

Human Stability

Is there a difference between men and women?

Science Fair project

Peter Halverson

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Introduction

I became interested in human stability as an undergraduate, working in the Biomechanics Laboratory of NYU. There, the lead researcher always used women as subjects. I felt he was being sexist but he insisted that women are more stable and consistent and by using women his research results were more reliable.

Is this true? Can we verify this claim?

Previous results.

There are few research results on the relative stability of men vs women. Some evidence suggests that it might be true. For example in Olympic marksmanship, women outscored men, until the competitions were segregated¹.

However, other more scientific studies don't support this claim. For example, female ballet dancers take more time than men to regain balance after a jump onto an uneven surface². and marksmanship tests conducted by the military have found no significant gender differences³.

Background

The act of standing up, of holding an object steadily, requires the skeleton and muscles for support and the nervous system, for control. In addition, the act of aiming a gun (or a laser pointer as in this research) requires the cooperation of the visual system.

Muscles and the nerves that control them cannot be completely stable. That is because of the "all of nothing rule" of muscles and nerves⁴. Nerves and muscles can be either completely "on" or "off", much like boolean logic elements in computers. However, the effect (or illusion) of muscles turned "on" partially is achieved by rapidly repeated nerve pulses. How this happens is explained next:

When a nerve triggers a muscles cell, the cell twitches (contracts) for about 0.1 seconds^{5,6}. If a nerve triggers a muscle cell once per second, it will be "on" about 10% of the time. In robotics, this would be analogous to a 10% duty cycles in a PWM (Pulse Width Modulated) motor controller. But if the trigger arrives 10 time per second, the muscle cell will be "on" all the time, until it has exhausted its fuel (ATP).

Consequently muscles are not steady. The overall pull of a muscle is the average of millions of cells that are pulsing on and off. You can actually hear this pulsing by making a tight fist against your ear. You will hear a deep rumbling sound. This is the sound of million of muscle cells twitching on and off.

When a human aims a rifle (or laser pointer) the muscle control nerves get their data from the brain, the visual system, balance sensors in the inner ear and from special sensors inside of muscles. The special sensors are called muscle spindles and they measure the contraction length of the muscle⁷.

Somehow, our nervous system integrates all this information to hold an object steady.

Experiment

Figure 1 shows the experimental setup: A laser pointer was mounted on a cardboard “paddle.” An infrared distance sensor monitored the position of the paddle as it was held with horizontally outstretched arm by the subject. The distance from the subject’s shoulder to end of the paddle was kept at one meter, regardless of the length of his/her arm.

The height of the paddle was sensed by a Sharp GP2Y0A02YK0F distance measuring unit⁸. The output voltage of the distance measuring unit was reduced by a factor of 0.688 and low-pass filtered with an cut-off frequency of 10 Hertz, to make it compatible with the data acquisition interface.

The data acquisition was performed by a LabJack U3-LV⁹. We used one of the 12 bit analog inputs, at a 100 samples per second rate. Appendix 1 has the Python code for the data acquisition.

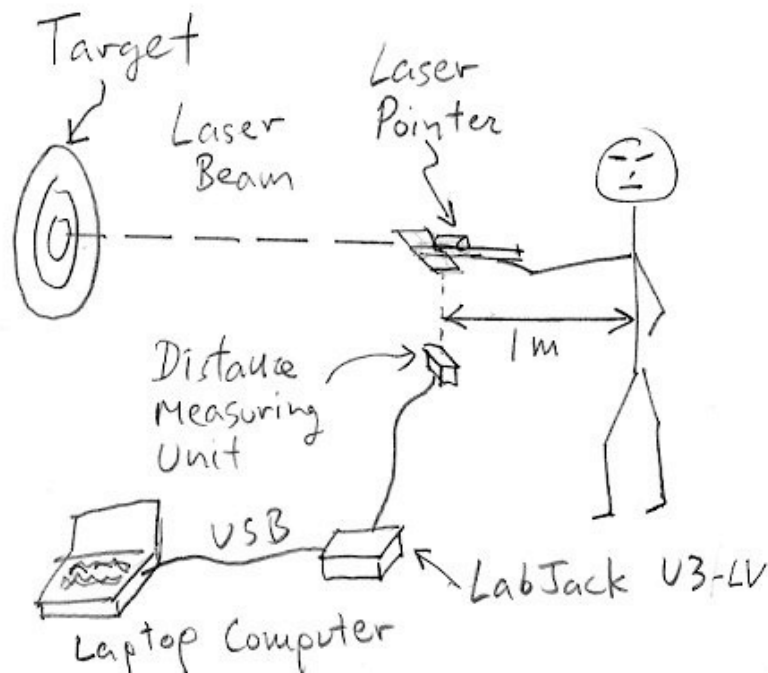


Figure 1. Experimental setup. The human subject aims the laser pointer at the target. The distance monitoring unit monitors his/her stability. Any shaking will be recorded by the laptop computer.

The distance measuring unit works by triangulation¹⁰. A thin beam of infra-red (IR) light shines onto the paddle. Scattered light from the paddle is imaged onto an infra-red detector. The angle at which the IR light strikes the imaging lens and sensor indicates the distance. This is illustrated in figure 2.

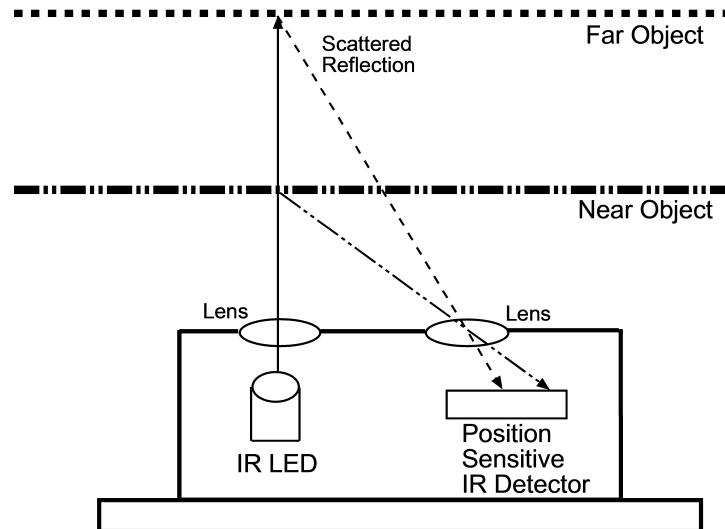


Figure 2. Conceptual diagram of the Sharp infra-red distance measuring unit¹¹. The “object” in our experiment is the paddle that the human subject holds.

I need a diagram of the low-pass filter. Put it here.

Figure 3. Voltage divider and low-pass filter.

Data and Results

Figures 4 and 5 show typical data from a 10 second run where a human subject (Dr. Halverson) was aiming the laser pointer. The shaking was about 3 mm peak-to-peak. (That means maximum to minimum.) Figure 5, the histogram, shows that the shaking does not produce a “Normal” or “Gaussian” or “Bell shape” error distribution. Hence it is more difficult to characterise the mathematical form of the shaking. The author has decided to calculate both the Standard Deviation (even though its not necessarily appropriate) and the average deviation.

The formula used for the Standard Deviation was
$$\sigma = \sqrt{\frac{1}{n} \sum_{i=1}^{i=n} (d_i - \langle d \rangle)^2}$$
 where d_i

are the individual distance measurements and $\langle d \rangle$ is the average of all the measurements. n is the number of measurements.

The formula used for the Average Deviation was
$$D = \frac{1}{n} \sum_{i=1}^{i=n} |d_i - \langle d \rangle|$$

The data for various human subjects was processing in this way and the result are shown in Table 1. Note that there is no obvious male-versus female trend apparent. (Yet.)

I need more data. Any volunteers????

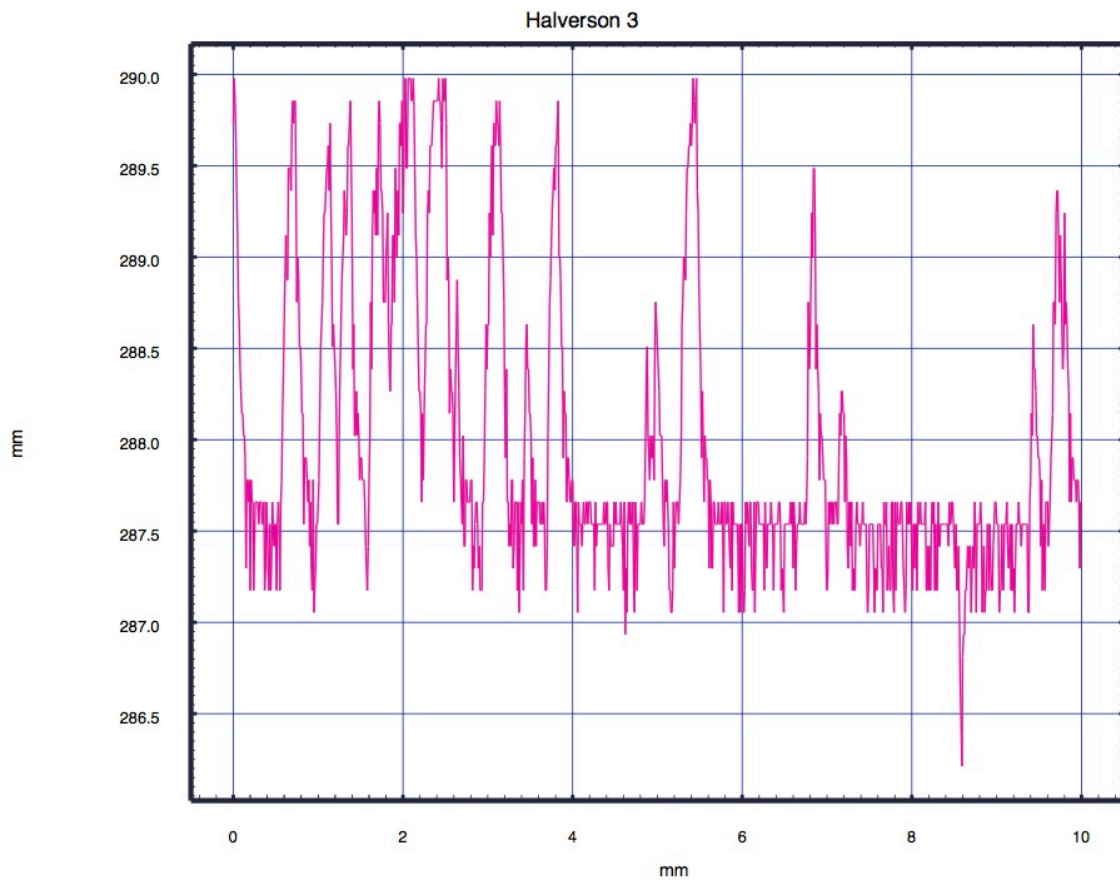


Figure 4. Measured distance of the paddle, held by Dr. Halverson, for 10 seconds. The vertical axis is in millimeters. We can see that the shaking was about 3 mm, peak-to-peak.

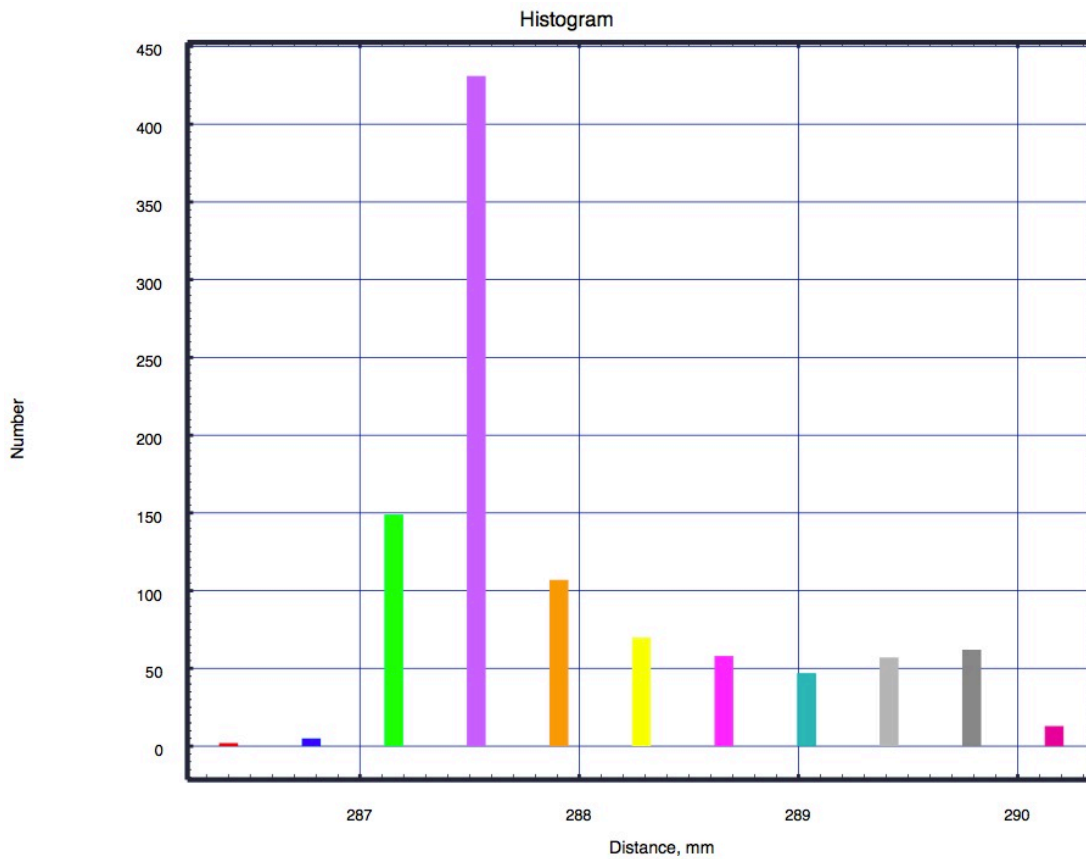


Figure 5. Histogram of data in figure 4. We see that the position does not follow a Normal or Gaussian distribution. Therefore the technique of Standard Deviation might not be appropriate for calculating the size of the shaking.

Subject	Year	M/F	Mean distance mm	D, Avg. Dev., mm	σ . Std. Dev., mm	Range (maximum-minimum) mm
Halverson 1	Teacher	M	280	0.36	0.50	3.5
Halverson 3		M	287	0.64	0.79	3.8
Kayoko 2	Teacher	F	223	1.83	2.37	9.8
Kayoko 3		F	221	0.37	0.56	3

Table 1. Summary of data showing the Average Deviation D and the Standard Deviation σ for various human subjects. The Range is the minimum distance minus the maximum distance in a data run.

Conclusion

I need to summarize my results and put that here.

References

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- ¹ *The Wall Street Journal*, Feb. 23, 2012 “Taking Aim at an Old Debate Can Female Athletes Compete Against Men? In Shooting, Yes—But Not in the Olympics”, Mark Yost, <http://www.wsj.com/news/articles/SB10001424052970203960804577239540945498130>
- ² *Clin J Sport Med*. 2011 Jul;21(4):325-9. doi: 10.1097/JSM.0b013e31821f5cfb. “Time to stability differences between male and female dancers after landing from a jump on flat and inclined floors.” Pappas E, Kremenic I, Liederbach M, Orishimo KF, Hagins M. <http://www.ncbi.nlm.nih.gov/pubmed/21694591>
- ³ *Percept Mot Skills*. 2001 Oct;93(2):479-85. “Relation of rifle stock length and weight to military rifle marksmanship performance by men and women.” Kemnitz CP1, Johnson RF, Merullo DJ, Rice VJ. <http://www.ncbi.nlm.nih.gov/pubmed/11769906>
- ⁴ *Encyclopædia Britannica Online*, s. v. "All-or-none law", accessed May 17, 2015, <http://www.britannica.com/EBchecked/topic/15886/all-or-none-law>.
- ⁵ Lecture Notes for Human Structure and Function, *Control of muscle contraction*, Stefano Casalotti, University College London <http://www.ucl.ac.uk/~sjjgsca/MuscleControl.html>
- ⁶ Lecture Notes for Human Physiology, *Muscle*, Gary Ritchison, Department of Biological Sciences Eastern Kentucky University, <http://people.eku.edu/ritchisong/301notes3.htm>
- ⁷ *Encyclopædia Britannica Online*, s. v. "Mechanoreception", accessed May 17, 2015, <http://www.britannica.com/EBchecked/topic/371976/mechanoreception/64724/Vibration-reception>
- ⁸ Sharp Electronic Compnents GP2Y0A02YK0F <http://sharp-world.com/products/device/lineup/selection/opto/haca/diagram2.html>
- ⁹ LabJack U3-LV Multifunction DAQ with USB <http://labjack.com/u3>
- ¹⁰ *Society of Robots*, SENSORS - SHARP IR RANGE FINDER http://www.societyofrobots.com/sensors_sharpirrange.shtml
- ¹¹ *Stack Exchange Electrical Engineering*. “Real time short distance range finder and visual output.” <http://electronics.stackexchange.com/questions/83328/real-time-short-distance-range-finder-and-visual-output>

Appendix 1: Python code

```
##### distance_recorder_U3.py #####
def v_to_d(v):
    v=v*3.2/2.2    #Account for the 1 kOhm into 2.2 kOhm voltage divider
    return 600.0/v    #Return the distance in *** millimeters ***

def statistics(y):
    sum = 0.0
    sum_of_deviations = 0.0
    sum_of_squares = 0.0
    for i in range(0,len(y)):
        sum = sum + y[i]
    average = 1.0*sum/len(y)
    for i in range(0,len(y)):
        deviation = y[i] - average
        sum_of_deviations = sum_of_deviations + abs(deviation)
        sum_of_squares = sum_of_squares + deviation*deviation
    average_deviation = sum_of_deviations/len(y)
    standard_deviation = (sum_of_squares/len(y))**0.5
    minmaxrange=max(y)-min(y)
    print "Statistics: # of points = ",len(y)," average= ",average," avg. dev.=
",average_deviation,
    print " std. dev.=","standard_deviation," range=","minmaxrange
    return

print "Temperature recorder.  Connect a Sharp GP2Y0A02YK0F sensor to the LabJack U3"
print "The +5 Volts power wire (red) should go to VSS"
print "The Ground wire (black) should go to GND"
print "The signal wire (white) should go to a voltage divider & low-pass filter"
print "1 kOhm into 100 uF in parallel with 2.2 kOhm (0.1 s time constant)"
print "then to FIO6"

seconds_per_loop = 0.01    #100 samples/s

import sys
mypath=sys.path[0]
if mypath.find('my_python')== -1:    #If true, then "my_python" could not be found
    print "Sorry.  You need to be in my_python for Halverson's program to work."
    print "(That's because I am assuming that the tgraphlibx.py and ezu3.py libraries
are there.)"
    exit()
sys.path[0]=mypath[0:mypath.find('my_python')]+my_python'

import pyaudio
import u3
from ezu3 import *
from tgraphlibx import *
from time import sleep
x_array=[ ]
y_array=[ ]
d = u3.U3() # Opens the first LabJackU3 found on the USB
u3setup(d,['ain','ain','ain','ain','ain','ain','ain','ain'])
print "Get ready.  There will be three short beeps and the recording will begin."
print "recording will last 30 seconds, and then there will be a long beep"
#sleep(2)
```

```

# Three 0.1 s beeps, each one second apart
# Open the stream required, mono mode only...
stream=pyaudio.PyAudio().open(format=pyaudio.paInt8,channels=1,rate=16000,output=True)
for beep_num in range(0,3):
    # Now generate the 1KHz signal at the speakers/headphone output for about 10
seconds...
    # Sine wave, to 8 bit depth only...
    for n in range(0,100,1): stream.write("\x00\x30\x5a\x76\x7f\x76\x5a
\x30\x00\xd0\xa6\x8a\x80\x8a\xa6\xd0")
    # Close the open _channel(s)...
    sleep(0.9)
stream.close()
pyaudio.PyAudio().terminate()

seconds=0.0    #This will be the number of seconds the program has run
while seconds<10.0:
    V6=ain6(d)    #Get Voltage from temperature sensor    LM34
    distance=v_to_d(V6)
    #print "V6=",format(V6,"5.3f"),"Volts, "," Time=",seconds," d=",distance," cm"
    x_array=x_array+[seconds]    # Array of times for the graph
    y_array=y_array+[distance]    # Array of distance for the graph
    seconds=seconds+seconds_per_loop
    sleep(seconds_per_loop)

# One 1 s beep
# Open the stream required, mono mode only...
stream=pyaudio.PyAudio().open(format=pyaudio.paInt8,channels=1,rate=16000,output=True)
# Now generate the 1KHz signal at the speakers/headphone output for about 10
seconds...
# Sine wave, to 8 bit depth only...
for n in range(0,1000,1): stream.write("\x00\x30\x5a\x76\x7f\x76\x5a
\x30\x00\xd0\xa6\x8a\x80\x8a\xa6\xd0")
# Close the open _channel(s)...
stream.close()
pyaudio.PyAudio().terminate()
statistics(y_array)
graph_xy(x_array,y_array)

```