Distraction and Reaction Time

1 INTRODUCTION

How does distraction affect one's reaction time? Is one's distracted reaction time significantly different from their normal reaction time? Today you will experiment to formulate quantitative answers to these questions.

2 LEARNING GOALS

- To design an experiment to test a hypothesis.
- To understand what it means for a measurement to be meaningful.
- To quantify the effect that distraction has on reaction time.

3 BACKGROUND

3.1 STANDARD DEVIATION AND STANDARD ERROR

In this course we've already encountered the average and standard deviation as ways to characterize a sample.

The average of N measurements is given by:

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \ldots + x_N}{N} = \frac{\sum x_i}{N} \tag{3.1}$$

and describes our best estimate of the quantity being measured.

The standard deviation is used to describe the spread observed in a sample of N measurements. Mathematically, the standard deviation σ_x is given by:

$$\sigma_x = \sqrt{\frac{1}{N-1} \sum \left(x_i - \bar{x}\right)^2}. \tag{3.2}$$

The standard deviation not only describes the spread of an entire sample but it can also be used to estimate the uncertainty associated with an *individual* measurement. That is:

$$\delta_{x_i} = \sigma_x. \tag{3.3}$$

In most cases, as more measurements are made, we expect that the precision of the best estimate for the value of interest should improve. This trend is typically not observed in the standard deviation alone. Instead a quantity called the *standard error* or *standard deviation of the mean* is used.

The standard error describes the uncertainty associated with our best estimate for a given quantity x. Our best estimate is often the average, $\bar{x}$. The standard error of the mean, $\sigma_{\bar{x}}$, is given by:

$$\sigma_{\bar{x}} = \frac{\sigma_x}{\sqrt{N}} \tag{3.4}$$

where σ_x is the standard deviation of the sample and N is the total number of measurements.

The important feature of the standard error of the mean is that as more data are taken (*i.e.* N increases), the standard error of the mean, $\sigma_{\bar{x}}$, decreases. Large samples lead to a higher degree of confidence in the final measurement. Note that Equation 3.4 only applies if the variable being measured is truly random. For example, measuring the length of nail with a ruler an infinite number of times will not yield a measurement with zero uncertainty.

When stating a result, that is the result of an average, it is often appropriate to quote the standard error of the mean as the uncertainty. That is, the final result will be presented as:

$$\bar{x} \pm \sigma_{\bar{x}}. \tag{3.5}$$

The standard error of the mean can be calculated in a spreadsheet by using something like `=STDEV(`*`sample`*`)/SQRT(COUNT(`*`samp`*

For a concise discussion on standard deviation and standard error, see Taylor's, *An Introduction to Error Analysis*, Chapters 4.3 and 4.4, pp. 101-103.

3.2 Histograms

A histogram is a type of chart that is useful for representing the frequency of measurements graphically. Histograms are often used to illustrate how data are distributed. It is possible to generate histograms using most spreadsheet programs.

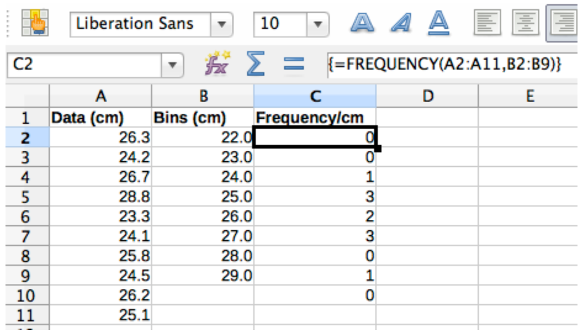
Suppose that we record the following distance measurements (in cm):

$$26.3, 24.2, 26.7, 28.8, 23.3, 24.1, 25.8, 24.5, 26.2, 25.1. \tag{3.6}$$

For this example, a histogram is a useful tool to answer the question; "how many measurements fall between 24.0 and 25.0 cm?"

To generate a histogram in a spreadsheet, a list of bins (or category classes), must be supplied (see Figure3.1). The built-in spreadsheet function, `=FREQUENCY(`*`data, classes`*`)` can be used to count how frequently the *`data`* fall into one of the prescribed *`classes`*. `FREQUENCY()` is an array function (similar to `LINEST()`) that returns an array that is one cell larger than the number of *class* cells used.

The results from the `FREQUENCY()` function and the list of bin classes can be used to plot a histogram. When generating the plot, use the list of bins as labels for a column-type chart of the frequency (See Figure 3.2).



	A	B	C	D	E
1	Data (cm)	Bins (cm)	Frequency/cm		
2	26.3	22.0	0		
3	24.2	23.0	0		
4	26.7	24.0	1		
5	28.8	25.0	3		
6	23.3	26.0	2		
7	24.1	27.0	3		
8	25.8	28.0	0		
9	24.5	29.0	1		
10	26.2		0		
11	25.1				

Figure 3.1: The distance data (3.6) are listed in column A. The bins shown in column B were chosen arbitrarily. The way `FREQUENCY()` interprets the bin numbering can be confusing. In this example, cell C2 records the number of measurements that are less than 22.0 (the value in B2). C3 counts the number of measurements that are between 22.0 and 23.0 (cells B2 and B3 respectively), *etc*. Cell C10 counts the number of measurements that are greater than 29.0 (cell B9). Note that the `FREQUENCY` function is displayed in braces on the input line indicating that it is a function that returns an array. These braces are not input manually but are automatically added by Excel when an array function is executed.

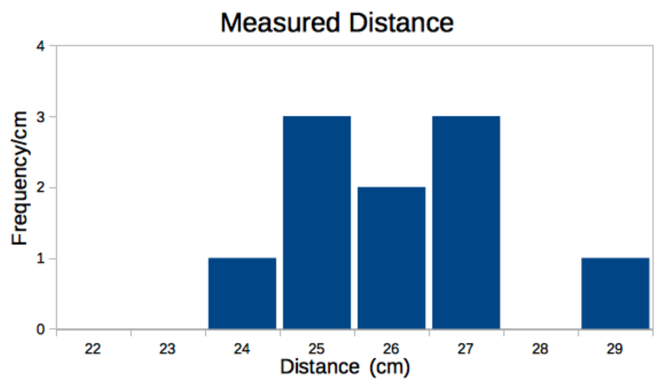


Figure 3.2: A histogram of the distance data shown in Figure 3.1. Column B was used to label the output of the `FREQUENCY()` function in Column C. The data range used to generate the chart includes values in the range C2:C9. A chart type of "column" was used.

3.3 One Dimensional Kinematics

Kinematics is the portion of physics that compares and classifies the motion of objects. In general, motion is complex and difficult to describe mathematically. However, we are often able to limit the types of motion we study to simplify the calculations.

Consider the motion of an object in one dimension with a constant acceleration. These are conditions with which we are familiar as they are satisfied for objects in free-fall near the surface of the earth. The acceleration due to gravity at the surface of the earth is constant and is typically called g.

Under any constant acceleration, a, the position of an object as a function of time, $y(t)$, is give by:

$$y(t) = y_i + v_i t + \frac{1}{2} a t^2, \tag{3.7}$$

where y_i is the position at $t = 0$ and v_i is the velocity at $t = 0$.

3.4 Error Propagation

Error analysis is the process by which we quantify our confidence in a measurement. Much of the time required to make a measurement is spent trying to understand – and quantify – the uncertainties in the measurement. This is true not only in the General Physics Lab, but in real-world scientific pursuits as well.

In many cases, the value in which we are interested is not measured directly but is calculated using other observable quantities. In the case of the dropped ruler, we obtain a better measurement by measuring distance (and calculating a resulting time) than we would by using a manual stopwatch. A stopwatch is limited by the reaction time of the user - which is exactly the quantity we hope to measure.

How do we estimate the uncertainty for a calculated value based on the uncertainty associated with each measurement used in the calculation? The technique used in these cases is called *error propagation*.

Suppose we calculate a quantity, q, based on several independent measurements, $x, \ldots, z$. Each measurement has an associated uncertainty, $\delta_x, \ldots, \delta_z$. The uncertainty in q is then given by:

$$\delta_q = \sqrt{\left(\frac{\partial q}{\partial x}\delta_x\right)^2 + \cdots + \left(\frac{\partial q}{\partial z}\delta_z\right)^2}. \tag{3.8}$$

In other words, the total uncertainty in q is the quadratic sum of the partial uncertainties due to each of the separate uncertainties, $\delta_x, \ldots, \delta_z$.

One strategy that can be used to compute the total uncertainty is to compute each of the partial uncertainties,

$$\left|\frac{\partial q}{\partial x}\right| \delta_x \tag{3.9}$$

separately. The separate partial uncertainties can then be combined in quadrature to obtain the total uncertainty, δ_q as shown in Equation 3.8. This method will also help to identify which of the measured quantities contributes the most uncertainty to the final result.

There are several shortcuts and special techniques that can be used to estimate the uncertainty for various special cases. The form shown in Equation 3.8 is the most general, and will work in nearly all of the situations you encounter in the lab. For a more detailed and systematic introduction to error propagation see John R. Taylor, *An Introduction to Error Analysis*, 2nd ed., Chapter 3.

4 Procedure

Design an experiment to measure your reaction time. What effect do you anticipate distraction will have on your reaction time? Is your distracted reaction time significantly different from your normal reaction time?

In order to create your experiment, you have been provided with a ruler and a *drop apparatus*.

The *drop apparatus* is an aluminum shield intended to minimize systematic error in the experiment by preventing the *catcher* from anticipating the drop of the ruler. A pin at the top of the shield helps to align the ruler and make the position repeatable between trials. Two pins at the bottom of the shield also help the *catcher* to position their hand consistently.

In designing and conducting your experiment, you may want to consider the following:

- How will you use the apparatus to measure reaction time?
- Are there possible systematic biases that can be introduced by not using the drop apparatus as it was intended?
- What will you measure? How will you collect and organize the data?
- How will you decide how many trials you will conduct?
- What factor(s) will you control to obtain the most accurate measurements?
- How do you plan to present the data?
- How will you simulate distraction?
- What steps will you take to keep the distraction realistic, consistent, and repeatable?

5 Lab Report

What conclusions are you able to draw from your data? Are reaction time and distraction correlated?

Before you leave the lab, submit to your TA, via Blackboard, a lab report. Be sure to address the following items:

- Experiment Design: Briefly describe your experimental design – use sketches or diagrams when appropriate.
- Data: What physical quantities did you decide to measure?
  What range of values did you test?
  How many trials did you use?
  Explain why you chose to measure this way.
- Presentation: Present your data in tables and graphs so that they are clear and readable. Tables should be well labeled and include the appropriate units. Graphs should have a title, axis labels, error bars, and fits when appropriate.
  What trends are seen in your plotted data?
  What quantities can be determine by fitting the data?
- Results: State your final result(s). Be sure to include a label, appropriate uncertainty estimates, measurement units, and significant figures.
- Uncertainty: What are some reasonable sources of random uncertainty?
  What are some reasonable sources of systematic uncertainty?
  For each identified source of systematic uncertainty, clearly state how it affects your result.

- Discussion: Discuss your findings.
  What physical principles can be used to explain your observations?
  Do you observe what you expect?
  Do your data and observations make sense?
  What changes could be made to improve the accuracy and precision of your measurement?