QUANTITATIVE EVALUATION OF THE OCULAR MOTOR SYSTEM

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http://omlab.org/Teaching/BME319/bme319.html

Introduction and Background

This experiment demonstrates ways in which human eye movements can be recorded and quantitatively evaluated, and illustrates how these techniques are used to study the different neural mechanisms responsible for control of the eyes. It is only through quantitative recording of eye movements that an accurate idea of how these systems work can be obtained; simple observation is insufficient because “the eye may be quicker than vision.” Such an understanding is important in a clinical setting because many neurological disorders affect the ocular motor system, and precise evaluation of its performance may aid in diagnosis or treatment. The ocular motor system is also of theoretical and practical interest to bioengineers and neurophysiologists because it is the most readily quantifiable and accessible motor system in the body.

You will gain experience in techniques for recording and evaluating eye movements, and will apply them to the examination of several of the ocular motor subsystems responsible for different types of eye movements. The responses of these systems will be studied and their limitations explored. You will then be relate these findings to the different roles that these mechanisms play in normal life. Although the instrumentation required for this lab will be discussed, the emphasis is on the physiology. To help guide you through this work, you should carefully read this brief summary of the organization and function of the ocular motor system.

Although our eyes are rarely completely at rest, we are normally (if all is well) unaware of their activity. The types of movements of which they are capable can be grouped into several different categories. Despite some shared anatomical structures, the responsible mechanisms are remarkably distinct in both their underlying pathways and their modes of action. The three major categories are the fast eye movements (saccadic), slow eye movements (pursuit, vestibulo-ocular reflex (VOR) etc.) and vergence eye movements. Note that the word “slow” is used here to distinguish the motion from saccadic movements and not to imply that the movements cannot be rapid; VOR velocities can reach 500°/sec. The vergence subsystem, which causes the eyes to move in opposite directions as an object becomes closer or more distant, will not be treated further here. The other two motor subsystems will be studied on their own and together as substrates for the vestibulo-ocular reflex (VOR), which is the mechanism responsible for maintaining stable gaze as we move through our environment. Phylogenetically, the VOR is the oldest ocular motor pathway, functionally recognizable going back to early fish.

Fast eye-movement subsystem

This system is responsible for the generation of the fast, "saccadic" eye movements which we make almost constantly throughout the day as we redirect our gaze from place to place. These movements may vary in size from a fraction of a degree of arc to 90°, and may reach angular velocities of up to 800°/sec. They may be made volitionally or unconsciously; we can make 200,000 or more over the course of a day. Their function is to maintain the image of the desired region of regard upon the retinal fovea, which is the 1° diameter portion of the retina with the highest resolution. Saccades are also made involuntarily as the fast phase of nystagmus—an involuntary oscillation of the eyes, usually with alternating fast and slow components—where they attempt to return the eyes to a desired location after a slow phase has carried them off target. We make saccades to all sorts of stimuli, not necessarily visual (e.g. towards a loud or unexpected noise). We can also make them to remembered, predicted or imagined locations. We can even make them *away* from a target ("anti-saccades").

Slow eye-movement subsystem

This system is responsible for the generation of smooth pursuit eye movements and related phenomena. These are the movements made as we track a continuously moving object (e.g., watching a person walk past). They are velocity-driven movements (unlike saccades, which are based on position error). The velocity range covered goes from arbitrarily slow to about 40°/sec; for large excursions this limit may reach 200°/sec. As you will see in the lab, smooth pursuit eye movements, unlike saccades, cannot be made (by most people) without a moving target (either *actual* or *perceived* motion is needed).

Vestibulo-ocular reflex

Although it evolved earlier than the two above systems, the VOR is not a separate motor pathway. Instead, it is a non-visual input to them. It serves the crucial function of keeping the eyes fixed on a target while the head and body move through the environment, or during rotational perturbations of the head. To appreciate what life without this reflex would be like, close one eye and wiggle the other by gently pressing on the eyelid while trying to walk around. Or you could test your reading ability looking at the page of a book while rotating your head, and then compare the result to what you see while keeping your head still but moving the paper at the same velocity you had just been moving your head. The vestibulo-ocular reflex performs this function by receiving information about head velocity from the semi-circular canals of the inner ear, which produce this signal by integrating head acceleration. This input is used to generate the input needed to drive the eyes opposite to the head motion. Remarkably, this is done in open-loop fashion; there is no feedback possible to the ears to tell them if the eyes are moving correctly. But there are times when we *don't* want VOR to counteract our motion. For example when we *and* the target are moving together. At times like this, we need to be able to modulate the VOR, perhaps even *suppressing* it entirely. (Hint, hint.)

Evaluation of the ocular motor system

Each of the eye movement mechanisms described above has certain normal limits within which it operates. These are, to varying degrees, functions of the age and alertness of the individual subject. In addition, different subjects may show greatly varying responses to the same task. A given person, however, will generally respond the same to repeated testing. Also, even allowing for the variations between subjects, statistically normal ranges can be established for the various kinds of eye movements. This lab will demonstrate some of the ways in which these different responses can be evaluated. Some of the relevant parameters to be examined are described below.

Saccadic subsystem

The responses of this subsystem can be easily characterized by their accuracy, velocity and latency (the time between stimulus and response). Recording is essential if these quantities are to be evaluated in any but the coarsest fashion. If only analog recording was possible, they could still be computed by detailed measurements from a strip chart record (if a differentiator was available for each position signal). But obviously this activity becomes boring very quickly. Fortunately we have a faster way: through the use of a computer with an A/D hardware and software. The amplitude, peak velocity and latency of saccades can all be easily calculated and stored for use as desired. Care must be taken to see that the machine receives only good data, as it will otherwise be quite content to analyze garbage, with the well known result. Since quantifying what constitutes bad data is not an easy task, this is one of the major difficulties in automating ocular motor evaluation.

Pursuit subsystem

Since the eyes are moving much more slowly under the control of this subsystem, its performance can be evaluated to a greater degree through simple observation. If the pursuit system allows the eyes to fall behind the target, “catch-up” saccades are made to put the desired object back on the fovea. Thus, insufficient, impaired or absent pursuit produces a characteristic “cog-wheeling” when an attempt is made to follow a smoothly moving object. The simplest way to evaluate smooth pursuit, and the one which corresponds best to such a clinical exam, is to compute the gain of the pursuit system for both directions and at various target velocities. This can be done most straightforwardly by moving a target at a constant velocity, enthusiastically encouraging the subject to follow it as best she can, and then comparing the eye velocity during periods of (saccade-free) pursuit with the target velocity. This ratio (eye velocity/target velocity) is the definition of pursuit gain. You will calculating this for targets moving to the left and to the right, because one of the most important results to look for in a pursuit test is asymmetry of response. You will plot the pursuit gain the two directions and for different target velocities. When the target moves sinusoidally, a frequency response plot is constructed by taking the response for each half-cycle, best measured about the zero crossings (not including intervals interrupted by saccades), and computing the ratio of the smooth pursuit velocity to the stimulus velocity. Since pursuit is the system most sensitive to inattention or fatigue, it is essential to keep the subject alert, through encouragement, friendly threats, etc.

Vestibulo-ocular reflex

Evaluation of this response has much in common with testing of the smooth pursuit system since, if all is working optimally, slow eye movements are produced. The VOR is generally tested under three conditions. The first is in darkness. To maintain alertness, the subject is generally asked to do mental arithmetic, name a different animal for each letter of the alphabet, or the like while being rotated (usually sinusoidally). Eye movements are recorded and the amplitude of the resulting reconstructed smooth movement compared with the target rotation. A fixation light is then turned on and the subject is asked to keep her eyes on it while she is again rotated. This should bring the VOR gain up to almost 1, as this test corresponds to what the reflex is asked to do when we look at something as we move around. The final test also corresponds to a common condition—that of looking at an object moving with us, as when we read while riding in a car. This is done by having the subject hold a small light, fixing it to the chair, or projecting it from the chair, so that it rotates with her. In this case, the VOR gain should drop to approximately zero. VOR gain is calculated as the eye velocity/head rotation velocity, not including saccades. When the subject is properly stabilized in the chair we will define head velocity equal to chair velocity.

A word about calculating gain

Note that in the discussion for smooth pursuit and VOR gains, you have been told repeatedly to avoid including saccades. Why? It is because the definition of gain is the output of a system divided by the input to the system—but *only* for those inputs that act to drive the system. For example, saccades don't count toward any smooth movement gain, because the movement of the eye was not a direct response to the smoothly moving target, but to a jump caused by the saccadic system. Ignoring this basic definition will likely contaminate any results you calculate.

References

1. Abel LA, Schmidt D, Dell'Osso LF and Daroff RB: Saccadic system plasticity in humans. Ann Neurol 4:313-318, 1978.

2. Daroff RB, and Dell'Osso LF: Eye Movement Characteristics and Recording Techniques. In "Clinical Ophthalmology, Vol. II", edited by T. Duane, Harper and Row, Hagerstown, chap. 9, pp. 1-16, 1985.

3. Leigh RJ and Zee DS: "The Neurology of Eye Movements", FA Davis, Philadelphia, chap. 1-5, pp. 1-108, 1983.

4. Schmidt D. Abel LA and Dell'Osso LF: Saccadic velocity characteristics: Intrinsic variability and fatigue. Aviat Space and Envir Med 50:393-396, 1979.

5. Sharpe JE and Sylvester TO: Effect of aging on horizontal smooth pursuit. Invest Ophthalmol Vis Sci 17:465-468, 1978.

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7. Spooner JW, Sakala SM and Baloh RW: Effect of age on eye tracking. Arch Neurol 37:575-576, 1980.

Materials and Methods

Apparatus

You are going to test several of the ocular motor subsystems described above, to evaluate their capabilities under various conditions. You will use the following equipment: computer-based high-speed digital video eye tracker, rotating chair with head stabilization, laser aimed at a 2-D mirror galvanometer system, amplifiers, and the LabVIEW data acquisition system (computer with analog and digital input and output cards and custom-written software).

Experimental Procedures

Experiment I. Smooth pursuit performance.

a. Pick a volunteer to serve as subject for this and the visual gain test to follow.

b. Fit your subject with the eye tracker and chin rest. Run the calibration routines to insure that the tracker and recording system accurately detect the subject's eye position. We calibrate each eye separately (with the other under cover) to insure that the subject isn't inadvertently using the other eye, which could invalidate the results.

> **Before running the data acquisition VI, make sure that you have turned off the calibration VI.**

c. You will use the LabVIEW VI (Virtual Instrument file) "Acq_Disp_AO_Vpx" (Acquire, Display and perform Analog Output/Video Presentation) to record eye movements and control the presentation of the stimuli.

Set the "Manual/Scripted" switch to "Scripted" and enter the name of the experiment script: "bmelab:bmelab.scr". This script contains the equipment settings for all of the pursuit tasks, including the ones with an imaginary target. By automating parts of an experiment, the investigator isn't forced to pay as much attention to the equipment, and can instead follow the actual experiment more closely. This also removes potential sources of errors, such as typos, that can be very frustrating.

There are several settings on the program's control panel that will change from trial to trial (as well as several that will remain constant).

Settings that will change (done automatically by experiment scripting):

Stimulus File 0:	"*.stm" files (will vary with experiments)
Comments	

Settings that will remain CONSTANT:

Input Source:	Eyelink	Sampling freq.:	500 Hz
Display Delay:	0.1 seconds	AI board:	1
AO Board:	1	D/A channels:	0,1

d. The “TRAPxx.STM” family of stimulus files contain digital representations of the waveforms that will drive the galvanometer+laser with a constant-velocity signal:

Trial	1	2	3	4	
velocity (°/sec)	5	10	20	40	
amplitude (°)	15	15	15	15	
cycles	5	5	10	10	
“TRAPxx.STM” file	05	10	20	40	(The script changes these
duration (sec)	70	40	50	35	settings automatically)

The script will place the name of the appropriate stimulus file into the “Stimulus File 0” field and set the duration of the recording prior to each trial. The person operating the computer should verify that these values are correct prior to starting each trial.

When everyone is ready, select “Run” from the “Operate” menu, or click on the “Run” arrow in the upper left of the VI. It is important to let everybody know that the experiment is about to begin by counting down **loudly** prior to running the VI. (“Three… two… one… **go!!!**”)

After the first trial, give the subject a little rest (they can close their eyes for 15 seconds or so). Then repeat the test for 10, 20, and 40°/sec, with rest periods between each run. To keep your subject from becoming inattentive to the task, provide appropriately loud and directed **encouragement.**

e. Now, use the “SINE” family of stimulus files to drive the target with sinusoidal motion. The subject will pursue sine waves of 0.05, 0.1, 0.5 and 1.0 Hz, allowing a brief rest between trials. As before, the script will automatically change the filenames and durations after each trial.

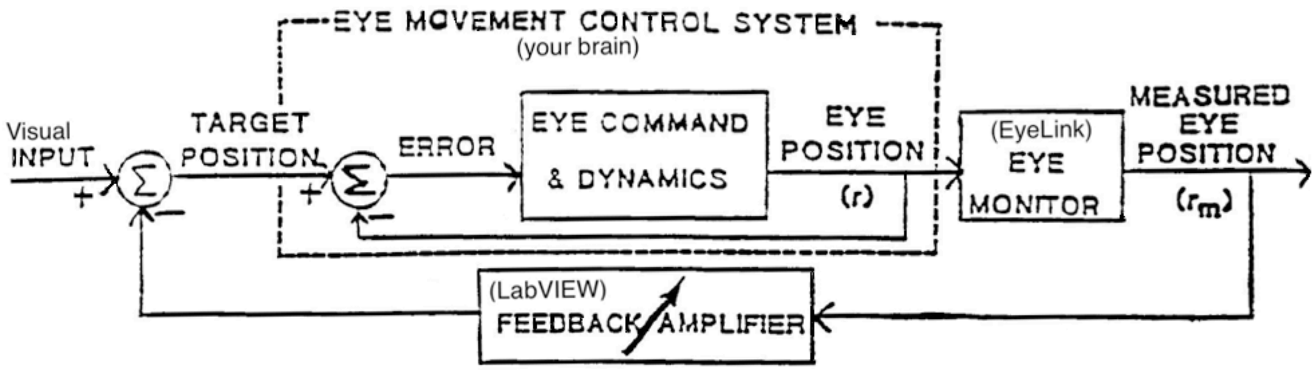
Trial	1	2	3	4	
frequency (Hz)	0.05	0.1	0.5	1.0	
amplitude (°)	15	15	15	15	
# of cycles	5	5	10	10	
“SINExx.STM” file	0_05	0_1	0_5	1_0	(The script changes these
duration (sec)	100	50	20	10	settings automatically)

f. Next, make sure that the laser and other lights are off in the recording room. Close the door and, shouting to the subject, tell her to try and imagine a moving spot and to follow it. Record about 30 seconds of this, while exhorting, cajoling or threatening her. Ask if she thought she made smooth movements.

g. While it is still dark, ask the subject to try and track her finger while moving it back and forth slowly in front of her, for about 30 seconds. Ask if she thought she made smooth movements.

Experiment II. Visual gain and ocular motor control.

You will test how varying the effective feedback of the eye movement control system by driving the target with a signal proportional to eye position using the scheme shown below:



Close the VI "Acq_Disp_AO" and open "Acq_Disp_AO_Feedback". Make sure that the "Display Delay" control is set to 0.02 seconds. You will **manually change the gain** with the VI's "Galvo Gain" control prior to running each trial.

By connecting the eye tracker output to the mirror galvanometer and varying the fraction and polarity of the feedback, we will make the effective eye movement control system unstable through positive feedback or high gain negative feedback.

We will demonstrate both of these conditions, working through the list of the 5 gain settings **{0.25, 0.5, 1.0, 1.5, 2.0}** for each polarity. Each trial will run for 5 seconds and will start with the subject looking at the laser at 0°. The target will jump to 3° and the subject should try to catch up with it. Notice the time interval between successive saccades in each of these conditions. When you have finished, release and thank your subject. (Thanks to Prof. L.R. Young, MIT, for this experiment).

Experiment III. Saccadic performance.

Calibrate your new subject. **Don't forget to turn off the calibration VI when done.**

The saccadic latency test uses the LabVIEW VI "Acq_Disp_AO_Vpx" and the script "bmelab:SACCLAT.scr". (This will also control the VOR experiments in part IV below.)

This test will take 360 seconds. The stimulus file ("bmelab:SACCLAT.STM") will present a target that starts at 0° and jumps to one of the 5° positions (i.e. either left or right). After a variable delay (20 ≤ T ≤ 500ms) it will jump to the opposite 5° point. The subject's job is to FOLLOW THE LIGHT! ***Loudly*** and ***repeatedly*** encourage your subject to keep following the light. **DON'T BE SHY—Keeping the subject attentive is CRITICAL for getting usable data!**

[NOTE: it may take a few seconds for the computer to load in the saccade target data once you run the VI. This delay is normal, so don't panic.]

Experiment IV. Vestibulo-ocular reflex performance and control.

The final tests examine the VOR, in particular the degree of voluntary control we have over its function.

Connect the chair velocity signal to Ch 1 of the strip chart recorder, and in place of the RV signal in the acquisition breakout box. This will allow us to monitor the quality of the chair rotation on the chart recorder before starting the data acquisition (on the RV channel).

Attach the LED arm to the back of the chair and position the LED so the subject says it appears roughly in the same place as the laser dot on the wall. Release the lock on the chair footrest. Practice rotating the chair until the signal on the chart recorder is suitable. It should be about ±15°, and about one cycle every three to four seconds (0.25–0.33 Hz). We are not trying to make the subject sick, or launch him into orbit.

Tell the subject to sit still, facing straight ahead at all times. Close the recording room door, making sure that the lights are out. Then run the following tests:

a) In complete darkness, have the subject to count backwards from 100 by 3's (silently, to himself), while someone rotates the chair back and forth by hand. [Is subject supposed to be trying to fix at the center, or just look straight ahead?]

b) Next, turn on the laser at 0°. Tell the subject to fixate on this and repeat the rotation. Try to keep the chair motion the same.

c) Turn off the laser and turn on the LED. Now, tell the subject to fixate the LED as it moves with him and again repeat the above rotation.

You will now repeat these three tests but without any visual cues (laser or LED targets).

d) Exactly like a), with the room in complete darkness, rotate while doing silent arithmetic.

e) The subject should remember what it was like looking at the stationary laser on the wall.

f) Now remember what it was like watching the LED that stayed directly in front of him.

Carefully release the subject. Make sure the area around the chair is clear. Without touching the gains on channel 1, run velocity calibration signals (**±20°/sec**) into the chair.

IMPORTANT: If you are the subject and begin to feel any discomfort or symptoms of motion sickness during the recording, let someone know, and we'll stop the session; we are not trying to see how much you can take. Remember: heroes die first.

——————THAT'S IT!——————

Questions to Answer in the Report

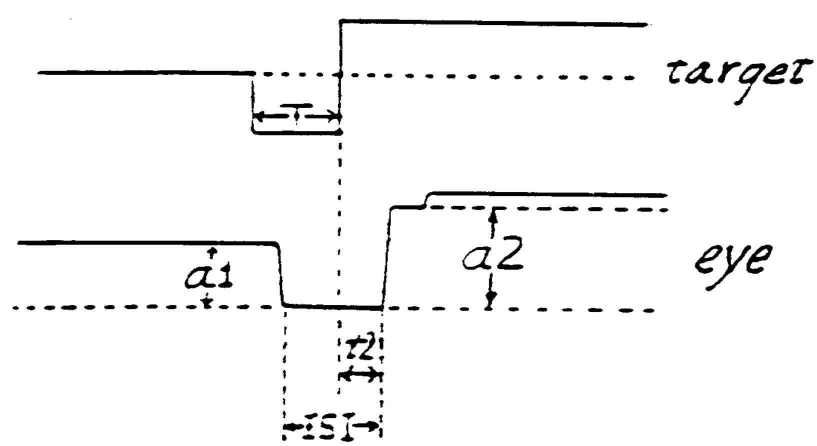
1. [15 pts] (a, 7.5) Plot a graph of your subject's smooth pursuit gain, G, (eye velocity/target velocity) versus the four constant target velocities. *For this question only,* make separate calculations for pursuit **to the left** and pursuit **to the right.** You can calculate the velocities in MATLAB from the position data using a simple difference equation. **Use only the smooth pursuit component. Do not measure across the saccades.** The two eyes should be moving together, so only plot the results from *one eye*. (b, 7.5) How do your results compare with published normal data (Refs. 1 & 5)? If the results are not as expected, propose reasons why.

2. [20 pts] (a, 7.5) Plot the pursuit gain, G, for the four frequencies tested. **Use only the smooth pursuit component, avoiding the saccades.** Base your velocity calculations on the region around the zero crossing, to get peak velocities. (b, 7.5) Plot the phase lag (or lead), in degrees, of eye velocity relative to target velocity and its change with target frequency. (Lead is positive, lag is negative.) (c, 2.5) Was the tracking primarily pursuit or saccadic at low frequencies? At high frequencies? (d, 2.5) Do you think that the frequency response of the system would be the same if it was measured using less-predictable target motion? If so, *how* and *why?*

3. [5 pts] For the two attempts at pursuit in the dark, after the experiment, did the subject think that she made any smooth movements? Measure the records to see if any smooth pursuit was present. SHOW ILLUSTRATIVE DATA. (a, 2.5) If so, what were the velocities? (b, 2.5) Which did she track better: her finger or the imagined target? SHOW SOME DATA.

4. [10 pts] For the experiment using the feedback of eye position to move the target, (a, 2.5) estimate the level of ***external negative*** feedback gain that was necessary to sustain saccadic oscillations. SHOW DATA TO SUPPORT YOUR CLAIM. (b, 5.0) Is it what you'd theoretically expect; if not, what value would you have anticipated and why? (c, 2.5) What might account for any discrepancy?

5. [20 pts] For the saccadic tests, measure and tabulate the following data for one eye: amplitude of the first saccade (a1), amplitude of second saccade (a2), latency of second saccade (t2) and intersaccadic interval (ISI). Also measure the delay of the second target jump (T). If only one saccade occurred, measure its amplitude and latency from the onset of the first target jump and note the value of T involved. Otherwise, the above parameters are:



Now, for each of the 11 different target delays, T={0.02, 0.05, 0.1, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50} seconds, compute means for all of the above four parameters: a1, a2, t2 and ISI. Do **NOT** include responses where there was only one saccade. Include your table of measurements as an appendix. (a, 5.0) Plot your mean values for a1 and a2 vs. T on one set of axes and (b, 5.0) t2 and ISI vs. T on another graph. (c, 2.5) Is there a value of T below which a single jump was more often performed by the saccadic system? (d, 2.5) What values do you expect for a1 and a2? What, if any, was the effect of T on the accuracy of the ***second*** saccade? (Remember: don't include responses with only one saccade.) (e, 2.5) Does there appear to be a minimum intersaccadic interval and, if so, what is it? (f, 2.5) How does your answer support either the continuous or sampled-data model of the saccadic system?

6. [10 pts] (a, 5.0) Compute the gains (averages of the peak eye *velocity* divided by peak chair *velocity)* for the stationary and moving targets (second and third VOR tests) and their corresponding "rotation in the dark" conditions, where your subject was *imagining* stationary and moving targets (i.e., the fifth and sixth VOR test records). Show your data. Remember: use only the smooth components, *omitting saccades.* (b, 2.5) First, how do the gains compare for the visible stationary and moving target conditions, what mechanism might have been used in modulating the responses? Why do you think so? (c, 2.5) Next, how do the respective visual and non-visual cases (i.e. second vs fifth, third vs sixth) compare? What does this tell you about the need for visual information in VOR? (NOTE: the chair data as provided are already velocity; the eye data are still position.)

7. [10 pts] Based on the experiments, and your personal experiences, discuss the roles in day-to-day life of the three ocular motor subsystems (saccadic, pursuit, and VOR) that you studied. Consider the degree to which each can be volitionally controlled: why might it be useful to be able to make these movements *with or without* a visual stimulus? (Consider other modes of stimulation, e.g., sound, memory, etc.) And under what conditions might it be desirable, and how easy is it, to override a normal response (e.g. ignore a stimulus)? Drawing a conclusion from your discussion, rank the degree of voluntary control—from most to least—that we have over each system.

You probably have already added up these points and saw that they summed to only 90. Why? Those last ten points aren't missing; they will be awarded for the overall quality and formatting of your presentation as follows:

- Properly organized: (2.5)
- Properly formatted: (2.5)
- All questions numbered: (2.5)
- Grammatically correct, clear answers: (2.5)

Conversely, there are several ways to lose points, per question (if specifically applicable):

- Incorrect answer: (-2.0)
- No data shown: (-1.0)
- No methods shown: (-2.0)
- No/wrong graph labels: (-1.0)
- No marker points/no line between data points: (-1.0)

Specific Requirements for the Report:

The purpose of a report is to transmit information to others. With this goal in mind, here are several crucial requirements you must meet. Please keep in mind that someone (we) must actually read your reports. Therefore, to save our eyesight and your grade, you should follow these points to the letter:

1. Even for engineers, standard English is the expected medium of communication. Therefore you must use it in your reports. Use proper grammar. Sentence fragments? No! **IF I CAN'T UNDERSTAND YOUR ANSWER, YOU WON'T GET CREDIT FOR IT.** A good check is to have someone (who is *not* taking this lab) read your report for clarity.

2. How long should the report be? As long as it needs to be. Provide enough information to show that you understand *how* and *why* you did what you did, and concluded what you concluded. Share your thought process, but don't bury me in details. Write so that an educated layperson would be able to get your points.

3. Use the style of the reference papers as a (loose) guide when writing your report. Clearly separate and title each section, maintaining the same order as in the lab procedure handout. Please be both *precise* and *concise*. Do not include large portions from the handout material into your report (especially "Introduction" and "Methods"). You should include only what is necessary to provide context for your answers. The **"Results"** and **"Discussion"** section are **combined** for answering the questions, i.e., presenting your data analysis, explaining what you have found, and what you believe it means. **You must *number, letter* and *answer* each question specifically.** Failure to do so will cost you points.

4. A picture can be worth a thousand words. Therefore, figures should be large enough to be easily readable (≥3" high by ≥4" wide). There is no award for the person who manages to cram the most graphs on a page. **LABEL YOUR AXES APPROPRIATELY!** Connect the data points with a line, and use marker symbols to indicate the points. Examine your figures critically and ask yourself if they make sense: is it clear what you are trying to convey? Also, remember that your figures are a complement *to* a well-written explanation, not a replacement *for* it.

5. Show an ***illustrative*** sample of the data you used. (Don't show ALL your data, just what you need to get your point across.) Show ***where*** you performed your analysis (i.e. mark the relevant points) and ***how*** you performed it. If your approach was sound but your arithmetic wrong, you'll get most of the credit. However, a wrong answer that doesn't show a derivation will get nothing.

6. Measurements (and ONLY measurements) of the raw data may be made collectively, dividing up the various sections among group members. However, the *ANALYSIS* and *INTERPRETATION* of the results **MUST BE DONE INDIVIDUALLY.** A wrong answer arrived at by committee is still wrong, and it is quite easy to tell if results have been shared.

7. You heard this several times in the lectures and the lab, and just read it above, but allow me to repeat myself: do not, **UNDER ANY CIRCUMSTANCE,** share *any* part of your ANALYSES or WRITEUP. If we catch you (and the odds are in our favor) you will FAIL. Good rule of thumb: If in doubt, *don't.*

Secrets to a Successful Lab Session and Report:

1. Follow all the instructions in the handout. This means you MUST read it carefully and completely *prior* to your laboratory session. (You may find that there is information in each section that will help you write your report, including the introductory material.) During an experiment is a bad time to start figuring out what you need to do. Bad experimental technique does not lead to good data, easy analysis or report writing.

2. Keep your eyes and ears open during the lab. Take good notes. Ask questions (at appropriate times). We have been known to “accidentally” let slip a helpful hint or even an answer now and again. (Reading the post-lab notes before the lab is also an excellent way to know what to expect and will help you understand what you are doing, and why.)

3. You will use the digitized data to perform your analyses. At least one person from each section should bring a USB flash drive with sufficient free storage capacity (~30MB).

4. If your calculations are giving unlikely results, take a close, careful look at the data. For example, if your pursuit gains are much greater than 1.0, ask yourself could there really be *that great a difference* between the eye and target trace slopes. (Probably not.) **Let the data be your reality check.** If you are convinced your results *are* correct you will need to point this out and justify or explain why you believe it to be so.

5. Keep track of your units at all times. Be aware of when you are working with position, and when you are working with velocity. You can calculate velocity from position as required (i.e., questions 1, 2, 3, 6) with a simple difference equation (“rise/run”). MATLAB provides some basic functions, or you can write your own differentiator. (Or you can ask nicely for the one we use in our laboratory.) Make sure that the result makes sense before using it. A good test is on a linear signal or a simple sinusoid.

6. Get an early start thinking about what you did and observed during the lab. This will give you time to organize your thoughts for the post-lab. Carefully go through the post-lab notes before we meet. This will be your best opportunity to ask questions.

7. For any questions, you should first check the (hopefully) helpful information I have compiled over the years (http://omlab.org/Teaching/BME319/BME319.html) to see if your question has been asked and answered. These documents give very specific information about how to answer the questions and may offer some helpful hints if you get stuck or confused.

8. Leave yourself sufficient time to prepare **and double-check** your report. This isn’t a one- or two-nighter. I suggest you have a friend (**NOT** taking this lab) proofread and sanity check it for you.

9. If your question wasn’t answered, or you need additional information, you can contact Dr. Jacobs at jxj24@case.edu (put EBME 319 in the subject line to avoid the spam filters). Remember: last-minute questions will get last-minute answers. Plan accordingly.