Psychology of Perception
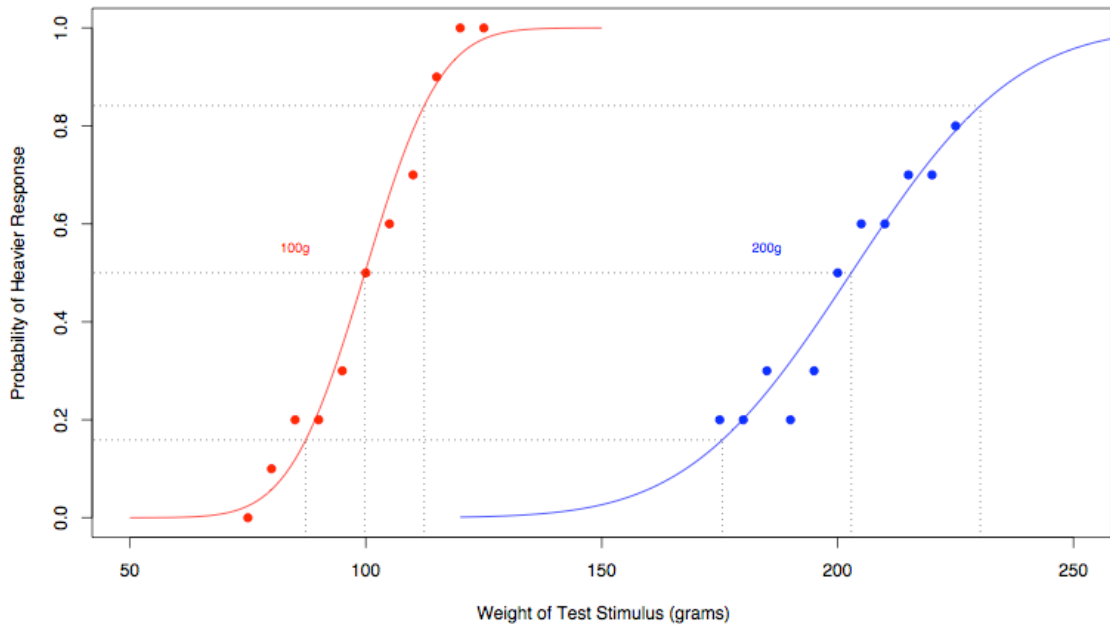
Psychology 4165, Fall 2007

Laboratory 1

Noisy Representations

Figure 1: Weight Discrimination Psychometric Functions

Lab 1: Noisy Representation

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Fall 2007   MUEN D156, 09:30–10:45 TR

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Introduction

Classical methods of psychophysics involve the measurement of two types of sensory thresholds: the absolute threshold, RL (*Reiz Limen*), the weakest stimulus that is *just* detectable, and the difference threshold, DL (*Differenz Limen*), the smallest stimulus increment that is *just* detectable (also called the Just-Noticeable Difference, the JND). Gustav Theodor Fechner (1801–1887), in *Elemente der Psychophysik* (Fechner, 1860) introduced three psychophysical methods for measuring absolute and difference (JND) thresholds: the method of adjustment; the method of limits; the method of constant stimuli.

The purpose of this laboratory is to give you experience with the measurement and computation of the JND for lifted weights using the method of constant stimuli and to test the predictions of Weber's Law (see below).

Experiment

You will determine difference thresholds for weight discrimination using the method of constant stimuli for two different standard weights: 100 and 200 grams. One of the foundations of psychophysics is Weber's Law. It states that the difference limen is a constant proportion of the standard:

$$\frac{\Delta I}{I} = k \qquad\qquad \text{Weber's Law}$$

In this experiment you will test the hypothesis that Weber's constant is the same for two different standard weights, thus validating Weber's Law.

Procedure

In the method of constant stimuli, a standard stimulus is compared a number of times with other fixed stimuli of slightly different magnitude. When the difference between the standard and the comparison stimulus is large, the subject nearly always can correctly choose the heavier of the two weights. When the difference is small, errors are often made. The difference threshold is the transition point between differences large enough to be easily detected and those too small to be detected.

Each of you will serve as subject, experimenter, and data recorder. You will use the method of constant stimuli to measure your ability to discriminate small differences in weight using two standard weights: 100 grams and 200 grams. Since there are two different standard weight conditions there are two possible testing orders. You should test yourself in the order assigned to you.

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Testing Orders

Order No	1st	2nd
1	100	200
2	200	100

The experimenter (E) presents a pair of weights (the standard and one of the test weights listed on the data sheet) to the observer (O). He/she arranges a support for the preferred arm of the subject or observer (O) so that his/her hand will extend over one weight. By flexion of the wrist O should be able to pick up the weight that E has placed in the appropriate position. O should lift the standard weight first (100 or 200 grams) and then the test weight and judge whether the test weight was heavier or lighter than the standard. The person recording the data needs to know the actual weight of the test weight. If the test weight was judged heavier than the standard, a "+" should be recorded on the data sheet. If the test weight was judged lighter, a "-" should be recorded. The 11 test weights should be scrambled on the table and presented in a "random" order. After all 11 are presented the experimenter should shuffle them again and repeat the presentation of each test weight.

Ideally O should be blindfolded, or at least turn his/her face away so that he/she gets no visual cue as to which weight is presented. E then gives O the necessary instructions:

1. "When I say, 'Now,' lift the standard weight which is directly below your hand, using a wrist motion. Notice its weight, return it to the table, and lift your hand again. When I repeat, 'Now,' do the same with the second weight."

2. "Report whether or not the test (second) weight seems **heavier** than the standard weight. **Do not give 'equal' judgments**. Guess if you are not certain."

3. E should present the weights in pairs, placing first the standard weight (either 100 or 200 grams, as appropriate) and then a test weight directly below O's hand. E should try to develop a regular rhythm. Stimuli should be presented for 1–2 sec. duration, separated by an equal period of time. The intervals between pairs should be longer. Allow the subject to rest from time to time. At least 10 presentations of each test stimulus should be made. The order of the test weights should be randomized.
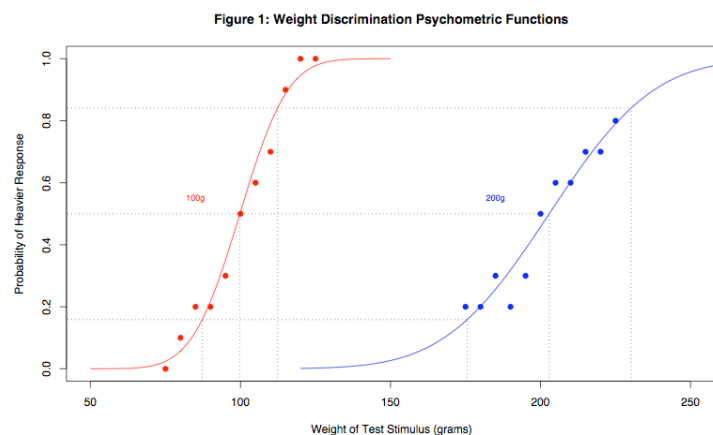
Data Tabulation and Analysis

1. Transfer the frequency of "heavier" and "lighter" judgments for each test weight from your data sheet to the summary sheet at the end of this handout. Compute the total of heavier and lighter judgments and then compute the

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probability of making a heavier judgment.

2. Now prepare a data file containing your data. Open the template data file "lab1_glm.txt" by double-clicking on it. It should open in Microsoft Excel. Replace the last two data columns with your own data (frequency of heavier and lighter judgments). Replace the "Lew" in column 1 with your own name (no spaces). When you are finished, choose SaveAs… from the File menu and save the file as a *Text File* with your own name (e.g., HarveyData.txt). Do not use spaces in the file name.

3. Use the R commands listed in the file "lab1_glm.R" (reproduced at the end of this handout) to carry out your data analysis (R Development Core Team, 2007). There are two basic steps to the analysis: 1) the generalized linear model function of R (glm()) is used to fit a smooth, s-shaped psychometric function to your 100 gram and 200 gram data; and 2) graphs of your results are plotted in two separate figures.

4. The results of the curve-fitting are stored in R objects glm100 and glm200. These results may be viewed using the summary() command: summary(glm100) and summary(glm200). You can copy the badness-of-fit index, AIC, from your screen to your data sheet. The mean and standard deviations of the best-fitting Gaussian distributions are in R objects mu100, sd100, mu200, and sd200 respectively.

5. **The JND**: There are two ways to estimate the JND. One way is to compute the reciprocal of the steepness of the best-fitting psychometric function. The steepness is given by the glm coefficient corresponding to Test_Weight. So the steeper the function, the smaller the JND. Computed this way, one JND is equivalent to one standard deviation of the Gaussian distribution underlying the psychometric function.
    The second, equivalent method, is to use the difference, in grams, between the weight corresponding to the 0.84 point on the ordinate, and the weight corresponding to the 0.16 point on the ordinate divided by 2.0. Compute the Weber fraction for the 100 and the 200 gram standard by dividing the appropriate JND by the corresponding standard weight. Is the Weber fraction constant?
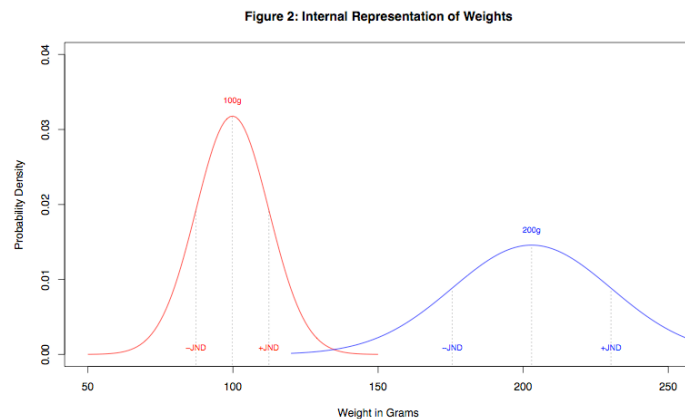
6. Prepare two graphs illustrating your results. Figure 1 should be a plot of your observed psychometric function data for the 100 and 200 gram standards along with the best-fitting s-shaped psychometric function. The graphic commands to make

Figure 1: Weight Discrimination Psychometric Functions

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the figure on the front of this handout an below are given in the file "lab1_glm.R". Feel free to use help(plot) and modify the plotting parameters to achieve the kind of plot that appeals to you. Your Figure 1 should look like the graph above. You save a graph in R as a file by clicking on the graph window and choosing save from the File menu.

7. The second figure plots the noisy representations of the 100 and 200 gram standard weights using dnorm(). Check out the graphing commands in the lab1_glm.R file. Your Figure 2 should like something like this:

Figure 2: Internal Representation of Weights

8. **Hypothesis Testing**: We will assemble your individual data into a single data file that will be available for the next lab meeting. Test the hypothesis, using R, that the value of the Weber fraction is the same for 100 grams as for 200 grams. The appropriate analysis is a repeated measures analysis of variance.

9. When you have a lot of data from different people it is a good idea to make graphs of them so you get an idea what they look like and whether or not there are differences among different groups or levels of factors. This strategy is part of what is called exploratory data analysis (Tukey, 1977). Two such plots are called strip charts and box plots. The R commands to produce them are given in the file "lab1_aov.R" and are reproduced at the end of this handout.

Lab Report

Your lab report should be brief and contain five sections: cover sheet, introduction, methods, results, and discussion. These sections should conform to the American Psychological Association (APA) style (American Psychological Association, 2001) as described in Chapter 13 of the Martin textbook (Martin, 2007).The results section should have the graphs described above and a table giving the JND and Weber's k for the 100 and 200 gram conditions. Do your results support Weber's Law?

The report is due at the beginning of the lab meeting **(18 & 20 September 2007)**. Late labs will receive a grade of zero. All lab reports must be prepared with a word processor. This lab report is worth 30 points.

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Psychology 4165-100
Fall 2007

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References

American Psychological Association. (2001). *Publication Manual of the American Psychological Association* (5th ed.). Washington, DC: American Psychological Association.

Fechner, G. T. (1860). *Elemente der Psychophysik*. Leipzig, Germany: Breitkopf and Härtel.

Martin, D. W. (2007). *Doing psychology experiments* (7th ed.). Belmont, CA: Thomson Wadsworth.

R Development Core Team. (2007). *R: A language and environment for statistical computing*. Retrieved. from http://www.R-project.org/.

Tukey, J. W. (1977). *Exploratory data analysis*. Reading, MA: Addison-Wesley.

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Method of Constant Stimuli Data Sheet — 100 gram Standard											
Trial No.	75	80	85	90	95	100	105	110	115	120	125
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
Frequency of Test "Heavier"											
Frequency of Test "Lighter"											

Note: The judgment of the observer should be which weight (Test or Standard) is heavier.

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Method of Constant Stimuli Data Sheet — 200 gram Standard											
Trial No.	175	180	185	190	195	200	205	210	215	220	225
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
Frequency of Test "Heavier"											
Frequency of Test "Lighter"											

Note: The judgment of the observer should be which weight (Test or Standard) is heavier.

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Data Summary Sheet

Weight in grams	No. Heavier than Standard	No. Lighter than Standard	Total No. of Judgments	Probability Heavier
75				
80				
85				
90				
95				
100				
105				
110				
115				
120				
125				
175				
180				
185				
190				
195				
200				
205				
210				
215				
220				
225				

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Curve-Fitting Summary from glm

Name	Order	Mean		Std Deviation		Index-of-Fit: AIC	
		mu100	mu200	sd100	sd200	100 g	200 g

Please transfer your results above to the master data sheet for the class and we will prepare a master file with everyone's data for analysis next meeting. Your name will not appear on the master file.

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```
# PSYC 4165 Lab 1
# command file for using glm to compute the best-fitting
# Gaussian integral (Gaussian CDF) to psychometric function data.
# Lewis O. Harvey, Jr.
# Department of Psychology
# University of Colorado

par(ask=TRUE) # ask before plotting the next graph


# ****************************************************
# Analyze the data
# ****************************************************

#fn <- "lew_glm.txt"
fn <- file.choose()
pf <- read.delim(fn, header=TRUE)

# compute the probability of making a "heavier" judgment for each
# of the test stimuli
pf <- cbind(pf, p_Heavier = pf$No_Heavier / (pf$No_Heavier +
pf$No_Lighter))

# put the two sets of data (100 and 200 gram) into separate data frames
pf100 <- subset(pf, Standard=="100_gr")
pf200 <- subset(pf, Standard=="200_gr")

# compute the best-fitting Gaussian integrals for each set of data
using
# a genealized linear model (glm).
# The "probit" link specifies that a Gaussian probability distribution
is being fit to the data.
# The "binomial" family specifies that the dependent variable (number
of heavier and lighter
# judgments) are drawn from a binomial distribution.
glm100 <- glm(cbind(No_Heavier, No_Lighter) ~ Test_Weight, data =
pf100, family = binomial(link = "probit"))
glm200 <- glm(cbind(No_Heavier, No_Lighter) ~ Test_Weight, data =
pf200, family = binomial(link = "probit"))

# compute the mean and standard deviations of the Gaussian probability
density functions from the glm solutions
mu100 <- -coefficients(glm100)[1]/coefficients(glm100)[2]   # mean of
the 100 gram representation
sd100 <- 1 / coefficients(glm100)[2]                        # standard
deviation of the 100 gram representation
mu200 <- -coefficients(glm200)[1]/coefficients(glm200)[2]   # mean of
the 200 gram representation
sd200 <- 1 / coefficients(glm200)[2]                        # standard
deviation of the 200 gram representation

# get the cumulative probability corresponding to plus and minus 1
standard deviation
# that we define to correspond to 1 JND (these should be 0.16 and 0.84)
pmJND <- pnorm(-1.0)    # probability 1 sd below the mean
```

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```
ppJND <- pnorm( 1.0)    # probability 1 sd above the mean

# weights corresponding to 1 JND above and below the means
q1 <- qnorm(pmJND, mu100, sd100) # lower jnd weight for 100 grams
q2 <- qnorm(ppJND, mu100, sd100) # upper jnd weight for 100 grams
q3 <- qnorm(pmJND, mu200, sd200) # lower jnd weight for 200 grams
q4 <- qnorm(ppJND, mu200, sd200) # upper jnd weight for 200 grams

# compute the JNDs from lower and upper 1 sd points
jnd100 <- (q2 - q1) / 2     # jnd in grams
jnd200 <- (q4 - q3) / 2     # jnd in grams

# compute the Weber fraction for 100 and 200 grams
web100 <- jnd100 / 100
web200 <- jnd200 / 200


# ****************************************************
# Plotting Section
# ****************************************************

# test stimuli used under the 100 and 200 standard conditions
ts100 <- c(75, 80, 85, 90, 95, 100, 105, 110, 115, 120, 125)
ts200 <- c(175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 225)

# plot Figure 1, the psychometric functions
plot(p_Heavier ~ Test_Weight, data = pf100, col = "red",
    xlim = c(50, 250), ylim = c(0, 1), pch = 19,
    xlab="Weight of Test Stimulus (grams)",
    ylab="Probability of Heavier Response",
    main="Figure 1: Weight Discrimination Psychometric Functions")

points(p_Heavier ~ Test_Weight, data = pf200, pch = 19, col = "blue")

# plot the predicted smooth curves
x100 <- 50:150
y <- predict(glm100, data.frame(Test_Weight=x100), type = "response")
lines(y ~ x100, col = "red")
x200 <- 120:280
y <- predict(glm200, data.frame(Test_Weight=x200), type = "response")
lines(y ~ x200, col = "blue")

# label each line
text( 85, .55, "100g", col="red",  cex=0.75)
text(185, .55, "200g", col="blue", cex=0.75)

# plot the alpha markers (the point of subjective equality)
lines(c(mu100, mu100), c(-0.1, 0.5), lty=3)
lines(c(mu200, mu200), c(-0.1, 0.5), lty=3)
lines(c(40, mu200), c(0.5, 0.5), lty=3)

# now draw the vertical JND lines (lty=3 makes the line dashed)
lines(c(q1, q1), c(-0.1, pmJND), lty=3)
lines(c(q2, q2), c(-0.1, ppJND), lty=3)
lines(c(q3, q3), c(-0.1, pmJND), lty=3)
```

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```r
lines(c(q4, q4), c(-0.1, ppJND), lty=3)

# draw the vertical JND probability lines
lines(c(40, q3), c(pmJND, pmJND), lty=3)
lines(c(40, q4), c(ppJND, ppJND), lty=3)


# plot Figure 2, Gaussian stimulus representations
plot(x100, dnorm(x100, mu100, sd100),
     type="l", col = "red",
     xlim = c(50, 250), ylim = c(0, 0.04),
     xlab = "Weight in Grams",
     ylab = "Probability Density",
     main = "Figure 2: Internal Representation of Weights")
lines(x200, dnorm(x200, mu200, sd200), col = "blue")

# probability density at each mean
dmu100 <- dnorm(mu100, mu100, sd100)
dmu200 <- dnorm(mu200, mu200, sd200)
lines(c(mu100, mu100), c(-0.1, dmu100), lty=3)
lines(c(mu200, mu200), c(-0.1, dmu200), lty=3)

# probability densities at each JND point
d1 <- dnorm(q1, mu100, sd100)
d2 <- dnorm(q2, mu100, sd100)
d3 <- dnorm(q3, mu200, sd200)
d4 <- dnorm(q4, mu200, sd200)

# now draw the vertical JND lines (lty=3 makes the line dashed)
lines(c(q1, q1), c(-0.1, d1), lty=3)
lines(c(q2, q2), c(-0.1, d2), lty=3)
lines(c(q3, q3), c(-0.1, d3), lty=3)
lines(c(q4, q4), c(-0.1, d4), lty=3)

# label each distribution
text(mu100, dmu100+0.002, "100g", col="red",  cex=0.75)
text(mu200, dmu200+0.002, "200g", col="blue", cex=0.75)

# label the JND markers
text(q1, 0.001, "-JND", col="red",  cex=0.75)
text(q2, 0.001, "+JND", col="red",  cex=0.75)
text(q3, 0.001, "-JND", col="blue", cex=0.75)
text(q4, 0.001, "+JND", col="blue", cex=0.75)

par(ask=FALSE)
```

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```
# PSYCH 4165 Lab 1
# command file for using aov to compute a repeated measures
# analysis of variance using lme() in R.
# Lewis O. Harvey, Jr.
# Department of Psychology
# University of Colorado

# load the nlme library to use lme()
library(nlme)

par(mfcol = c(2,1))

# Read data into R and store it in a data frame:
df <- read.delim("lab1_data.txt", header = TRUE)

# Calculate Weber's Constant (k) for each subject and
# add it to the data frame
df <- cbind(df, Weber_k = df$Dist_StandardDev / df$Standard)
df <- cbind(df, Log_k = log10(df$Weber_k))

# Specify standard weight as a factor in our design:
df$Standard <- factor(df$Standard)

# Write out a summary of the variables in the data frame:
summary(df)

# Make a strip chart of the data
with(df, stripchart(Weber_k ~ Standard,
    method = "jitter", jitter = 0.03,
    xlab = "Weber's k",
    ylab = "Standard Weight",
    main = "Strip Chart of Lab 1 Data"))

# Make a box plot of the data:
boxplot(Weber_k ~ Standard, data = df,
    horizontal = TRUE,
    ylab = "Standard Weight",
    xlab = "Weber's k",
    main = "Box and Whisker Plot of Lab 1 Data")

# compute the means
print(" ", quote = FALSE)
print("means", quote = FALSE)
print(with(df,tapply(Weber_k, Order, "mean")))
print(with(df,tapply(Weber_k, Standard, "mean")))

# use lme() to compute the ANOVA
print(" ", quote = FALSE)
print("Results of lme() Analysis Of Variance", quote = FALSE)
a <- lme(Weber_k ~ Standard * Order, data = df, random = ~ 1|Subj)
print(anova(a))

par(mfcol = c(1,1))
```