Measuring Difference Threshold with Line Length
A Psychophysical Experiment using the Method of Constant Stimuli
www.eFishentArt.com/psyc.html

:: INTRODUCTION ::

This experiment deals with the idea of difference threshold, that is, the minimum amount by which a stimulus must be changed in order to be detected (also known as just noticeable difference). Ernest Weber found that the size of the difference threshold is related to the initial stimulus size in that the ratio between the two is always constant. Therefore, this equation can be written:

$$\Delta I / I = C$$

...where ΔI represents the difference threshold, I represents the initial stimulus value and C signifies the more-or-less constant ratio between the two. Since C is constant for a given stimulus, the relationship between ΔI and I is that as the initial stimulus value (I) increases, so then must the difference threshold (ΔI) to still account for the same ratio C.

:: THE DESCRIPTION ::

This experiment attempts to determine what difference in line length is necessary to be detected, for any given base length. That is, for two lines of the same length, how much longer does one line have to be in order for a subject to notice a difference in length? This experiment is made possible through the use of the program FlashTM and the Internet.

This experiment uses the Method of Constant Stimuli, meaning, the stimuli is the same (a line) but one of its properties, length, is varied. By using this method, the experiment can test specified length differences and record what percent of the time the subject can correctly identify which line is longer. In accordance with Weber's Law, the expected results should be that as the length difference increases, so then will the percent correct. The Method of Constant Stimuli balances out at about 75% correct. The difference in length at this percent correct value will yield the difference threshold for that particular line length.

This experiment is a three-alternative forced-choice experiment (3AFC) because on any given trial, the subject must decide whether (a) the lines are the same length, (b) the left line is longer or (c) the right line is longer. The experiment is designed this way so as to ensure the subject does not guess. It is reasonable to believe the subject might see two lines as being the same length but want to say they are different because he/she guesses that they probably are but it's undetectable. Having two buttons for saying "different" still allows the subject to be wrong, if he/she cannot really tell the difference between the two lines.

The reason why there aren't just two buttons "left is longer" and "right is longer" is because in the situation where the lines look to be the same length and the subject knows they're different (given the two button options), he/she could correctly guess the right button by chance, which does not lead to good data. Having the third "same" button increases the changes from 50/50 to 66/33 that the subject will not detect the line difference.

:: THE PROCEDURE ::

The elements of the FlashTM program are as follows: there is a box on the bottom left that tells the subject what the base line length is, in pixels (the base lengths are 30, 90, 150 and 210 (all odd multiples of 30). There is also a box on the bottom right that tells the subject what trial number he/she is on. Note: for each base line length,

there are 60 trials (10 trials each for 6 predetermined differences). On each trial, the subject is presented with two lines and is asked to determine if the left line is longer, the right line is longer or both lines are the same. If subject clicks the correct button, the score for that particular difference is incremented. Clicking any other button will leave the score as is (all scores are initially 0). Once a button is clicked, the program automatically moves to the next pair of stimuli, after a short (700 ms) delay of blank space.

But here's the catch: the lines presented are never the same length. At minimum, they are different by one pixel. But it is randomly decided which line is different; it could be the left line that is longer or the right line. Therefore, a lot of the time, the subject will click "same" even though the lines are different, signifying that the difference threshold has not yet been reached.

At the end of the 60 trials for a base length, the program will contain a table that shows what percent of time the subject correctly answered for each length difference, calculated by dividing the particular difference by 10 (see example below):

Table 1.1: An example of experiment results, which evinces the relationship between percent correct and line difference. Through graphing, the difference threshold can be interpolated at 75% correct

Base Length:	30	Base Length: 90		Base Length: 150		Base Length: 210	
Difference	%Correct	Difference	%Correct	Difference	%Correct	Difference	%Correct
1	0 (0/10)	3	20	5	30	7	20
2	20 (2/10)	6	40	10	50	14	40
3	50 (5/10)	9	50	15	60	21	60
4	80 (8/10)	12	70	20	70	28	90
6	90 (9/10)	18	90	30	80	42	100
8	100 (10/10)	24	100	40	100	56	100

So then here is, in words, an example experiment:

Trial one will start with a base length of 30 pixels. Two lines appear on the screen that are actually different by 2 pixels in length (a value chosen at random). Which line is different is randomly determined (left or right). Subject clicks appropriate button and screen goes blank for a second. Then two new lines are presented that are different by 8 pixels in length. Subject clicks appropriate button, screen goes blank, and two more lines are presented that are different by 4 pixels. Then 6 pixels. Then 3 pixels. Then 1 pixel. No difference is repeated in a given set of 6 differences. And then the whole process is repeated 10 more times.

It is important to note that the next successive difference presented is randomly generated. That is, difference does not change in increasing order. Rather, it jumps around so the subject does not get used to any pattern. Then once all trials are done for one base length, screen goes blank, let's the subject know that it is moving to the next base length, and the whole thing starts over again, but with the next base length.

:: THE DATA ::

Once all the data has been collected, it is easy to find the difference threshold for each base line length. Plotting %Correct on the Y-axis and the length difference on the X axis for each base line length will yield a best-fitting curve, which can then be used to estimate the just noticeable difference (which occurs where the subject has 75% correct).

Perfect experimental data would yield an S-curve, whereby when the difference is very small, %correct is close to 0% but as the difference gets closer to threshold, there is a dramatic increase in %Correct and past the threshold is almost 100% correct.

This is the psychometric function and there is one for each base line length. The next step then is to plot the psychophysical curve, which will plot the difference thresholds on the Y-axis and the base line lengths on the X-

axis. This graph will determine the relationship between the two, hopefully yielding Weber's results of a constant slope: $\Delta I / I = C$.

In total, there will be five graphs: one graph plotting all the difference thresholds against base lengths, and four graphs plotting % correct against differences (that will determine the difference threshold).

:: THE CODE ::
TheExperiment.fla, TheExperiment.swf

Here is the ActionScript code that makes the FlashTM program work as it does. The entire program is contained in 10 slides: 5 slides to initialize all the variables for each of the five base line lengths, 4 slides to do all the extra computing (choosing lists and differences, determining which button is pressed and pausing for a moment) and 1 last slide to display the results to the user.

The program has a list of 5 arrays, each containing 6 difference values. Program picks at random a list, and then from that list, it randomly picks a difference value. It never picks the same list or difference value twice. It then picks at random which line (left or right) will be the different line and decrements its initial base length by this difference value. When subject selects a button, lines are cleared for one second, and then two more lines are presented.

Slide 1: (START BUTTON) //nothing here except gotoAndPlay(2) //move to next slide

Slide 2: (initialization)

//Purpose of this slide is to set the global variables FOR A BASE LENGTH OF 30 px

```
_global.base = 30;                  //base length, a global variable to be used on other slides
_global.trialnum = 1;               //trial number, a global variable to be incremented and printed on other slides
_global.unusedLists = [0,1,2,3,4];  //the array of unused lists, a global variable to be decremented on other slides
_global.lists = [ [1,2,3,8,4,6], [2,4,1,3,6,8], [3,6,4,1,8,2], [8,3,2,6,1,4], [4,1,6,2,8,3], [6,8,1,4,3,2], [3,4,2,6,8,1], [1,2,3,4,6,8], [4,6,2,3,1,8], [6,3,2,4,1,8] ];
//an array of arrays, each containing length difference values
_global.where = 7;                  //points to which base length to go to next (starts at slide 7, gets incremented)
//also initialize all the scores for each difference to 0
gotoAndPlay(3);                     //go to next slide
```

Slide 3: (initialize list)

//Purpose of this slide is to choose a list and then remove it from the list of lists so it won't use it again!

```
var i = Math.floor(Math.random()*lists.length);   //generate random index value between 0 and list length
_global.newList = lists[i];                       //set the list specified as a global variable
lists.splice(i,1);                                //take out this index from the list (list length decrements)
gotoAndPlay(4);                                   //go to the next slide
```

Slide 4: (initialize difference)

//Purpose of this slide is to choose a difference value at random from the list and remove it from the list (so it won't pick it again!)

```
d = Math.floor(Math.random()*newList.length);        //generate a random index value from within the list determined in slide 2
_global.difference = newList[d];                     //sets the difference value at this index to a global variable for later use
newList.splice(d,1);                                 //takes this index out of the array of difference (array length decrements)
gotoAndPlay(5);                                      //go to the next slide
```

Slide 5: (the main code)

```
//Purpose of this slide is to define the user interface, i.e. what is displayed and what the user can do

stop();

trialnumber.text = "Trial Number: " + trialnum;                  //display trial number
baselength.text = "Base Length: " + base;                        //display base length

var r = Math.floor(Math.random()*2);                             //generate random value 0 or 1
if (r == 0) {                          //half the time this will be true
        leftLine._width = base;
        rightLine._width = base;
        rightLine._width = rightLine._width - difference;        //right line is shorter than left
}
else {                                 //half the time this will be true
        rightLine._width = base;
        leftLine._width = base;
        leftLine._width = leftLine._width - difference;          //left line is shorter than right
}
var diff = leftLine._width - rightLine._width;                   //this variable tells which line is longer
                                                                 //if diff is positive, left is longer, else right is longer

samebutton.onRelease = function(){ gotoAndStop(6); }             //clicking same just moves to the next slide

left_btn.onRelease = function()                                  //clicking "left is longer" checks if it's true. If it is, it scores and moves on
{                                                                //if it's false, it doesn't score, it just moves on
        if (diff > 0) { // meaning left - right is positive, meaning left is longer
                if (difference == 1) score1++;
                else if (difference == 2) score2++;
                else if (difference == 3) score3++;
                else if (difference == 4) score4++;
                else if (difference == 6) score6++;
                else score8++;
        }
        gotoAndStop(6);
}
right_btn.onRelease = function()                                 //clicking "right is longer" does the same thing as clicking "left is longer"
{
        if (diff < 0) { //meaning right is left - right is negative since right is larger
                if (difference == 1) score1++;
```

```
            else if (difference == 2) score2++;
            else if (difference == 3) score3++;
            else if (difference == 4) score4++;
            else if (difference == 6) score6++;
            else score8++;
        }
        gotoAndStop(6);
}
```

Slide 6: (blank slide between stimuli)

```
//Purpose of this slide is to clear the lines for a second before going to the next stimuli pair, as well as determine
which slide to go to //next, depending on the list of difference lists length and the difference list length, as well as
increment the trial number

trialnumber.text = "Trial Number: " + trialnum;                    //still display the trial number
baselength.text = "Base Length: " + base;                          //still display the base length
trialnum++;                                                  //increment the trial number

goBack = function() {
        clearInterval(interval);
        if (newList.length == 0 && lists.length == 0) gotoAndPlay(7);                    //if all the differences in the
                                                                                    //list have been used and all the lists
                                                                            //have been used, go to the slide that displays results

        else if (newList.length == 0 && lists.length != 0) gotoAndPlay(3);          //else if all the differences in
                                                                                    //the list have been used but there are
                                                        //more lists to use, go back to slide 2 and generate a new list

        else goToAndPlay(4);                                                        //else go back to slide 3 and generate another
                                                                                    //difference value
}
interval = setInterval(goBack, 700);                                                //pause on this slide for 700 ms first
```

Slide 7: (results page)

```
//Purpose of this slide is to display results and determine which base line to go to next

resul.text = "Results: \n Diff   %Correct \n 1      " + score1 +"\n 2      "+ score2 +" \n 3      "+ score3+" \n 5      "+
score4 +" \n 7      "+ score6 +" \n 9      "+ score8;
stop();

where++;                                                    //increments global variable "where" to point to next base
length
next_btn.onRelease = function() {
        if (where <= 10) gotoAndPlay(where);                //if all the base lengths haven't been done, go to the
next one
        else gotoAndPlay(1);                                //else go back to the beginning because the program is done
}
```

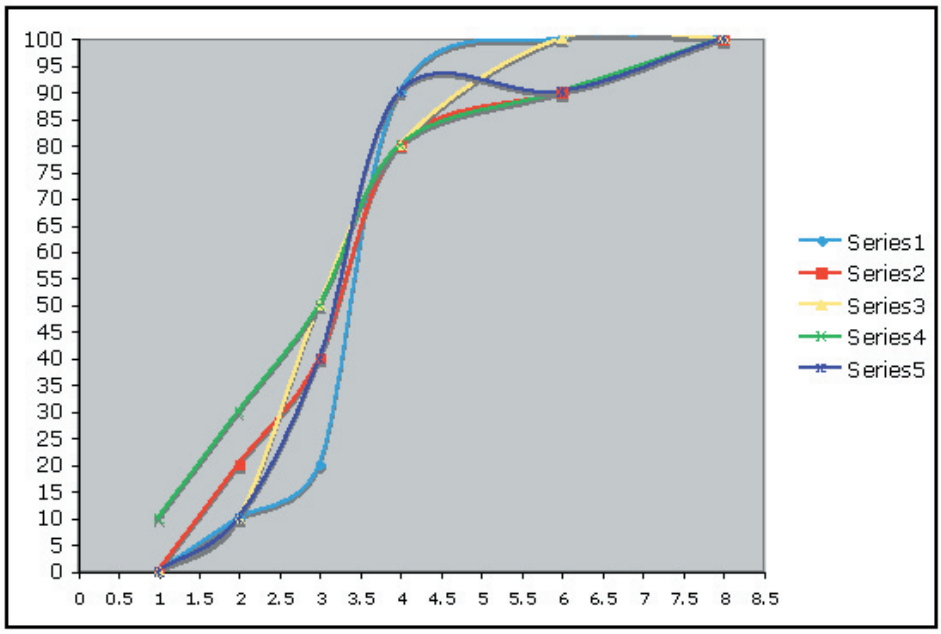
Slides 8, 9 and 10 are exactly like Slide 2 except that they make the global variable "base" to a new base length (slide 8 is 90, slide 9 is 150 and slide 10 is 210). They also do not re-establish the global variable "where" so it maintains its value.

:: THE RESULTS ::

Base Length = 30 px

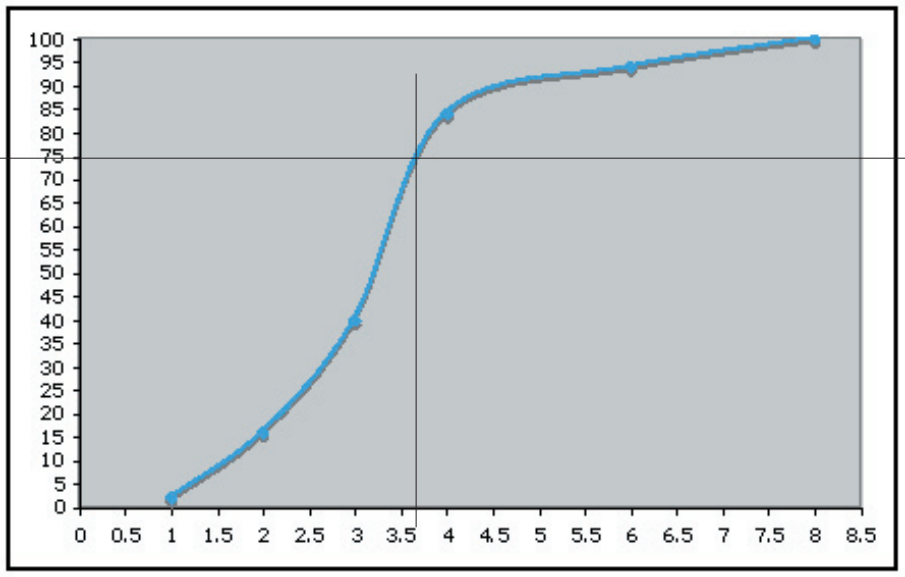
Five random people (men, women, older, younger) were tested for a base line length of 30 px. Their results are graphed here:

Graph 30A: % Correct vs Line Difference for a Base Length of 30 px



From here it is clear that every person has relatively the same curve. That is, as the difference increases, the % correct increases too at a steep slope. In order to figure out the average difference threshold at 75% correct, each point along each curve is averaged with the others so as to form a single curve, shown below:

Graph 30B: Plotting a single line to average the 5 from Graph 30A



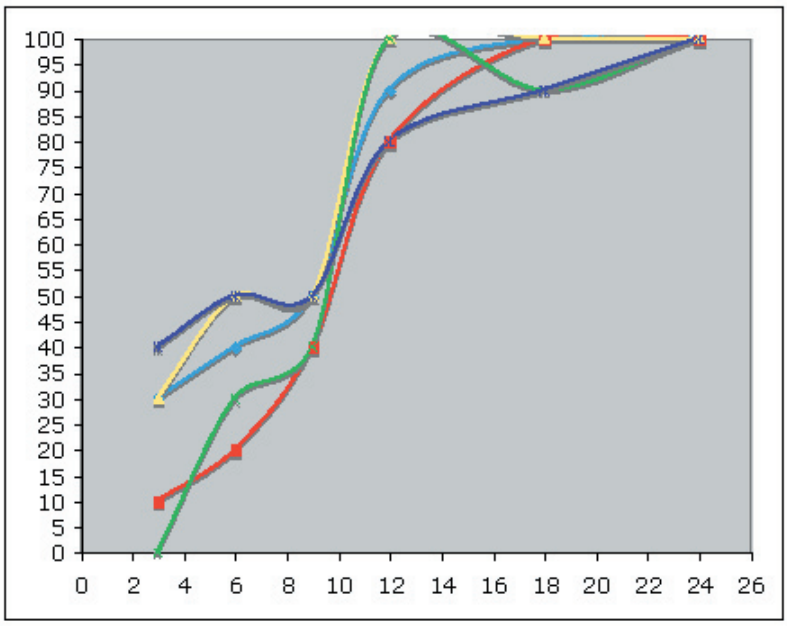
From here, the difference threshold can be estimated by drawing a horizontal line from the Y-axis at 75% correct to the line, and then drawing a vertical line from that point on the line to the X-axis to find the X-axis value.

The average difference threshold found for a base line length of 30 px is about **3.65** px which yields the first value for C, the ratio of ΔI and I: 3.65/30 = **0.122**

Base Length = 90 px

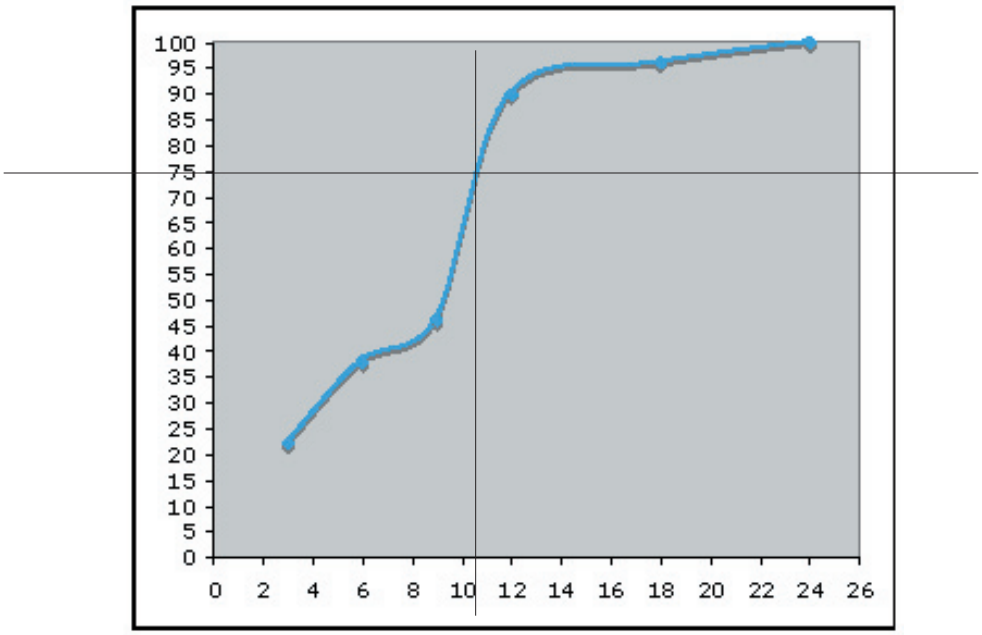
Five random people tested for a base line length of 90 px. Their results are graphed here:

Graph 90A: % Correct vs Line Difference for a Base Length of 90 px



From here it is clear that every person has relatively the same curve. That is, as the difference increases, the % correct increases too at a steep slope. In order to figure out the average difference threshold at 75% correct, each point along each curve is averaged with the others so as to form a single curve, shown below:

Graph 90B: Plotting a single line to average the 5 from Graph 90A



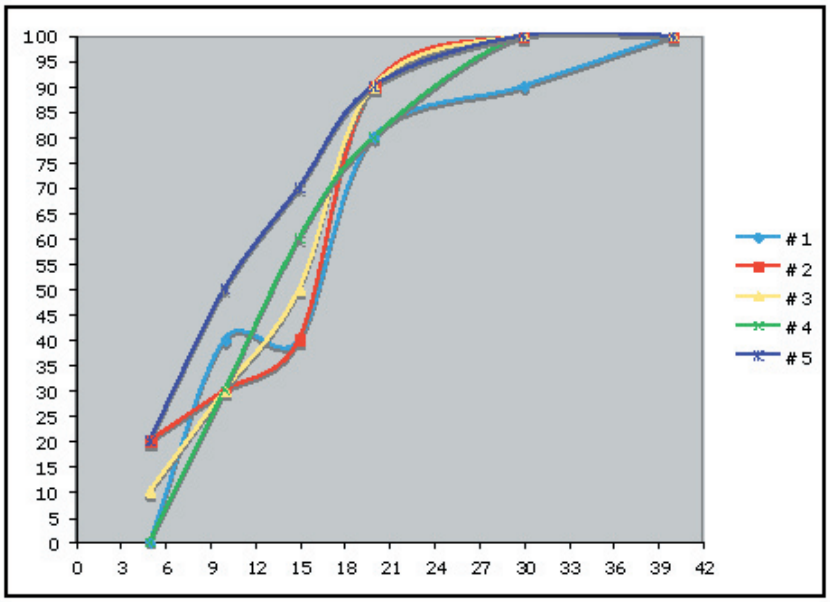
From here, the difference threshold can be estimated by drawing a horizontal line from the Y-axis at 75% correct to the line, and then drawing a vertical line from that point on the line to the X-axis to find the X-axis value.

The average difference threshold found for a base line length of 90 px is about **10.5** which yields the first value for C, the ratio of ΔI and I: 10.5/90 = **0.117**. *Note how similar this value is to that for the 30 px base length.*

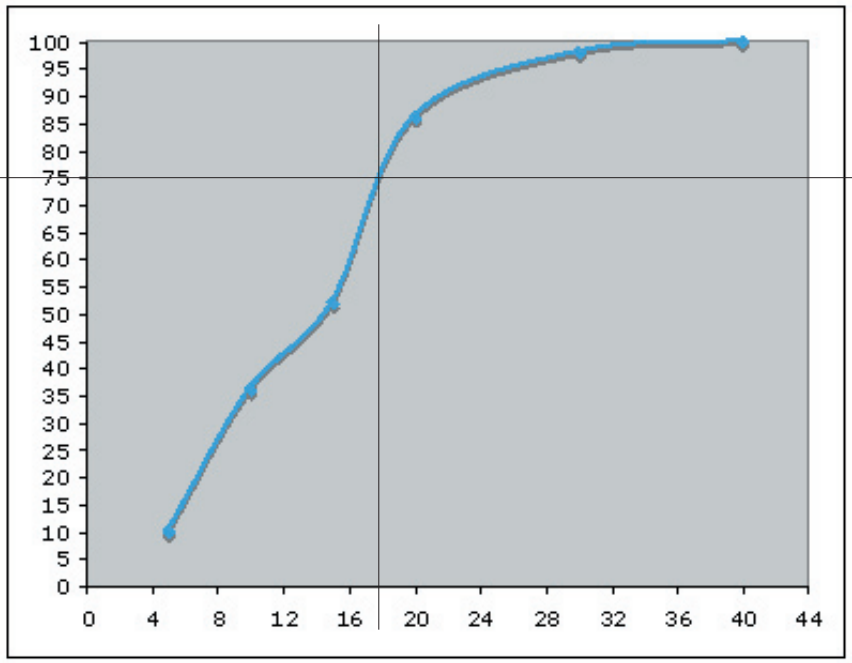
Base Length = 150 px

Five random people tested for a base line length of 150 px. Their results are graphed here:

Graph 150A: % Correct vs Line Difference for a Base Length of 150 px



From here it is clear that every person has relatively the same curve. That is, as the difference increases, the % correct increases too at a steep slope. In order to figure out the average difference threshold at 75% correct, each point along each curve is averaged with the others so as to form a single curve, shown below:



Graph 150B: Plotting a single line to average the 5 from Graph 150A

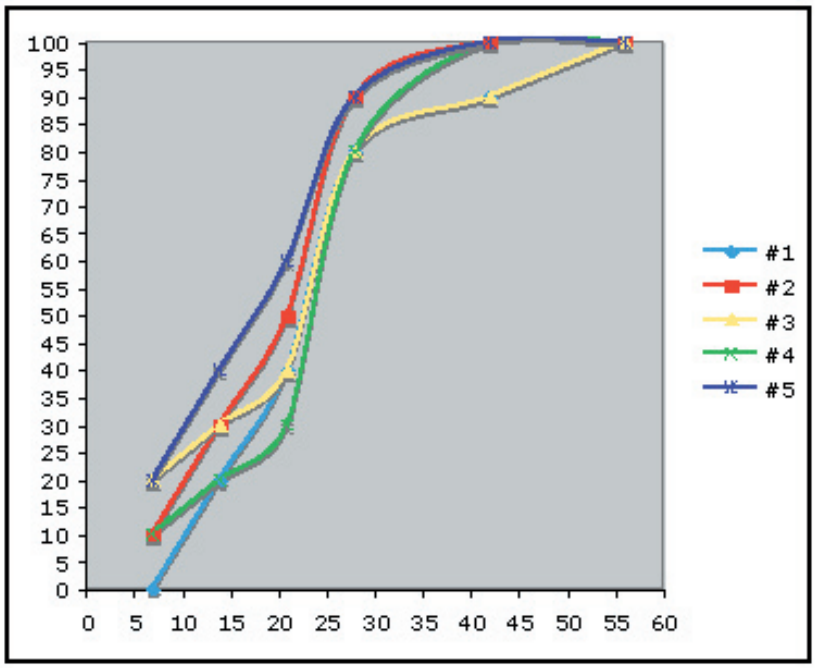
From here, the difference threshold can be estimated by drawing a horizontal line from the Y-axis at 75% correct to the line, and then drawing a vertical line from that point on the line to the X-axis to find the X-axis value.

The average difference threshold found for a base line length of 150 px is about **17.8 px** which yields the first value for C, the ratio of ΔI and I: 18/150 = **0.119**. *Again note the similarity to the previous experiment results.*

Base Length = 210 px

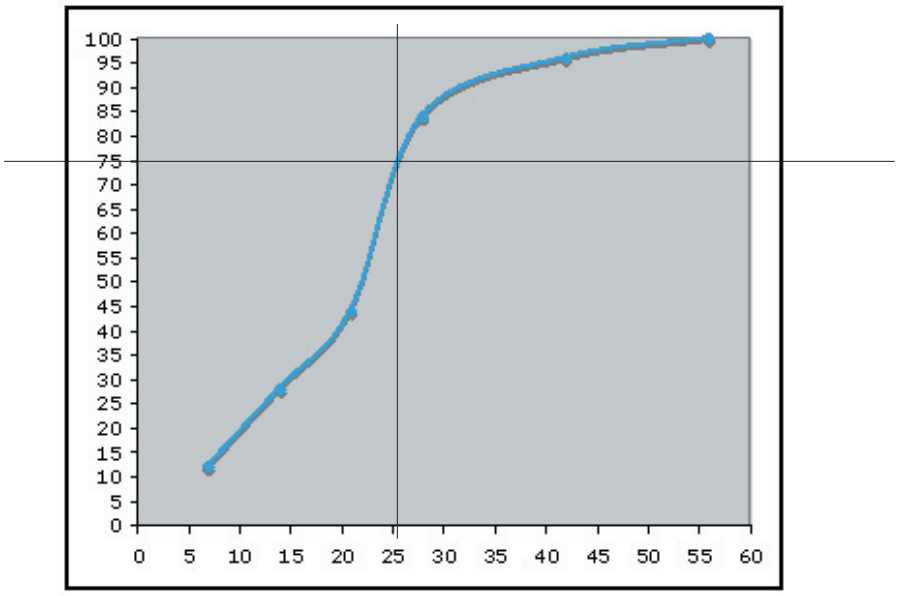
Five random people tested for a base line length of 210 px. Their results are graphed here:

Graph 210A: % Correct vs Line Difference for a Base Length of 210 px



From here it is clear that every person has relatively the same curve. That is, as the difference increases, the % correct increases too at a steep slope. In order to figure out the average difference threshold at 75% correct, each point along each curve is averaged with the others so as to form a single curve, shown below:

Graph 210B: Plotting a single line to average the 5 from Graph 210A



From here, the difference threshold can be estimated by drawing a horizontal line from the Y-axis at 75% correct to the line, and then drawing a vertical line from that point on the line to the X-axis to find the X-axis value.

The average difference threshold found for a base line length of 210 px is about **25.5** which yields the first value for C, the ratio of ΔI and I: 25.5/210 = **0.121**. *Again, note the similarity to the previous three experiment results.*

:: CONCLUSION ::

Graph 30B finds that the Just Noticeable Difference for a Base Line Length of 30 px is about 3.65 px. Graph 90B finds that the JND for 90 px is about 10.5 px. Graph 150B finds that the JND for 150 px is about 17.8 px and graph 210B finds that the JND for 210 px is about 25.5 px.

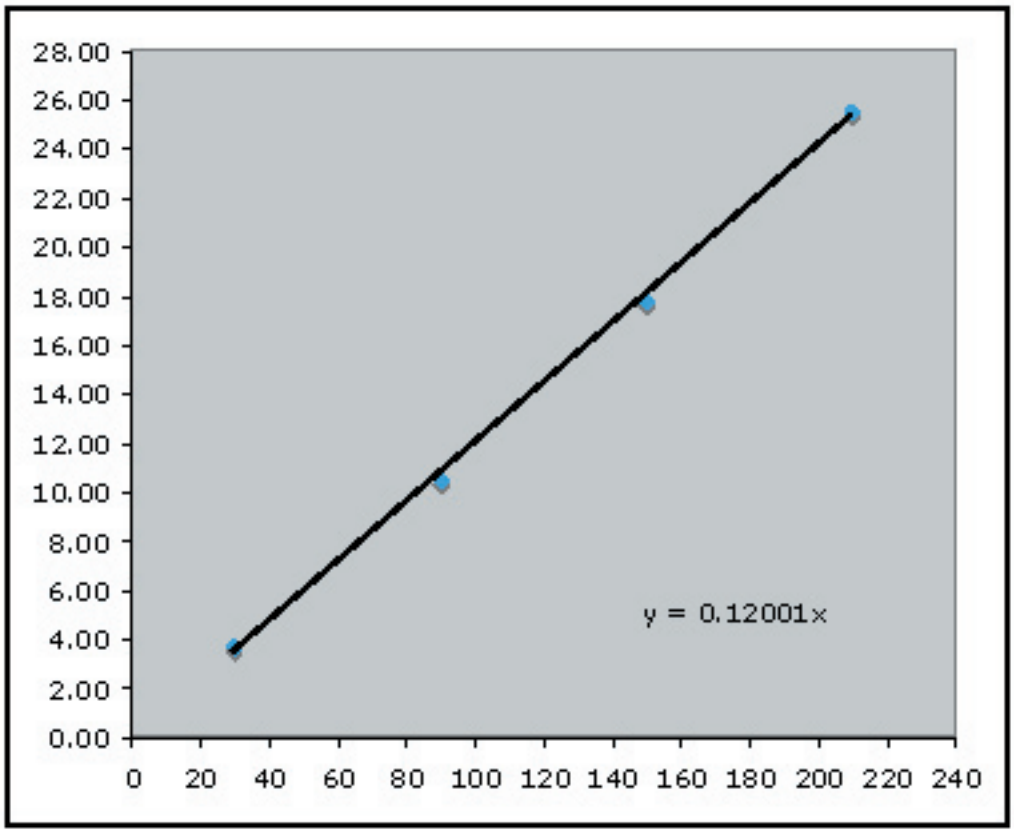
From this it is obvious that as the base length increases, so does the difference threshold. However, dividing the difference thresholds by their respective base lengths always yields the same value! For a base length of 30 px, 3.65/30 = 0.122. For a base length of 90 px, 10.5/30 = 0.117. For a base length of 150 px, 17.8/30 = 0.119 and for a base length 0f 210 px, 25.5/210 = 0.121.

Taking an average of all four ratio values yields a difference threshold value of about 0.11975, which can be rounded to 0.12. This is apparently the common ratio between change in length/base length for all line lengths.

Therefore, this experiment has shown:

When testing Weber's Law in relation to measuring the
Difference Threshold for Line Length, the ratio was found to be 0.12 px.

The graphs previously presented were the psychometric graphs. The graph below is psychophysical and it plots all the difference values on the Y-axis and all the base intensities on the X-axis.



This graph is a pure linear curve, with a slope of 0.12, which is the average difference threshold for line length. Because the slope is linear, meaning Y/X is always constant as both increase, *this experiment has proven that Weber's Law is true for line length.*