIT Press, 2005), and Steve Luck's [An Introduction to the Event-Related Potential Technique](#) (MIT Press, 2005).

8.3 Photometers and Matters Photometric

The lab owns a Minolta LS-100 photometer, which is used to calibrate and linearize stimulus displays. For use, the photometer can be mounted on the lab's large aluminum tripod for stability. After finishing with the instrument, the photometer **must** be turned off and returned to its case, with its lens cap replaced. This is essential for the protection of the photometer, and so that its battery will not run down, making the photometer unusable by the next person who needs it. Luminance measurements should always be reported in candelas/m². A second, more compact device is available for calibrating displays, an [Eye-One Display 2](#) from Greatagmacbeth. Section 8.3.1 describes one important application of the Eye-One Display.

8.3.1 Display Linearity.

A cathode ray tube display's luminance depends upon the analog signal the CRT receives from the computer; that signal, in turn, depends upon a numerical value in the computer's digital to analog converter (DAC). Display luminance is a highly non-linear function of the DAC value. As a result, if a series of values passed to the DAC are sinusoidal, for example, the screen luminance will *not* vary sinusoidally. To compensate, a user must linearize the display by creating a table whose values compensate for the display's inherent non-linearity. This table, called a lookup table (LUT), can be generated in OS9 and Matlab 5.x, using the lab's Minolta 1000 photometer, together with a Matlab[®] routine called "calibration." That routine is found in JMGtoolbox for Matlab.

In OSX, calibration requires the lab's GretaMacbeth *Eye-One Display 2* colorimeter, which can profile the luminance output of CRT, LCD, and laptop displays. The steps needed to produce an OSX LUT with this colorimeter are outlined in a document prepared by Kristina Visscher. For details on CRT linearity and lookup tables, see R Carpenter & JG Robson's book *Vision Research: A Practical Guide to Laboratory Methods*, a copy of which is kept in the lab. A brief introduction to display technology, lookup tables, graphics cards, and display specification can be found in DH Brainard, DG Pelli, and T Robson (2002) Display characterization, from the *Encyclopedia of Imaging Science and Technology*, J. Hornak (ed.), Wiley, 172-188. This chapter can be freely downloaded from <http://www.psych.nyu.edu/pelli/pubs/brainard2002display.pdf>.

8.3.2 Photometry vs. Radiometry.

What quantity is measured by lab's Minolta photometer, and why does that quantity matter? An answer must start with *radiometry*, the determination of the power of electromagnetic

radiation over a wide range of wavelengths, from gamma rays (wavelength $\approx 10^{-6}$ nm) to radio waves (wavelength ≈ 1 km). Typical units used in radiometry include watts. The human eye is insensitive to most of this range (typically, the human eye is sensitive only to radiation within 400-700 nm), so most of the watts in the electromagnetic spectrum have no *visual* effect. Photometry is a system that evaluates or weights a radiometric quantity by taking into account the eye's sensitivity. Note that two light sources can have precisely the same *photometric* value –and will therefore have the same visual effect– despite differing in *radiometric* quantity.

8.4 Computers.

Most of the laboratory's two-dozen computers are Apple Macintoshes of one kind or another. We also own five or six Dell computers, one of which is the host machine for our Eyelink Eye-Tracker (See Section 8.1); the remaining Dells are used in our electroencephalographic research (See Section 8.2) and in some of our imitation/virtual reality research.

8.4.1 Lab Computers

As most of the lab computers have LCD (liquid crystal display) rather than CRT displays, they may be less suitable for luminance/contrast crucial applications. LCD displays have a strong angular dependence: even small changes in viewing angle alter the retinal illuminance; additionally, LCDs have relatively sluggish response, and require long warmup time before achieve luminance stability.

8.4.2 Laptops.

The lab owns a herd of Macintosh iMacs, macMinis and MacBook Pros. Laptops are lent to lab members who have long-term need for such machines.

8.4.3 Scheduling lab computers.

When you need regular access to a particular computer, such as for running subjects, please use the lab's web calendar to reserve the testing room you need.

8.4.4 Backup. Backup. Backup. Backup. Backup.

Backing up data and programs could not be more important. They should be done regularly –obsessively, even. If you have even the slightest doubt about the wisdom of backing up, talk to someone who has suffered a catastrophic loss of data or programs that were not backed up. And such victims are very easy to find. Lab members have several different ways to backup. One option is to use the lab's dedicated backup space made available by the university. See the Lab Director for info.

8.5 Contrast sensitivity charts.

To screen and characterize subjects for experiments with visual stimuli, we use either the Pelli-Robson contrast sensitivity charts, or the newer, “Lighthouse” charts, which are more convenient and possibly more reliable than the [Pelli-Robson charts](#).

8.6 Audiometrics

To support experimental protocols that entail auditory stimuli, the laboratory owns a sound level meter and a Beltone audiometer. For audio-critical applications, stimuli should be delivered via the lab’s Sennheiser headphones. All subjects tested with auditory stimuli should be audiometrically screened and characterized. When calibrating sound levels, be sure that the appropriate weighting scale, A or C, is selected on the sound level meter. It matters. The normal, young human ear responds best to frequencies between 500 and 8 kHz, and is less sensitive to frequencies lower or higher than these extremes. To ensure that the meter reflects what a subject might actually hear, the frequency weightings of sound level meters are related to the response of the human ear.

It is extremely important that sound level measurements be taken with the correct frequency weighting -usually, this is the A-weighting. For example, measuring a tonal noise of around 31 Hz could result in a 40 dB error if using C-weighting instead of A-weighting. The A-weighting tracks the frequency sensitivity of the human ear at levels below ~ 100 dB. Any measurement made with the A-weighting scale is reported as dBA or $db(A)$. At higher levels, ~ 100 dB and above, the human ear’s response is flatter, as represented in the C-weighting. Figure 1 shows the frequency weighting produced by the A and C scales. Incidentally, there are other standard weighting schemes, including the B-scale (and blend of A and C), and perfectly-flat Z-weighting scale, which certainly does not reflect the perceptual quality –produced by the ear and brain– called *loudness*.

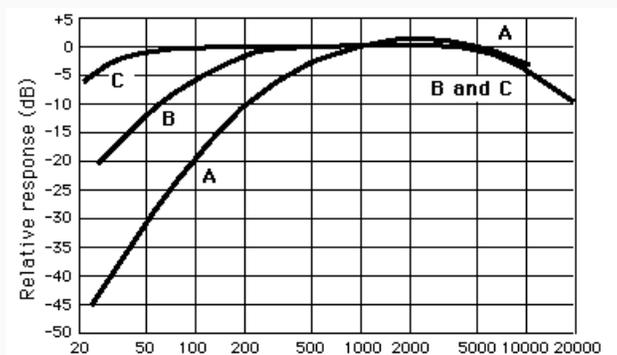


Figure 1: Frequency weights for the A, B and C scales of a sound level meter.

9 Essential software.

Several software packages are essential for the lab’s experiments, modeling, data analysis, and manuscript preparation. Here is a brief introduction to each of those packages.

9.1 MATLAB.

Most of the lab's experiments make use of MATLAB, often in concert with the [PsychToolbox](#). The PsychToolbox's hundreds of functions afford excellent low-level control over displays, gray scale, stimulus timing, chromatic properties, and the like. The current stable (non-beta) version of the PsychToolbox is 3.10; its [Wiki site](#) explains the advantages of the PsychToolbox, and gives a short tutorial introduction.

9.1.1 MATLAB reference books.

Outside of the several web-based tutorials, the single best introduction to MATLAB, hands down, is David Rosenbaum's *MATLAB for Behavioral Scientists* (2007, Lawrence Erlbaum Publishers). Rosenbaum is a leader in cognitive psychology, an expert in motor control, so the examples he gives are super useful and salient for lab members. Rosenbaum's book is a fine way to learn how to use MATLAB in order to control sound and image stimuli for experiments. A close second on the list of useful MATLAB books is *Matlab for Neuroscientists: An Introduction to Scientific Computing in Matlab* (Academic Press, 2008) by Pascal Wallisch, Michael Lusignan, Marc Benayoun, Tanya I. Baker, Adam Seth Dickey, and Nicho Hatsopoulos. This book is especially useful as for learning how MATLAB can be used for data collection and analysis of neurophysiological signals, including signals from EEG. For a more plain-vanilla introduction, the lab owns several copies of *Mastering Matlab*, by [Duane Hanselman](#) & Bruce Littlefield.

9.1.2 Debugging in MATLAB.

A good deal of program development time and effort is spent debugging and fine-tuning code. Matlab has a number of built-in tools that are meant to expedite eradicating all three major types of bugs, typographic errors (typos), syntax errors, and algorithmic errors; for a brief, but useful introduction to these tools, go to the [Matlab debugging](#) introduction page on the web.

9.1.3 MATLAB-PsychToolbox introductions.

Keith Schneider (University of Missouri) has written an terrific, short, five-part introduction to generating vision experiments using MATLAB and the Psychtoolbox. Schneider's introduction is appropriate for people with no experience programming, or no experience with computer graphics or animation. Schneider's document can be downloaded from his website: <http://web.missouri.edu/~schneiderkei/ptb.htm>. Mario Kleiner (Tuebingen University) has produced a very worthwhile tutorial on the current version of Psychtoolbox: <http://www.kyb.tuebingen.mpg.de/bu/people/kleiner/m/ptbosx/ptbdocu-1.0.5MK4R1.html>.

9.2 Best coding practices

Because most of our work is collaborative, it is very important to make sure that coding, as in *MATLAB*, is done in a way to facilitates collaboration. In that spirit, Brian J. Gold, a lab alumnus, crafted a set of norms that should be followed when coding. The aim of

these Commandments? To facilitate debugging, and to aid understanding of code written by someone else (or by you, some time ago). Here are the highlights; a more detailed description is available on the web, at <http://brandeis.edu/~sekuler/codingCommandments.html>.

- Thou shalt give meaningful, descriptive names to program- and analysis-files.
- In Matlab code, thou shalt use the SmartIndent feature.
- In Matlab code, thou shalt begin each program with a descriptive set of comments, including your name and date of your revision.
- In Matlab, thou shalt use the change log feature.
- Thou shalt comment thy code with generosity of spirit.
- Thou shalt make liberal use of white space to make code easier to read/follow/decipher.
- Before asking others for help with code, be sure thou hast obeyed all the preceding commandments.
- Thou shalt assign files meaningful, easily remembered and easily interpreted names.

9.2.1 Final coding commandment

A Commandment important enough to merit its own section.

- Thy code with which experiments are run must ensure that everything about the experiment is saved to disk: everything.

“Everything” goes far beyond the ordinary information, such as subject ID, age, date and time; “everything” includes *every* detail of the display or sound card calibration, viewing distance, and the details of every stimulus presented on every single trial (*e.g.*, contrast, frequency, duration, location), as well as every response (*e.g.*, the judgment and its associated response time) made on every single trial. There can be no exceptions. And all of this information such be in a format that makes it relatively to analyze, including for insights that were not anticipated when the experiment was being designed. That means each item in the record should be labelled so that someone else can look at the record and understand what each item represents. It goes without saying that information not captured when an experiment is run is lost forever, which can greatly diminish the value of the experiment.

9.3 Skim: PDF reading, filing and annotating

Currently at version 1.4.14, *Skim* is brilliant Mac-only software that can be used for reading, annotating, searching and organizing PDFs. *Skim* works and plays well with *BibDesk*, which is a big plus. You can search, scan, and zoom through PDFs, but you also get many custom features for your work flow, including:

- Adding and editing notes
- Highlighting important text
- Making “snapshots” for reference
- Reading while in full screen mode
- Giving presentations

9.4 Inspect your data; inspect your data; inspect your data

Data analysis software can do its job too well, making data analysis seem too easy. You enter your data, and out pops tables of numerical summaries, including ANOVAs, regression coefficients, etc. The temptation is to base your interpretation of your data on these summaries, without taking time to inspect the underlying data. That's not good; in fact, it can be downright disastrous: Numerical summaries can be very misleading. So inspect your data at appropriate level(s), for example, at the level of individual subjects. Be sure that the software has read in and interpreted values correctly. Be sure that rows and columns have not been interchanged or mislabelled. Remember: Garbage in, garbage out. If the data are incorrect, it would be a true miracle if the analysis on the input data turned out to be correct.

In doing a careful inspection of the data, verify that a result is not unduly influenced by the behavior of one or a just a few subjects. And of course think long and hard about the variability in your data. To expand on this point, consider three of the data sets (1-3) in Figure 2. (These data come from 1973 paper by F. J. Anscombe in *American Statistician*). If your software computed a simple linear regression for each of the data sets, you'd get the same numerical summary values (regression equation, r^2). In each case, the best-fit regression equation is exactly the same: $y = 3 + 0.5X$, with $r^2 = 0.82$. But if you took the time to *look* at the plots or even better, wade through the underlying raw data, you would realize that equal r^2 values or not, there are substantial differences among what the different data sets say about the relationship between \mathbf{x} and \mathbf{y} . As John Fox⁶ put it, "Statistical graphs are central to effective data analysis, both in the early stages of an investigation and in statistical modeling." One last bit of wise advice about graphs, this from John H. Maindonald and John Braun⁷

Draw graphs so that they are unlikely to mislead.⁸ Ensure that they focus the eye on features that are important, and avoid distracting features. Lines that are designed to attract attention can be thickened.

That's good advice, which should be heeded by anyone who appreciates the role the perception plays in reading graphs.

9.5 Graphing software.

Graphs are important, very important. But how can you make ones that best serve your needs? Matlab and **R** are two software suites that the lab uses to produce graphs. Depending upon how much care is expended, the resulting graphs can range in quality from "quick and dirty" rough sketches all the way up to publication quality graphs.

⁶ *Applied Regression Analysis, Linear Models, and Related Methods*, Sage Publications, 1997)

⁷ *Data analysis and graphics using R*, 2nd ed, 2007, p. 30

⁸ For an example of highly misleading graphs, see Figure 3.

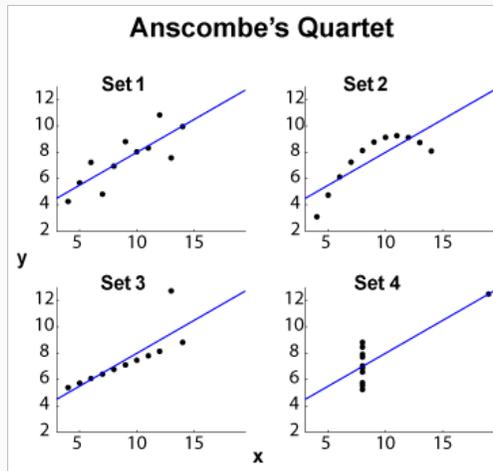


Figure 2: Plots of data sets from Anscombe (1973)

9.5.1 Venial sins

No matter what software you use to graph your data, be careful *never ever* to commit either of the following venial sins⁹

9.5.2 Venial Sin 1: Scale/size of y-axis.

It is difficult to compare graphs or neuroimages when their y-axes cover different ranges. In fact, such graphs or neuroimages can be downright misleading. Sadly, though, many programs seem not to care, but you must. Check your graphs to make **absolutely** sure that their y-axis ranges are equivalent. Do not rely on the graphing program's default choices.

The graphs in Figure 3 illustrate this point. Each graph presents (fictitious) results on three tasks (1, 2 and 3) that differ in difficulty. The graph at the left presents results from subjects who had been dosed with Peets' coffee; the graph at the right presents results from subjects who had been dosed with Starbucks coffee. Clearly, at first, quick glance, as in a Keynote/Powerpoint presentation, a viewer may conclude that Peets' coffee leads to far better performance than Starbucks. This error arises from a careless (hopefully, not intentional) change in y-axis range.

9.5.3 Venial Sin 1a: Color scales.

It is difficult to compare neuroimages whose color maps differ from one another.

9.5.4 Venial Sin 2: Unwarranted metric continuum.

If the x-axis does not actually represent a continuous metric dimension, it is not appropriate to incorporate that dimension into a line graph; a bar graph or box plots are preferred alternatives. Note that ordinal values, such as "first", "second", and "third", or "high",

⁹As [Wikipedia](#) explains, a venial sin entails a partial loss of grace and requires some penance; this class of sin is distinct from a mortal sin, which entails eternal damnation in Hell –not good.

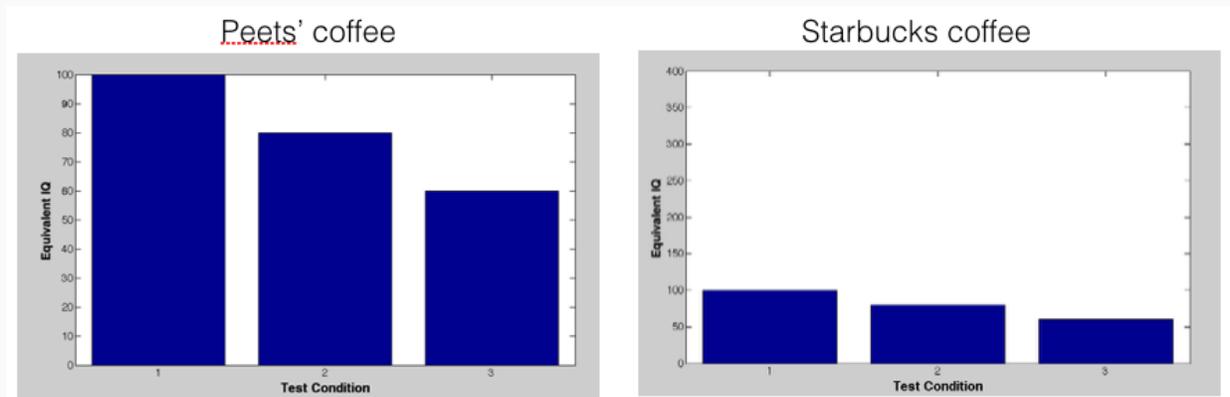


Figure 3: Subjects performance on Tasks 1, 2 and 3 after drinking Peets' coffee (left panel) and after drinking Starbucks coffee (right panel). At first glance, performance *seems* to be far better with Peets', but look more carefully: the scales of the vertical axes differ by $4\times$. In fact, the two sets of data are numerically identical. Note also, that neither graph has error bars, which would indicate the underlying variability of the measurement. With sufficiently large variability, differences among conditions in each panel might be unreliable.

“medium”, and “low”, do *not* comprise a proper continuous dimension, nor do categories such as “younger subjects” and “older subjects”.

9.5.5 Venial Sin3: Graphics that are pretty but misleading.

Bar graphs and line graphs are common ways to present results. However, even with appropriate error bars, they may not accurately reflect the underlying data, a point made clearly in a recent paper by TL Weissgerber *et al.* (Beyond Bar and Line Graphs: Time for a New Data Presentation Paradigm, *PLoS One* 2015). As they put it, we urgently need to change our practices for presenting continuous data in small sample size studies. Papers rarely included scatterplots, box plots, and histograms that allow readers to critically evaluate continuous data. Most papers presented continuous data in bar and line graphs. This is problematic, as many different data distributions can lead to the same bar or line graph. The full data may suggest different conclusions from the summary statistics. Solutions include the use of dotplots, box plots or the like, as in Fig. 4. Incidentally, the Weissgerber *et al.* article presents some compelling graphical demonstrations of cases in which bar and line graphs seriously misrepresent the underlying data.

9.5.6 Matlab graphics

Matlab makes it easy, very easy, to plot your data. So easy, in fact, that you might overlook the fact that the results often are not quite what you really want. The following hints may help to enhance the appearance of Matlab-produced graphs.

Making more-effective ones Matlab affords control over every feature of a graph –color, linewidth, text size, and so on. There are three ways to take advantage of this potential.

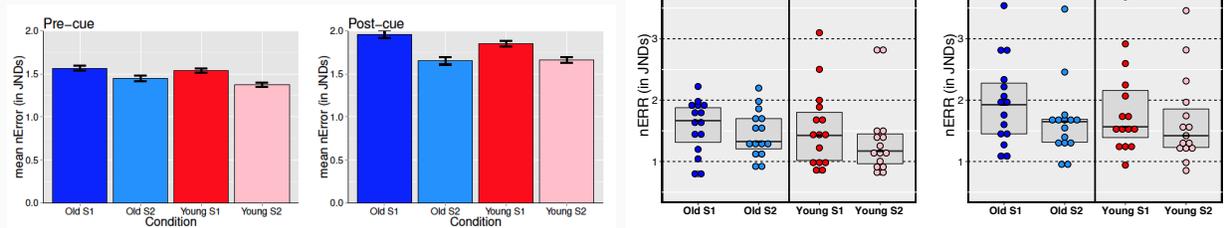


Figure 4: Left: Bar graphs showing some typical data (from R. Sekuler, Huang, A. B. Sekuler & Bennett). Right: Dotplots of the same data. Each dot represents a single subject; error bars are within subject standard errors of the mean. The box overlaying the dots covers range from first to third quartile; the horizontal line inside each box is the median value. Note that the dot plots, but not the bar graphs, make it possible to see the large differences among subjects.

One is to make the changes from the plain-vanilla unattractive, standard, default format via interactive manipulation of the features you want to change. For an explanation of how to do this, check Matlab’s Help menu. A second approach is to use the powerful figure editor built into Matlab (this is likely to be the easiest approach, once you learn the editor’s in’s and out’s). A final way is to hard-code the features you want, either in your calling program or with a function called after an initial, plain-vanilla plot has been generated. This latter approach is especially good when you’ve got to generate several graphs and you want to impose a common, attractive format on all of them. Figure 5 shows examples of a plain vanilla plot from a Matlab simulation and a slightly embellished plot of the same simulation. Just a few lines of code can make a huge difference in a graph’s appearance and its effectiveness. For sample, simple, easily-customized code for embellishing plain-vanilla Matlab plots, check [this webpage](#).

Finally, excellent publication quality graphs can be made in **R**, using either its base (default) graphics or Hadley Wickham’s *ggplot* package.

9.6 Software for drawing/image editing.

The lab’s standard drawing/illustration programs are *EazyDraw* and *Inkscape*, both powerful and flexible pieces of software, which are worth learning to use. *EazyDraw* can save output in different formats, including .svg and .png, which are useful for import into KeyNote or PowerPoint presentations. (.tiff stands for “Tagged Image File Format”.) *Inkscape* is freely-downloadable vector graphics editor with capabilities similar to those of Illustrator or Corel-Draw. To learn whether Inkscape would be useful for your purposes, check out the brief, basic tutorial on inkscape.org’s website, <http://www.inkscape.org/doc/basic/tutorial-basic.html>. To run *Inkscape* on a Mac, you will also need to install X11. This is an environment that provides Unix-like X-Window support for applications, including *Inkscape*.

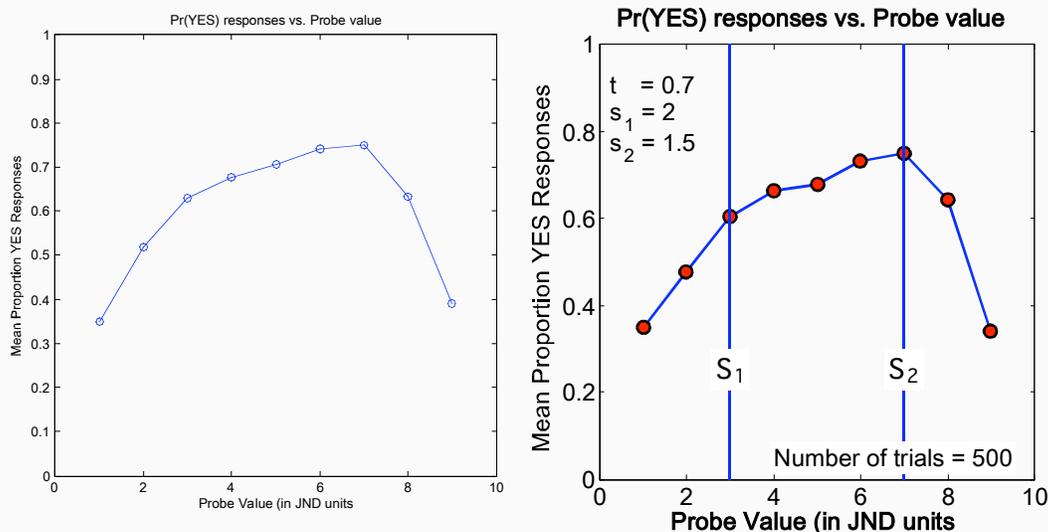


Figure 5: Graphs produced by a Matlab simulation of a recognition memory model. Left: A “plain vanilla” plot generated using default plot parameters; Right: A modestly-embellished plot that was generated by adding just a few lines of code to the Matlab plotting code. Especially useful, are labels that specify the parameter values used by the simulation.

9.6.1 Graphics editing.

Simple editing, reformatting, and resizing of graphics are conveniently done in *Graphic Converter*, a wonderful shareware program developed by Thorsten Lemke. This relatively small, but powerful program is easy to use. If you need to crop excess white space from around a figure, *Graphic Converter* is one vehicle; Adobe Acrobat, not Acrobat Reader, is another; the Macintosh *Preview* is a third. Cropping is important for trimming .pdf figures that are to be inserted into L^AT_EX documents (see section 12.2). Unless the .pdf figure has been cropped appropriately, there will excess –sometimes, way too much excess– white space around the resulting figure. And that’s not good. *GIMP*, an acronym for “GNU Image Manipulation Program”, is a powerful, freely downloadable, open source raster graphics editor that is good for tasks including photo retouching, image composition, edge detection, image measurement, and image authoring. The [OSX version](#) of this cross-platform program comes with a set of “plug-in”s that are nothing short of amazing. To see if GIMP might serve your needs, look over the many beautifully illustrated step by step [tutorials](#).

9.6.2 Fonts.

When generating graphs for publication or presentation, use standard, sans serif fonts, such as Geneva, Helvetica or Arial. Text in some other fonts may be “messed up” when graphics are transformed into .pdf or .tiff or .png.

9.6.3 ftp’ing.

FTP stands for “file transfer protocol.” As the term suggests, ftp’ing involves transferring files from one computer to another. For Macs, FETCH is the lab’s standard client for *secure*

file transfer protocol (sftp), which is the only file transfer protocol allowed for accessing Brandeis' servers. The current version of FETCH is 5.7.6.

9.7 Statistical analysis

9.7.1 Matlab

Matlab's Statistics Toolbox supports many different statistical analyses, including multidimensional scaling. Standard Matlab installations do not provide routines for doing some of the statistics that are important in the lab, e.g., repeated-measures ANOVAs. However, good routines for one-way, two-way, three-way repeated measure ANOVAs are available from the Mathworks' fileExchange. To find the appropriate Matlab routine, do a search for ANOVA on <http://www.mathworks.com/matlabcentral/fileexchange/loadCategory.do?objectType=category&objectId=6>.

Brandeis has a campus wide site license for SPSS, but lab members are encouraged to avoid SPSS like the plague that it is. Graphs produced by SPSS are, to put it nicely, well-below lab standards; SPSS's output is cumbersome, and its proprietary code can make it difficult to know all the details of an analysis. Because backwards compatibility is not a high propriety for the SPSS makers, an analysis run today may not yield the same results some years in the future, when SPSS code has changed, and the version originally used will no longer be available. Sad!

9.7.2 R

Lab members are encouraged to learn to use **R**, a powerful, flexible statistics and graphical environment. **R** is freely downloadable from the web, and is easily installed on any platform. **R** is tested and maintained by some of the world's leading statisticians, which means that you can rely on **R**'s output to be correct. The current version of **R** is 3.40 (fancifully codenamed "Your Stupid Darkness"). Among **R**'s many virtues are its superb data visualization ability, including [sophisticated graphs](#) that are perfect for inspecting and visualizing your data (see section 9.4. **R** also boasts superb routines for bootstrapping and permutation statistics (see section 9.7.3. **R** can be downloaded from <http://www.r-project.org/>, where you can also download various **R** manuals. Yuelin Li and Jonathan Baron (University of Pennsylvania) have written a brief, but excellent introduction to **R**, *Behavioral research data analysis with R*, which includes detailed, explanations of logistic and linear regression, basic R graphics, ANOVAs, etc. Li and Baron's book is available to Brandeis users as an internet resource, either viewable online or downloadable as a pdf. Another R resource is *Using R for psychological research: A simple guide to an elegant package* is precisely what its title claims: An excellent introduction to **R**. This guide, created by [Bill Revelle](#) (Northwestern University), was recently updated and expanded. Revelle's guide includes useful **R** templates for some of the lab's common data analysis tasks, including repeated measures ANOVA, and pretty nice [box and whisker plots](#).

RStudio. Although **R** can be run from its command line interface, its power and usefulness is greatly amplified when run within the sophisticated GUI¹⁰ of **RStudio**. **RStudio** is free and open source, and works great on Windows, Mac, and Linux. It can be downloaded from RStudio.com. From this website you can download “cheatsheets”, summaries that explain how to exploit many of **RStudio**’s features. Useful and very effective short [webinars](#) explain **RStudio**’s essentials. Finally, **RStudio** makes it very easy to generate reproducible and literate data analyses, using the *knitr* package.

Some R tips Here is a highly-selective, quite incomplete set of pointers to useful **R** features.

- **head** and **tail** functions. These functions give convenient short form summaries of a matrix or data frame. The first several rows of a matrix or data frame are printed by a call to *head*, and the last several rows are printed by a call to *tail*. Example? “head(x, n=6)” causes the first 6 rows of matrix x to be printed. These functions have many uses, including verifying that the data read in actually conform to what you’d expected.
- **ez** This **R** package contains some components that are extremely useful for data analysis. Take just two of those components. **ezStats** provides very easy computation of descriptive statistics (between-Ss means, between-Ss SD, Fisher’s Least Significant Difference) for data from factorial experiments, including purely within-Ss designs (i.e., repeated measures), purely between-Ss designs, and mixed, within-and-between-Ss designs. **ezANOVA** provides very easy analysis of data from factorial experiments, including purely within-Ss designs (i.e., repeated measures), purely between-Ss designs, and mixed within-and-between-Ss designs. Its output includes ANOVA results, effect sizes (generalized η^2 and assumption checks. Both of these **ez** components live up to their names: they are easy to use.

9.7.3 Normality and other convenient myths

In a 1989 *Psychological Bulletin* article provocatively titled, “The unicorn, the normal curve, and other improbable creatures,” Theodore Micceri reported his examination of 440 large-sample data sets from education and psychology. Micceri concluded that “No distributions among those investigated passed all tests of normality, and very few seem to be even reasonably close approximations to the Gaussian.” Before dismissing this discovery, remember that standard parametric statistics –such as the *F* and *t* tests– are called “parametric” because they are based on particular assumptions about the population from which the sampled data have been drawn. These assumptions usually include the assumption of normality. Gail Fahoome, an editor of the (online) *Journal of Modern Statistics Methods*, quoted one statistician as saying, “Indeed, in some quarters the normal distribution seems to have been regarded as embodying metaphysical and awe inspiring properties suggestive of Divine Intervention.”

Bootstrapping, Permutation Tests and Robust statistics When data are not normally distributed (which is almost all the time for samples of reasonable size) or when sets of

¹⁰Technically, this is not merely a GUI; it is an integrated development environment (IDE).

data do not have equal variance, the application of standard methods (ANOVA, t -test, etc.) can produce seriously wrong results. For a thorough, but depressing description of the problem, consult the lab's copy of [Rand Wilcox's](#) little book *Fundamentals of Modern Statistical Methods: Substantially Improving Power and Accuracy* (2002). Wilcox also describes one way of addressing the problem, robust statistics. These include the use of sophisticated, so-called M -statistics or even garden variety medians as measures of central tendency, rather than means. Other approaches commonly used in the lab are various *resampling methods* such as bootstrapping and permutation tests. Simple introductions to these methods can be found at http://bcs.whfreeman.com/pbs/cat_160/PBS18.pdf, and in a web-book by [Julian Simon](#). Note that these two sources are *introductory*, with all the limitations implied by that adjective. (The section on Error bars & confidence intervals explains another application of bootstrapping.)

9.7.4 Error bars & confidence intervals.

Graphs of results are difficult or impossible to interpret without error bars. Usually, each data point should be accompanied by ± 1 standard error of the mean (SeM), that is, SD/\sqrt{n} , where n is the number of subjects. Off-the-shelf software produces incorrect values of SD, and consequently of SeM. Basically, such software conflates between-subject and within-subject variance—we want only within-subject variance, with between-subject variance factored out. The discrepancy between ordinary SDs and SeMs on one hand and their within-subject counterparts grows with the difference among subjects. Explanations of how to compute and use such estimates can be found in a paper by [Denis Cousineau](#),¹¹ and in publications by [Geoff Loftus](#). For a good introduction to error bars of all sorts, download [Jody's Culham's PowerPoint](#) presentation on the topic.

Finally, editors of many journals recognize the value of confidence intervals, but there are many methods for generating such values. Some methods assume that your data are distributed normally, others make no assumption about the underlying distribution. Given that your distribution is only rarely normal, assumption-free estimates of confidence intervals are preferred. One really good method is the adjusted bootstrap percentile procedure, which is implemented by the “bcacanon” function available in R's “bootstrap” package. This procedure is easy and fast to use, which is always to the good.

10 Experimental design.

Without good, smart, efficient experimental design, an experiment is pretty much worthless. The subject of good design is way too large to accommodate here—it requires books (and courses), but it is vital that you think long and hard about experimental design well before starting to collect data. The most common fatal errors involve confounds—where two independent variables co-vary, so that one cannot partition resulting effects cleanly between those variables. The second most common error is to implement a design that is bloated, that is, loaded down with conditions and manipulations not all of which are necessary for

¹¹Note: there are multiple arithmetic errors in Table 2 of Cousineau's paper

addressing the hypothesis of interest. There is much more to say about this crucial issue; nearly every one of our lab meetings touches on issues related to experimental design –how the efficiency and power of a particular design could be improved.

11 Literature sources.

11.1 Electronic databases.

Two online databases are particularly useful for most of our lab’s research: PubMed and PsycINFO. These are described in the following sections.

11.1.1 PubMed

PubMed <http://www.ncbi.nlm.nih.gov/entrez/query.fcgi>. PubMed is freely accessible portal to the Medline database. It can be accessed via web browser from just about anywhere there’s a connection to the internet¹², off-campus, on-campus, at a beach, on a mountaintop, etc. It can also be searched from within BibDesk, as explained in Section 12.5. HubMed is an alternative, browser-accessible gateway to the same Medline database; HubMed offers some useful novel features not available in PubMed. These include a graphic, tree-like display of conceptual relationships among references, and easy export in .bib format, which is used with L^AT_EX (see Section 12.2). To reveal a conceptual tree in HubMed, select the reference for which you want to see related articles, and click “TouchGraph.” This invokes a Java applet. Once the reference you selected appears on the screen, double click it to expand that item into a conceptual network. You will be rewarded by seeing conceptual relationships that you had not thought of before. For illustrations of this process in action, go to <http://www.brandeis.edu/~sekuler/hubMedOutput.html>.

11.1.2 PsycINFO.

Another online database of interest is PsycINFO, which can be accessed from the Brandeis Library [homepage](#) –under [Find articles & databases](#). PsycINFO includes article and books from psychology sources; these books and many of the journal articles are not available in PubMed. To access PsychINFO from off campus, your web browser’s proxy settings should be set according to instructions on the library’s homepage.

11.1.3 CogNet.

This database maintained by MIT <http://cognet.mit.edu/> is accessible through Brandeis’ license with MIT. CogNet includes full text versions of key MIT journals, and books in both neuroscience and cognitive science, e.g. Michael Gazzaniga’s edited volume *The Cognitive Neurosciences, 4e* (2009), and *The MIT Encyclopedia of Cognitive Sciences*. The site is also a source of information about upcoming meetings, jobs, and seminars.

¹²This term follows the usage pioneered by the 43rd President of the United States

12 Document preparation.

12.1 General advice.

Some people prefer to work and re-work a manuscript until, in their view, it is absolutely, guaranteed, 100% perfect –or at least within ϵ of absolute perfection. Because the Vision Lab operates in an open, collaborative mode, keeping a manuscript all to yourself until you are sure it has achieved perfection is almost always a suboptimal strategy. It is a better idea, once a first draft of a document or document sections has been prepared, to seek comments and feedback from other people in the lab. People should not hesitate to share “rough” drafts with other lab members; advice and fresh eyes can be extremely valuable, save time, and minimize time spent in blind alleys.

12.2 L^AT_EX

L^AT_EX is the lab’s official system for preparing, editing, and revising documents. L^AT_EX is not a word processor; it is a document preparation and typesetting system. It excels in producing high-quality documents. L^AT_EX intentionally separates two functions that word processors, like Microsoft Word, conflate:

- Generating and revising words, sentences, and paragraphs, and
- Formatting those words, sentences and paragraphs

L^AT_EX allows authors to leave document design to document designers, while focusing on writing, editing and revising. Information about L^AT_EX for Macintosh OSX is available from the wiki, http://mactex-wiki.tug.org/wiki/index.php?title=Main_Page. L^AT_EX does have a bit of a learning curve, but users in the lab will confirm that the return is really worth the effort, particularly for long or complicated documents: manuscripts, theses, dissertations, grant proposals. It is also excellent for generating useful, reader-friendly cross-references and clickable hyperlinks to internet URLs, and during revisions of manuscripts, both of which greatly enhance a document’s readability. These features are well-illustrated by this very document, which was generated, of course, in L^AT_EX. For advice about starting to work with L^AT_EX, ask Bob or any other of the lab’s L^AT_EX-experienced users.

12.2.1 Obtaining and installing L^AT_EX on a Macintosh computer.

There are three or four ways to obtain and install L^AT_EX—assuming a clean install, that is, an installation on a computer that has no already-existing L^AT_EX installation. The easiest path to a functional L^AT_EX system is to download the MacTeX install package <http://www.tug.org/~koch>, which is maintained by Richard Koch (University of Oregon). The package includes all the components needed for a well functioning L^AT_EX system. The MacTeX site even offers a video that illustrates the steps to install the package once download has completed.

12.2.2 Where do L^AT_EX components and packages belong?

When MacTeX’s installer is used for a clean install, the installer has the smarts to know where various components and packages *should* be put, and puts them all in their place.

That ability greatly facilitates what otherwise would be a daunting process, as L^AT_EX expects to find its components and packages in particular locations. If you find that you must install some package on your own –say, a package not included among the many, many that come with MacTeX– files have preferred locations, which vary with the type of package or file. As the names of different types of files contain characteristic suffixes, the rules can be described in terms of those suffixes. In the list below, \sim signifies the user’s root directory.

- Files with suffix *.sty* should be installed in \sim /Library/texmf/tex/latex/misc
- Files with suffix *.cls* should be installed in \sim /Library/texmf/tex/latex
- Files with suffix *.bib* should be installed in \sim /Library/texmf/bibtex/bst/
- Files with suffix *.bst* should be installed in \sim /Library/texmf/bibtex/bib/.

12.2.3 Reference books and resources.

The lab owns some excellent reference books on L^AT_EX, including Daly and Kopka’s *Guide to L^AT_EX* (3rd edition), and Mittelbach, Goossens, Braams, Carlisle, and Rowley’s huge volume, *The L^AT_EX Companion* (2d edition). Recommendation: look first in Daly and Kopka; although *The L^AT_EX Companion* is far more comprehensive, its sheer bulk (>1000 pages) can make it hard find the answer to your particular question –unless, of course, you swallow your pride and turn to the massive index! Finally, the internet is a veritable treasure trove of valuable L^AT_EX-related resources. To identify just one of them, very good hypertext help with L^AT_EX, questions can be found at <http://www-h.eng.cam.ac.uk/help/tpl/textprocessing/teTeX/latex/latex2e-html/ltx-2.html>.

12.2.4 L^AT_EX editors and previewers.

There are several good Mac OSX L^AT_EX implementations. One that is uncomplicated, user friendly, but powerful is **T_EXShop**, which is actively maintained and supported by Richard Koch (University of Oregon) and an army of dedicated volunteers. Despite its intentional simplicity, T_EXShop is very powerful. The current version of T_EXShop, 3.61 can be downloaded separately, or installed automatically as part of the MacTeX package (described above, in Section 12.2.1).

Making T_EXShop even more useful. Herb Schulz produced and maintains an excellent introduction to T_EXShop, which he calls *T_EXShop Tips and Tricks*. Herb’s document covers the basics, of course, but also deals with some of T_EXShop’s advanced, very useful functions, such as “Command Completion”, a function that allows a user to type just the first letter or two of a L^AT_EX command, and have T_EXShop automatically complete the command. Pretty cool. The latest version of Herb’s “L^AT_EX Tricks and Tips” is part of the T_EXShop installation, and is accessed under T_EXShop Help window. Definitely worth checking out.

Macros and other goodies. T_EXShop comes complete with many useful macros, and facilities for generating tables and mathematical symbols (for example, $\not\in$, \in , \pm). The macros, which can save users considerable time, are quite easily edited to suit individual users’ tastes and needs. Another of T_EXShop’s useful features tends to get overlooked: the Matrix (table)

Panel and the \LaTeX Panel. These can be found under \TeX Shop's Window menu. The Matrix Panel eases the pain of generating decent tables or matrices; the \LaTeX Panel offers numerous click-able macros for generating symbols, as well as mathematical expressions and functions. It also offer an alternative way of accessing some nearly 50 frequently-used macros. Definitely worth knowing about. Finally, \TeX Shop can backup .tex files automatically, which anyone who's ever lost a file, knows is a very good thing to do. To activate the auto-backup capability, open the Terminal app, and enter `defaults write TeXShop KeepBackup YES`. If you ever want to kill the auto-backup, substitute `NO` for `YES` in that default line.

Templates A limited number of templates come with the \TeX Shop installation; other templates are easily added to the \TeX Shop framework. One template commonly used in the Vision Laboratory is an APA style template produced by [Athanasios Protopapas](#) and [John R. Vokey](#). Starting a manuscript from this template eliminates the burden of having to remember the arcane details, rules, and many, many idiosyncrasies of APA style; instead, you're guaranteed to get all that right. The APA template can be downloaded from <http://www.brandeis.edu/~sekuler/APATemplate.tex>. This version of the template has been modified slightly to permit **highlighting** and ~~strikeouts~~ during manuscript editing (see section 12.3.2).

12.3 \LaTeX line numbers.

Line numbers in a document make it easier for readers to offer comments or corrections. Inserted into a revision of an article or chapter, line numbers help editors or reviewers identify places where key changes were made during revision. Editors and reviewers are human beings, so, like all of us, they appreciate having their jobs made easier, which is what line numbers can do. Several \LaTeX packages can do the job of inserting line numbers. The most common of the packages is *lineno.sty*. It can be found, along with hundreds of other add-on packages, on the CTAN (Comprehensive \TeX Archive Network) site <http://www.ctan.org/>. One warning: *lineno.sty* works fine with APATemplate mentioned in the previous section, but can create problems if that template is used in *jou* mode, which produces double-column text that looks like a journal reprint.

12.3.1 \LaTeX symbols, math and otherwise

Often, when you're preparing a doc in \LaTeX , you'll need to insert a symbol such as \otimes , \cup , \pm or \sim . You know what it looks like (and what it means), but you don't know how to get \LaTeX to produce it. You could do it the hard way, by sorting through long, long lists of \LaTeX symbol calls, which can be found on the web or in any standard \LaTeX ref book. Or you could do it the easy way, going to the [detexify website](#). Once at the site, you draw the symbol you had in mind, and the site will tell you how to call it from within \LaTeX . Finally, for many symbols, you could do it an even easier way. The \TeX Shop editor's Window menu includes an item called \LaTeX Panel. Once opened, the panel gives you access to the calls for many mathematical symbols and function names. Very nice, but even nicer is a small application called TeX Fog, which is available at <http://homepage.mac.com/marco.coisson/TeXFoG/>. TeX Fog (*TeX Formula Graphic* user interface) provides \LaTeX code for many

mathematical symbols, Greek letters, functions, arrows, and accented letters, and can paste the selected L^AT_EX code for any of these directly into T_EXShop.

12.3.2 L^AT_EX highlighting and/or strike outs

A readily available L^AT_EX package, *soul*, enables convenient highlighting in any color of the user's choice and/or strike outs of text. These features are useful during document revision, as versions pass back and forth between separate hands. *soul* is part of the standard L^AT_EX installation for MacOS X. To use *soul*'s features, you must include that package and the color package (for **highlighting** in color).

To highlight some text, embed it inside `\hl{ }`; to **strikeout** some text, embed it inside `\st{ }`.

Yellow is the default highlighting color, but other colors, too, can be used. Here are preamble inclusions that enable user-defined, light red color highlighting.

```
\usepackage{color,soul} %Allow colored highlighting and strikeout
\definecolor{myRed}{rgb}{1.0,.5,.5}
\sethlcolor{myRed} % Make LIGHT red the highlighting color
```

If you are OK with one of the standard colors, such as yellow or red, omit `\definecolor`, and simply insert the color name into the `\sethcolor` statement, `\textit{e.g.}, \sethcolor{yellow}`.

12.4 L^AT_EX template for insertion of highly-visible notes for revision

The following template makes it easy to insert highly visible notes, which can be very important during the process of manuscript preparation, particularly when the manuscript is being done collaboratively. Such notes identify changes (additions and deletions) and questions/comments from one collaborator to another. MacOS X users may want to add this template to their T_EXShop templates collection. The template is easily modified as needed. Here's the text of the code for the preamble section of `foo.tex`. The example assumes that three authors are working on the manuscript, Robert Sekuler, Hermann Helmholtz and Sylvanus P. Thompson. If your manuscript is being written by other people, just substitute the correct initials for "rs" "hh" and "spt". For more details, see the Readme file for `changes.sty` available in CTAN.

```
% =====
% FOLLOWING COMMANDS ARE USED WITH THE CHANGES PACKAGE:
%
\usepackage[draft]{changes} % allows for text highlighting; 'draft'
% option creates a \listofchanges; use 'final' to show
% only correct text and no \listofchanges
%
```

```

% define authors and colors to be used with each author's comments/edits:
\definechangesauthor[name={Robert Sekuler},color={red!85!black}]{RS} %red
\definechangesauthor[name={Sylvanus Thompson},color={blue!90!white}]{ST} %blue
\definechangesauthor[name={Hermann Helmholtz},color={green!60!black}]{HH} %green
% for adding text:
\newcommand{\rs}[1]{\added[id=RS]{#1}}
\newcommand{\spt}[1]{\added[id=ST]{#1}}
\newcommand{\hh}[1]{\added[id=HH]{#1}}
% for deleting text:
\newcommand{\rsd}[1]{\emph{\deleted[id=RS]{#1}}}
\newcommand{\sptd}[1]{\emph{\deleted[id=ST]{#1}}}
\newcommand{\hhd}[1]{\emph{\deleted[id=HH]{#1}}}
%
% END OF CHANGES COMMANDS
% =====

```

12.4.1 Conversions between L^AT_EX and RTF

If you need to convert in either direction between L^AT_EX and RTF (rich text format, readable in Word), you can use *latex2rtf* or *rtf2latex*, programs designed to do exactly what their names imply. *latex2rtf* does not much “like” some special L^AT_EX packages, but once those offending packages are stripped out of the .tex file, *latex2rtf* does a great job. If your L^AT_EX code generates single-column output (as opposed to so-called “jou” formatted output) there’s an easy way to produce decent, but not letter-by-letter perfect conversion to Word or RTF. Open the L^AT_EX’s .pdf output in Adobe Acrobat and save the file as .htm. Then copy and paste the .htm to yourself. Most mail clients will automatically reformat the .htm into something that closely approximates useful rich text format, which is what the name RTF stands for. Finally, although rarely needed by lab members, [NeoOffice](#), an open source suite, has an export to .tex option that is a straightforward way to convert .rtf to .tex.

12.4.2 Preparing a dissertation or thesis in L^AT_EX.

Brandeis’ Graduate School of Arts and Sciences commissioned the production of .cls file to help users produce a properly formatted dissertation. This file can be downloaded <http://www.brandeis.edu/gsas/completing/dissertation-guide.html>. On that webpage, “style guide” provides the necessary .cls file; the “class specification document” is a .pdf that explains use of the dissertation class. Note that this .cls file is not a template, but with the .pdf document in hand, it is the next best thing. The choice of reference/citation format is up to the user. For standard APA format citations and references, be sure that apacite.sty has been installed on L^AT_EX’s path and include in the preamble

```
\bibliographystyle{apacite}
```

12.5 Managing your literature references.

BibDesk for MacOS X is an excellent freeware tool for managing bibliographical reference files. *BibDesk* provides a nice graphical user interface, and is upgraded frequently by a group of talented, dedicated volunteers. *BibDesk* integrates smoothly with L^AT_EX documents, and, properly used, ensures that no cited reference is omitted from the bibliography, and that no item in the bibliography has not been cited. That feature minimizes a reader's or a reviewer's frustration and annoyance at coming across an unmatched citation in a manuscript, thesis or grant proposal.

Download *BibDesk*'s current release (now version 1.6.5) from <http://bibdesk.sourceforge.net/>. *BibDesk* can import references saved from PubMed, preview how references will look as L^AT_EX output, perform Boolean searches, and automatically generate citekeys (identifiers for items) in custom formats. In addition, *BibDesk* can autocomplete partial references in a .tex file (you type the first several letters of the citekey, and *BibDesk* completes the citation, drawing from your database of references). Autocompletion is a very convenient, but too-little used feature, which makes it very easy to add references to a .tex document. Begin by using *BibDesk* to open your .bib file(s) on your desktop. Then in your .tex document, start typing a reference, for example,

```
\cite{Sek
```

and hit the F5 key. *Bibdesk* will go your open .bib file(s), find and display all references whose citekeys match

```
\cite{Sek
```

Choose the reference you meant to include, and its full citekey will be inserted into your .tex document. Among its other obvious advantages, this Autocompletion function protects you from typos. The Autocompletion feature is particularly convenient if you have consistently used an easily-remembered system for citekey naming, such as making citekeys that comprise the first four letters of each authors' name plus the year of publication. (Incidentally, once you hit upon a citekey naming scheme that's best for you, *BibDesk* can automatically make such citekeys for all the items in your .bib file.) To learn more about *BibDesk*'s Autocompletion feature, open *BibDesk* and go to its Help window.

To import search results from a browser pointed to PubMed, check the box(es) next to reference(s) you want to import, change the *Display option* to MEDLINE, and change the *Send to* option to FILE. This will do two things. First, it places a file *pubmed-result.txt* onto your hard disk. If you drag and drop that file to an open *BibDesk* bibliography, *BibDesk* will automatically add the item to the bibliography. I said that changing the *Send to* option to FILE did two things. The second? it generates and opens a plain text file on your browser. If you have a *BibDesk* bibliography already open, you can select that text and use the *BibDesk* item under File's Services menu to insert the text directly into the open bibliography.

Note that *BibDesk* supports direct searches of PubMed, Library of Congress, and Web of

Science –including Boolean searches¹³. To search PubMed from within BibDesk, select the “PubMed” item under the Searches menu, and enter your search terms in the lower of the two search windows. A maximum of 50 items per search will be retrieved; to retrieve additional items and add them to your search set, click the Search button and repeat as needed. When the Search button is grayed out, you know you have retrieved all the items relevant to your search terms. Move the items you want to retain into a library by clicking the Import button next to an item, and save the library.

¹³*BibDesk*’s Help screens provide detailed instructions on all of *BibDesk*’s functions, including Boolean searches. For an AND operation, insert + between search terms; for an OR operation insert |.

12.6 Reference formats

When references have been stored in a .bib file, L^AT_EX citations can be configured to produce just about any citation format that you want, as the following examples show:

COMMAND FORMAT	RESULTING CITATION
<code>\cite<e.g.,>[p. ~15]{Lash51,Hebb49}</code>	(e.g., Lashley, 1951; Hebb, 1949, p.15)
<code>\cite<e.g.,>[p. 11]{Lash51,Hebb49}</code>	(e.g., Lashley, 1951, p. 11; Hebb, 1949)
<code>\citeNP<e.g.,>[p. ~15]{Lash51,Hebb49}</code>	e.g., Lashley, 1951; Hebb, 1949, p.15
<code>\citeA{Lash51,Hebb49}</code>	Lashley (1951); Hebb (1949)
<code>\citeauthor<e.g.,>[p. ~15]{Lash51,Hebb49}</code>	e.g., Lashley; Hebb, p.15
<code>\citeyear<e.g.,>[p. ~15]{Lash51,Hebb49}</code>	(e.g., 1951; 1949, p. 15)
<code>\citeyearNP<e.g.,>[p. ~15]{Lash51,Hebb49}</code>	e.g., 1951; 1949, p. 15

13 Scientific meetings

It is important to present the lab's work to our fellow researchers in talks, colloquia or at scientific meetings. Recently, members of the lab have made presentations at meetings of the Psychonomic Society (usually, early in November; rotating locations), the [Cognitive Neuroscience Society](#) (mid-late April; rotating locations), the [Vision Sciences Society](#) (early May; Naples FL), [COSYNE \(Computational and Systems Neuroscience\)](#) (early March, Snowbird, UT), the Cognitive Aging Conference (rotating locations; April), the [Society for Neuroscience](#) (early November; rotating locations). For some useful tips on giving a good, effective talk at a meeting (or elsewhere) go to http://www.cgd.ucar.edu/cms/agu/scientific_talk.html; for equally useful hints on giving an awful, ineffective talk go to <http://www.casca.ca/ecass/issues/2002-js/features/dirobertis/talk.html>.

Assuming that you are using Microsoft's PowerPoint or Apple's Keynote presentation software, remember that your audience will try to read every word on each and every slide you show. After all, most of your audience are likely to be members of species *Homo sapiens*, and therefore unable to inhibit reading any words put before them¹⁴. Studies of human cognition teach us that your audience's *reading* what you've shown them will keep them from giving full attention to what you are *saying*. If you want the audience to *listen* to you, purge each and every word not 100%-essential. Ditto for non-essential pictures and graphical elements, including decorative but distracting graphical elements that mar too many PowerPoint and Keynote templates.

13.1 Preparation of posters

When a poster is to be presented at a scientific meeting, the poster is generated using PowerPoint and is then printed on campus, using a large format, Epson Stylus Pro 9600 44-inch large format printer. The printer is maintained by Ed Dougherty (dougherty@brandeis.edu); there is a fee for use. Savvy, well-illustrated advice on poster making and poster presenting

¹⁴Just think what *you* do with the cereal box in front of you at breakfast.

is available at [Colin Purrington](#) and at [Cornell Materials Research](#). And whatever you do, make sure that you know exactly what size poster is needed for your scientific meeting; it is not good when you arrive at a meeting with a poster that is larger than the space allowed.

14 Essential background info

14.1 How to *read* a journal article.

[Jody Culham](#) (University of Western Ontario) offers excellent advice for students who are relatively new to the business of journal reading –or who may need a reminder of how to read journal articles most effectively. Her advice is given in a document at <http://culhamlab.ssc.uwo.ca/CulhamLab/HTJournalArticle.html>.

14.2 How to *write* a journal article.

Writing a good article may be a lot harder than reading one. Fortunately, there is plenty of advice about writing a journal article, though different sources of advice seem to contradict one another. Here is one suggestion that may be especially valuable, and non-intuitive. However formal and filled with equations and exotic statistics it may be, a journal article ultimately is a device for communicating a narrative –a fact-filled, statistic-wrapped narrative, but a narrative nonetheless. As a result, an article should be built around a strong, clear narrative (essentially, a storyline). The communication of the story requires that the author recognize what is central, and what is secondary, tertiary, or worse. Downplaying what is less important can be hard, in part because of the hard work that may have gone into producing that less-crucial material. But do not imagine for even a moment that just because you (the author) find something to be utterly fascinating, that all readers will, too –at least not without some skillful guidance from you. In fact, giving the reader unnecessary details and digressions will produce a boring paper. If boring is your goal, and you want to produce an utterly, 100%-boring paper, Kaj Sand-Jensen’s [manual](#) will do the trick.

Following the Mosaic tradition of offering Ten Commandments to the People, Sand-Jensen, an ichthyologist at the University of Copenhagen, presented the Ten Commandments for guaranteed lousy writing:

1. Avoid focus
2. Avoid originality and personality
3. Write L O N G contributions
4. Remove implications and speculations
5. Leave out illustrations
6. Omit necessary steps of reasoning
7. Use many abbreviations and (unfamiliar) terms
8. Suppress humor and flowery language
9. Degrade ~~biology~~ science to statistics
10. Quote numerous papers for trivial statements

Note that the Sixth and Seventh of Sand-Jensen’s Ten Commandments are equally effective if your goal is to produce an utterly bewildering presentation for a scientific meeting.

Assuming that you don’t really want to write an utterly-boring paper, you must work to get readers interested enough to read beyond the article’s title or abstract, which means that those two items are “make or break” features for your article. Once you have a good title and abstract, the next step is to generate a compelling opener, that all-important framing device represented by the article’s first sentence or paragraph. For a thoughtful analysis of effective openers check out the examples and suggestions at this [website](#) at San Jose State University.

There’s no getting around the fact that effective *writing* has extensive, attentive *reading* as one prerequisite. Only by reading, analyzing and imitating successful models, will you become a better, more effective writer.

Finally, less-experienced writers tend to overlook the value of *transitional* words and phrases, which can be thought of as glue that binds ideas together, and helps a reader keep those ideas in the cognitive relationship that the writer intended. As Robert Harris put it, these transitional words and phrases promote “coherence (that hanging together, making sense as a whole) by helping the reader to understand the relationship between ideas, and they act as signposts that help the reader follow the movement of the discussion.” Anything that a writer can do to make a reader’s job easier will produce handsome returns on investment. Harris put together a lovely, easy-to-use table of words/phrases that writers can and should use to signal readers of transitions in logic, or transitions in thought. The table is downloaded from Harris’ website, <http://www.virtualsalt.com/transits.htm> and kept handy while you write.

14.3 A little mathematics.

Linear systems and frequency analysis play a key role in many areas of vision science. One very good, practical treatment is [Larry Thibos](#)’ *Fourier Analysis for Beginners*. Available by download from the library of the Visual Sciences Group at Indiana University School of Optometry, Thibos’ webbook starts with a simple review of vectors and matrices, and works its way up to spectral (frequency) analysis and an introduction to circular or directional data. It’s available at <http://research.opt.indiana.edu/Library/FourierBook/title.html>.

For more extensive review of topics in linear/matrix algebra, which is the principal brand of mathematics used in our lab, check out the lab’s copy of Ali Hadi’s little book *Matrix Algebra as a Tool*. A super introduction to linear systems in vision science can be found in [Brian Wandell](#)’s book *Foundations of Vision: Behavior, Neuroscience and Computation* (1995). Bob has used the Wandell book twice as the text in a graduate vision course. Some parts of the book can be hard slogging, but the resulting excellent grounding in vision makes the effort is definitely worth it.

14.3.1 Key numbers.

Wandell has also produced a [brief list](#) of key numbers in vision science, e.g., the area of area V1 in each hemisphere of the human brain (24 cm), the visual angle subtended by the sun (0.5 deg), the minimum number of photon absorptions required for seeing (1-5 under scotopic conditions). Many of these numbers are good to know, or at least to know where they can be found.

14.3.2 More numbers.

A superset of Wandell's numbers can be found at http://www.neuro.psychologie.uni-oldenburg.de/~rutschmann/forschung/optic_numbers.html. This expanded list contains memorable gems such as "The human eye is exactly the same size as a quarter. The rod-free, capillary-free foveola is 1/2 deg in diameter, same as the sun, the moon, and the pinky fingernail at arm's length. One deg is about 0.3 mm (~300 microns) on the (human) retina. The eyes are half-way down the head."

14.4 Early vision.

Robert Rodieck's clear, beautifully illustrated book *First Steps in Seeing* (1998) is hands down the best ever introduction to optics of the eye, retinal anatomy and physiology, and vision's earliest steps, including absorption and transduction of photon catch. A bonus is its short, highly accessible technical appendices, which are good refreshers on topics such as logarithms and probability theory. A close second to Rodieck in quality, with somewhat different emphasis, is Clyde Oyster's *The Human Eye* (1999). Oyster's book has more material on the embryological development of the eye and on various dysfunctions of the eye.

14.5 Visual neuroscience.

An excellent, up-to-date reference work on visual neuroscience is LM Chalupa & J S Werner's two-volume work, *The Visual Neurosciences*, MIT Press (2004). These volumes, which are owned by Brandeis' Science Library and by Sekuler, comprise 114 excellent review chapters, which span the gamut of contemporary vision research.

14.6 Methodology

Several chapters in Volume 4, *Stevens' Handbook of Experimental Psychology*, 3d edition, deal with essential methodologies that are commonly used in the lab: reaction time and reaction time models, signal detection theory, selection among alternative models, multidimensional scaling, and graphical analysis of data (the last of these in Geoff Loftus' chapter). For an in-depth treatment of multidimensional scaling there is only one first-rate, authoritative source: Ingwer Borg and Patrick Groenen's *Modern Multidimensional Scaling: Theory and Application* (2nd edition, Springer, 2005). The book is clear, well-written and covers the broad range of areas in which MDS is used. Though not a substitute for Borg and Groenen, here's a brief, focused introduction to MDS that was presented at a recent meeting of our lab

<http://www.brandeis.edu/~sekuler/MDS4visonLab.swf>. This introduction (in Flash format) was designed as background to the lab meeting's discussion of a 2005 paper in [Current Biology](#)

14.6.1 Visual angle

In vision research, stimulus dimensions are expressed in units of visual angle (in degrees, or minutes, or seconds). Calculation of the visual angle subtended by some stimulus involve two data: the linear size of the stimulus (in cm) and the viewing distance (distance between viewer and the stimulus, in cm). For example, imagine that you have a stimulus 1 cm wide, and a viewing distance of 57 cm. The tangent of the visual angle subtended by this stimulus is given by the ratio of size:viewing distance. In this case, the value = $\frac{1}{57} = 0.0175$. To find the angle itself, take the arctangent (a.k.a., inverse tangent) of this value, $\arctan 0.0175 = 1$ deg.

14.7 Adaptive psychophysical techniques

Many experiments in the lab require the measurement of a threshold, that is, the value of a stimulus that produces some criterion level of performance. For sake of efficiency, we use an adaptive procedure to make such measurements. These procedures come in many different flavors, but all use some principled scheme by which the physical characteristics of stimuli on each trial are determined by the stimuli and responses that occurred in the previous trial or sequence of trials. In the Vision lab, the two most common adaptive procedures are QUEST and UDTR (for up-down transform rule). A thorough, though not easy introduction to adaptive psychophysical techniques can be found in [B Treutwein \(1995\). Adaptive psychophysical procedures, Vision Research, 35: 2503-2522](#). A shorter, more accessible introduction to adaptive procedures can be found in MR Leek (2001) Adaptive procedures in psychophysical research. *Perception & Psychophysics* 63: 1279-1292.

14.7.1 Psychophysics

Psychophysics systematically varies the properties of a stimulus along one or more physical dimensions in order to define how that variation affects a subject's experience and/or behavior. Psychophysics exploits many sophisticated, quantitative tools, including psychometric functions, maximum likelihood difference scaling, various adaptive procedures for selecting stimulus levels to be used in an experiment, and a multitude of signal detection methods. Frederick Kingdom (McGill University) and Nick Prins (University of Mississippi) have put together an excellent Matlab toolbox for carrying out many key operations in psychophysics. Their valuable toolbox is freely downloadable from [Palamedes Toolbox](#).

14.7.2 Signal detection theory (SDT)

This set of techniques and associated theoretical structure is a key part of many projects in the lab. It is important that everyone who works in the lab has at least some familiarity with SDT. The lab owns a copy of an excellent introduction to this important methodology: Neil MacMillan and Doug Creelman's *Detection Theory: A User's Guide* (2nd edition); we

also own a copy of Tom Wickens' *Elementary Signal Detection Theory*.

There are also several good, **very short**, general introductions to SDT on the web. One was produced by David Heeger (NYU): <http://www.cns.nyu.edu/~david/sdt/sdt.html>. Another (interactive) tutorial is the product of the Web Interface for Statistics Education project. The project's SDT tutorial can be accessed at <http://wise.cgu.edu/sdt/intro.html>.

The ROC (receiver operating characteristic) is a key tool in SDT, and has been put to important theoretical use by researchers in vision and in memory. If you don't know exactly what a ROC is, or know why ROCs are such valuable tools, don't abandon hope. One place to start might be a 1999 paper by Stanislaw and Todorov: [Calculation of signal detection theory measures](#). *Behavior Methods, Research, Computers & Instrumentation*.

Often, ROCs generated in the Vision Lab come from the application of a rating scale, which is an efficient way to produce the requisite data. The MacMillan & Creelman book (cited above) gives a good explanation of how to go from rating scale data to ROCs. John Eng of The Johns Hopkins School of Medicine has produced an [excellent web-based app](#) that takes rating scale data in various formats and uses maximum likelihood to define the the best fitting ROC. Eng's app returns not only the values of usual parameters (slope and intercept of the best fitting ROC in probability-probability axes) and area under the best fitting ROC, but also the values of unusual, but highly useful ones, for example, the estimated values, in stimulus space, of the criteria that the subject used to define the rating scale categories, and the 95% confidence intervals around the points on the best-fit ROC. For a detailed explanation of the app's output, go to <http://www.bio.ri.ccf.org/doc/rocfit.f>.

Parametric vs. non-parametric SDT measures Sometimes, considerations of efficiency and/or experimental make it impossible to generate an entire ROC. Instead, researchers commonly collect just two measures, the hit rate (H) and the false alarm rate (F). This pair of values can be transformed into measures of sensitivity and bias if the researcher commits to some distributional assumptions. For example, if the researcher is willing to commit to the assumptions of equal variance and normality, F and H can straightforwardly be transformed into d' –SDT's traditional, parametric measure of sensitivity. To carry out that transform, one need only resort to the formula, $d' = z(\text{pr}[\text{H}]) - z(\text{pr}[\text{F}])$. But the formula's result is actually d' *only* if the underlying distributions *are* normal and equal in variance, which they usually are not.

Researchers who are mindful that the assumptions of equal variance and normality are not likely to be satisfied, can turn to a non-parametric measure of sensitivity and bias. Over the years, people have proposed a number of different non-parametric measures, the best known of which is probably one called A' . In a 2005 issue of *Psychometrika*, Jun Zhang & Shane Mueller of the University of Michigan presented the definitive formulas for computing *correct* non-parametric measures <http://obereed.net/docs/ZhangMueller2005.pdf>. Their approach, which rectifies errors that distorted previous non-parametric measures of sensitivity and bias, is strongly endorsed for use in our lab –if one cannot generate an actual ROC. The lab's

director wrote a simple Matlab script to carry out these computations; the script is available on request.

15 Labspeak¹⁵.

Newcomers to the lab will from time-to-time encounter unfamiliar terms that reference aspects of experiments, stimuli, data analysis or interpretation. Here are a few that are important to understand; additional terms and definitions are added on a rolling basis. Suggestions for additions are invited.

alpha oscillations Brain oscillatory activity within the frequency band from 8 Hz to 14 Hz. Note that there is not universal agreement on exact range of alpha, and some researchers argue for the importance of sub-dividing the band into sub-bands such as “lower-alpha” and “upper-alpha.” Some Vision Lab work focuses on the possible cognitive function(s) of alpha oscillations.

Bootstrapping A statistical method for estimating the sampling distribution of some estimator (e.g., mean, median, standard deviation, confidence intervals, etc.) by sampling *with* replacement from the original sample. This method can also be used for hypothesis testing, particularly when the standard assumptions of parametric tests are doubtful. See *Permutation Test* (below).

bouncingStreaming A bistable percept of visual motion in which two identical objects moving along intersecting paths seem sometimes to bounce off one another, and sometimes to stream through one another.

camelCase Term referring to the practice of writing compound words by joining elements without spaces and capitalizing initial letter of second word. Examples: iBook, misterRogers, playStation, eBay, iPad, bouncingStreaming. This practice is useful for naming variables in computer code, or for assigning computer files meaningful, easy to read names.

Drift diffusion model (DDM) A computational model of decision making that is often associated with Roger Ratcliff (The Ohio State University), although the basic ideas predate his work. In the model, perceptual evidence accumulates with a drift-diffusion process. It assumes that the brain extracts, per time unit, a constant amount of evidence from the stimulus (drift) which is disturbed by noise (diffusion) and subsequently accumulates these over time. This accumulation stops once enough evidence has been sampled and a decision is made.

ex-Gaussian analysis

¹⁵This coinage, *labspeak*, was suggested by Orwell’s coinage “newspeak” in his novel *1984*. Unlike “newspeak”, though, *labspeak* is meant to facilitate and sharpen thought and communication, not subvert them.

Fish Police!! A computer game devised by the lab in order to study audiovisual interactions. The game's fish can oscillate in size/brightness while also "emitting" amplitude modulated sounds. Synchronization of a fish's visual and auditory aspects facilitate categorization of the fish.

Forced choice In some other labs, this term is used to describe any psychophysical procedure in which the subject is forced to make a choice between n possible responses, such as "yes" or "no." In the Vision Lab, this term is restricted to a discrimination experiment in which n stimuli are presented on each trial, one containing a sample of S_1 , the remaining $n-1$ containing a sample of S_2 . The subject's task is to identify the stimulus that was the sample of S_1 . Consult a textbook on signal detection to see why this is an important distinction. If you're in doubt about whether your procedure truly comprises a forced-choice, ask yourself whether after a response you could legitimately tell the subject whether he/she is correct or not.

Flanker task A psychophysical task devised by Charles and Barbara Eriksen (1974) in order to study attention and inhibitory control. For obvious reasons, the task is sometimes referred to as the "Eriksen task."

Frozen noise Term describes a stimulus comprising samples of noise, either visual or auditory, that is repeated identically on multiple trials. Sometimes such stimuli are called "repeated noise" or "recycled noise." For examples of how visual frozen noise is used to probe perception and learning, see [Gold, Aizenman, Bond & Sekuler, 2013](#).

JND Acronym of "Just Noticeable Difference". Roughly, a JND is the least amount by which stimulus intensity must be changed so that the change produces a noticeable change in sensory experience. (See *Weber fraction*).

Leakage Term referring to intrusions from one trial of an episodic visual memory experiment into the following trial. A manifestation of proactive interference.

Lure trial A trial type in a recognition experiment; on lure trials, the probe item matches none of the study items. (See *Target trial*)

Mnemonometric function Introduced by [Zhou, Kahana & Sekuler \(2004\)](#), the mnemonometric function describes the relationship, in a recognition experiment, between the proportion of *yes* responses and the metric properties of the *probe* stimulus. The *probe* "roves" or varies along some continuum, such as spatial frequency, sweeping out a probability function that affords a snapshot of the memory strength's distribution.

Moving ripple stimuli Complex, spectro-temporal stimuli used in some of the lab's auditory memory research. These stimuli comprise a family of sounds with drifting, sinusoidal, spectral envelopes.

Multiple object tracking (MOT) Multiple object tracking is the ability to follow simultaneously several identical moving objects based only on their spatial-temporal visual history.

Mutual information (MI) A measure, usually expressed in bits, of the dependence between random variables. MI can be thought of as the reduction in uncertainty about one random variable given knowledge of another. In neuroscience, MI is used to quantify how much of the information contained in one neuron's signals (spike train) is actually communicated to another neuron.

NEMo The Noisy Exemplar Model of recognition memory; introduced by Kahana & Sekuler (2002), Recognizing spatial patterns: a noisy exemplar approach. *Vision Research* **42** 2177-2912. *NEMo* is one of a class of memory models known collectively Global Matching models.

Permutation test A type of statistical significance test in which some reference distribution is obtained by calculating all possible values of the test statistic under rearrangements of the labels on the observed data points, e.g., labels typically designate the conditions from which the data came. (Permutation tests are related to, but not exactly the same as, randomization tests and re-randomization tests.) See *Bootstrapping* (above).

QUEST An efficient, Bayesian adaptive psychometric procedure for use in psychophysical experiments. This method was introduced by Andrew Watson & Denis Pelli (1983), QUEST: A Bayesian adaptive psychometric method. *Perception & Psychophysics* **33**,113-120. The method can be tricky to implement, but good practical pointers on implementing and using this procedure can be found in P. E. King-Smith, S. S. Grigsby, A. J. Vingrys, S. C. Benes, & A. Supowit (1994). Efficient and unbiased modifications of the QUEST threshold method: Theory, simulations, experimental evaluation, and practical implementation. *Vision Research* **34**, 885-912.

Roving Probe technique Described in Zhou, Kahana & Sekuler (2004), a stimulus presentation schedule that is designed to generate a mnemonic function.

Sternberg paradigm Procedure, introduced by Saul Sternberg in the late 1960's, for measuring recognition memory. In this procedure, a series of study items is followed by a probe (test) item. Subject's task is to judge whether the probe was or was not among the series of study items. Either response accuracy, response latency, or both are measured.

Target trial One type of trial in a recognition experiment; on Target trials, the probe item matches one of the study items. (See *Lure trial*)

Temporal Context Model This theoretical framework, proposed by Marc Howard and Mike Kahana in 2002, uses an evolving process called "contextual drift" to explain recency effects and contextual retrieval in episodic recall. It is hoped that this model can be extended to the case of item and source recognition.

UDTR Stands for "up-down transform rule," an algorithm for driving an adaptive psychophysical procedure. UDTR was introduced by GB Wetherill and H Levitt (1965) Sequential estimation of points on a psychometric function, *British Journal of Mathematical Psychology* **18**: 1-10.

Vogel Task A change detection task developed by [Ed Vogel](#) (University of Oregon). This task is being used by the lab in order to assess [working memory capacity](#).

Weber fraction The ratio of (i) the JND change in some stimulus, to (i) the value of the stimulus against which the change is measured. (See *JND*)

Yellow Cab An interactive, virtual reality platform in which the subject takes the role of a cab driver, finding passengers and delivering them as efficiently as possible to their desired destinations. From the learning curves produced by this activity, it's possible to identify what attributes and features of the virtual city the subject-drivers used to learn their way about the city. Yellow Cab was developed by Mike Kahana, and results from Yellow Cab have been reported in several publications.