

AP Statistics Curriculum Module

Text Messaging: Communication in the Twenty-First Century

Sample Answers for $n = 40$ Data

Jared Derksen
Rancho Cucamonga High School
Rancho Cucamonga, California

David Ferris
Noblesville High School
Noblesville, Indiana

Trevor Herntier
Lawrence Free State High School
Lawrence, Kansas

Lee Kucera
Capistrano Valley High School
Mission Viejo, California

Text Messaging: Communication in the Twenty-First Century

Sample Answers for $n = 40$ Data

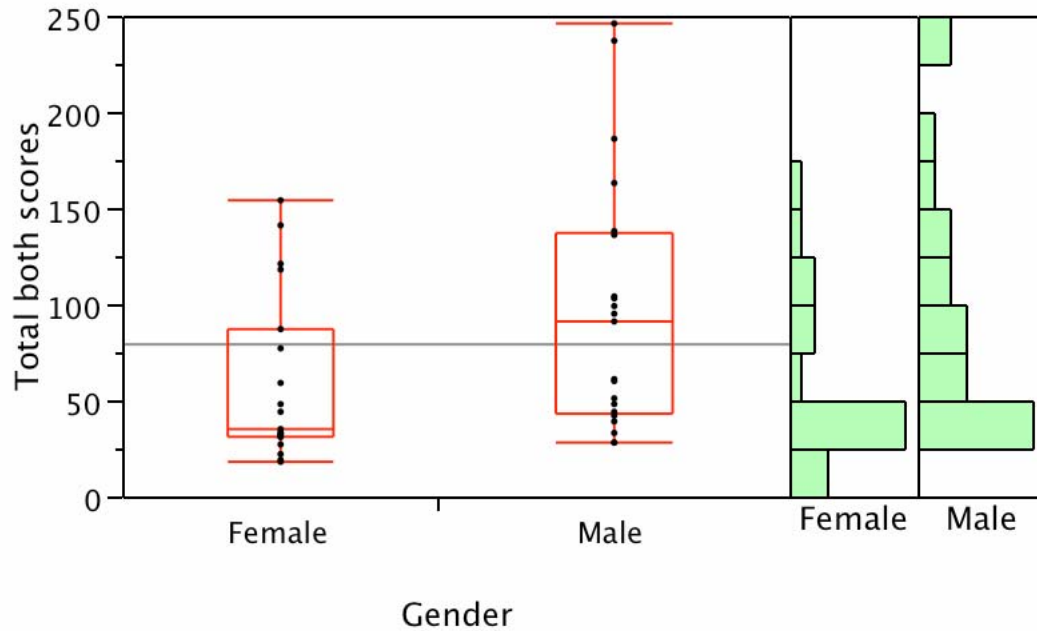
Part 1

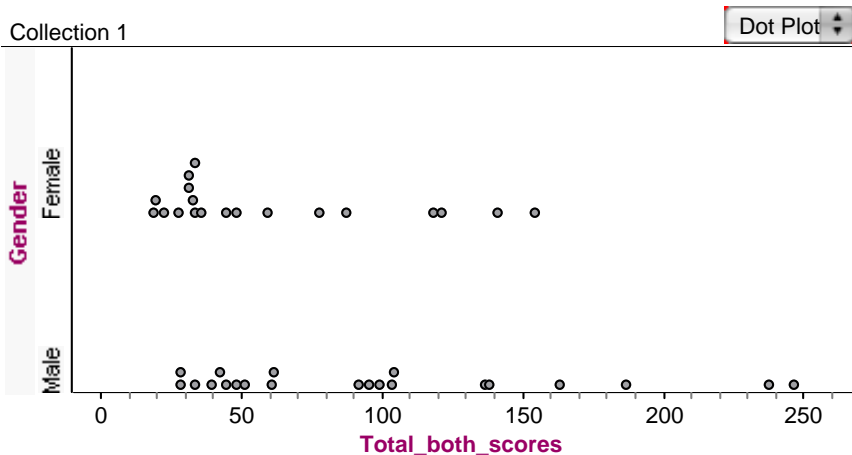
1a. Many graphs would show the differences in total scores by gender: parallel box plots, histograms, or dot plots of texting times for sentences A and B.

Some sample advantages and disadvantages:

- Box plots can show outliers and quartiles but do not show the distribution's shape as well as histograms.
- Histograms show the shape of the distribution, but do not show medians or quartiles.
- Dot plots show individual data points, shape, spread, and even clusters and gaps. However, outliers and medians are not as clear.

1b. Examples:





Both the mean and median text-messaging scores for females are lower than for males. The mean female score is 59.5 seconds and the mean male score is 96.8 seconds, while the median scores are 35 and 91 seconds respectively. Both genders' distributions are skewed right, but neither group has outliers. There are, however, two outliers when all 40 scores are considered regardless of gender. With these two outliers (both males) removed, the means are much closer (59.5 to 81.5 seconds).

The spread of scores is much less for females, indicating that females' texting speed is more consistent. The range of scores for females is 136 seconds, while the range of scores for males is 218 seconds. The interquartile range (IQR) for females is 56 seconds while the IQR for males is around 92 seconds.

- 2a. Gender and texting style appear to be independent. The ratio of counts across both genders is roughly equal (**and** roughly equal to the overall ratio of scores by style). The ratio among females is 9:10, and the ratio for males is 10:11, a statistically meaningless difference. Since the ratios are very close, it appears that gender and texting style may well be independent.
- 2b. A breakdown plot showing two independent variables would need to depict roughly equal ratios across both genders for texting style. Therefore, comparing the "blocks" of dots in the character style row with the blocks of dots in the word style row, the proportional sizes of the blocks should look roughly the same in each row. The two ratios do not need to be **exactly** equal for the variables to be considered independent. The difference in the ratios could be attributed to sampling variation. So how close can the ratios be for the variables to be considered independent? That will be discussed later in the course. (Look for the chi-square test in a statistics class near you!)

		Texting Style		
		Character	Word	
Female	9	10	19	
Male	10	11	21	
	19	21	40	

Part 2

- 1a. There are several well-reasoned arguments students could articulate from the given data. Here are just a few:

Since students may not have encountered matched-pairs design, they may not understand the difference between comparing mean scores versus looking at the mean of the differences in scores. This might be an opportunity to discuss the difference! A simple example with numbers and arithmetic might be helpful. Suppose four students had scores of (12, 13), (20, 21), (50, 51), and (100, 102) on sentences (A, B). The mean scores are 45.5 for A and 46.75 for B. These two means do not seem to be “much different.” However, looking at each ordered pair, it is obvious that all four students took longer to type sentence B than sentence A. That would seem to suggest that sentence B really did take longer to type. (If you conduct a two-sample t -test, you will find a p -value of .48, but a matched-pairs test produces a p -value of less than .01.)

Since the length of both sentences is roughly the same, one could argue that the time it takes to text each message could be compared. Since we have texting times with and without errors included, students can come to a reasonable decision about which data would be more appropriate to compare.

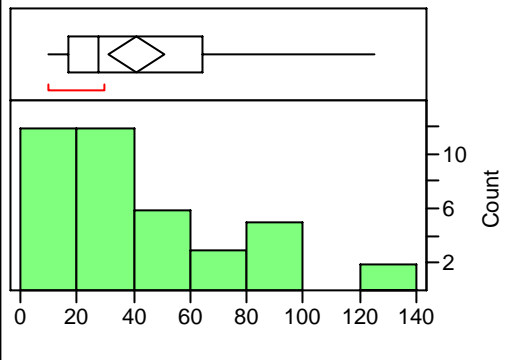
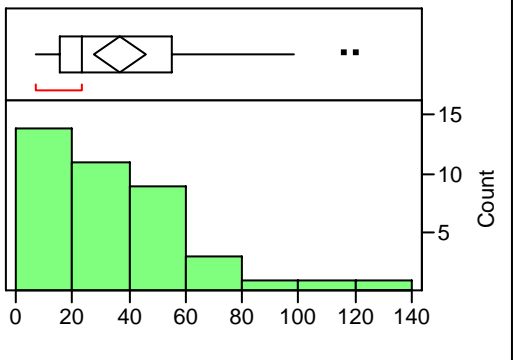
Students may argue that the number of mistakes for each sentence would be a measurement of “difficulty.” However, some of the texting times may include students who chose to correct their mistakes during the time trial. If this occurred, then measuring mistakes only may not be the most accurate measure of difficulty.

With regard to measuring mistakes, student may discuss the difference between making a mistake in word style versus a mistake using character style. A mistake of one character might not be significant since “context clues” might still render the message understandable. A mistake of an entire word, however, might be considered a worse mistake if the incorrect word is word critical to the message (e.g., “house” instead of “car” in sentence B).

Students may also wonder if the **order** in which sentences were typed made a difference. If all students in the survey typed sentence A first, perhaps there was a “practice factor” that made texting times for sentence B shorter (FYI: the order of sentences was randomized when the data was collected).

Some students may have enough experience with text messaging to notice that one sentence has more “uncommon” words: “statistics” and “average.” When texting using the word style, it may be more difficult to find “statistics” and “average” in the phone’s lexicon of commonly used words. Also, sentence A has more occurrences of the letter “s.” On some phones, the letter “s” is more difficult to access.

1b. Here are some possible graphs and the summary statistics:

"A" time in seconds	"B" time in seconds																																																																		
																																																																			
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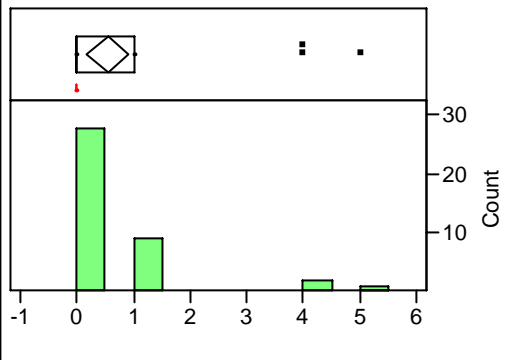
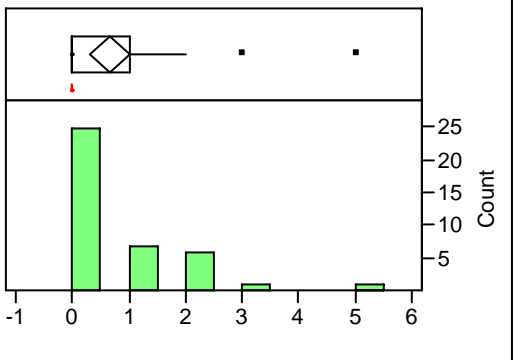
The distributions for both sentence A and sentence B are skewed to the right. Sentence A has a higher center than sentence B (medians are 27.5 and 23, respectively). The spreads for the two distributions are roughly the same, although sentence B has a slightly smaller spread with a lower standard deviation and lower IQR. Because the distribution of sentence B is slightly more compact, this causes its highest values to be classified as outliers: subject 12 at 120 and subject 20 at 116. There is a gap for sentence A, between 100 and 120, while sentence B has no gaps.

Upper fence for outlier check:

Sentence A: $64.5 + 1.5(64.5 - 17) = 135.75$

Sentence B: $55.25 + 1.5(55.25 - 15.25) = 115.25$

1c. Here are some possible graphs and the summary statistics:

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Sentence B has slightly more mistakes than sentence A, but only with a mean difference of 0.675 to 0.55. Both distributions have outliers. Sentence A has 9 people with 1 mistake and then outliers with 2 people with 4 mistakes and 1 person with 5 mistakes. Sentence B has 7 people with 1 mistake, 6 people with 2 mistakes, 1 person with 3 mistakes and 1 person with 5 mistakes. Thus while 12 people made a mistake with sentence A, 15 people made mistakes with sentence B.

1d. Here are some possible graphs and the summary statistics:

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Sentence A has a higher overall score than sentence B. The means are 41.85 vs. 37.4 and the medians are 27.5 vs. 24, respectively. Both distributions are skewed to the right. Both distributions have a gap before the highest scores. For sentence B, the highest scores are outliers at 117 and 120.

Upper fence for outlier check:

Sentence A: $65.6 + 1.5(65.5 - 17.25) = 137.9$

Sentence B: $55.25 + 1.5(55.25 - 16.25) = 113.75$

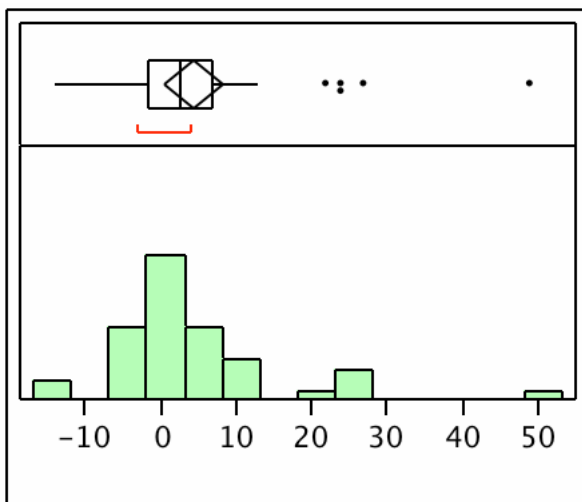
1e. The mean of the differences (A minus B) is 4.4 seconds.

1f. If sentence A were more difficult than sentence B, then it should take longer to text. Therefore the mean difference of A minus B should be positive. Some experienced texters might also mention that Sentence A contains several “s” characters, which are more difficult to locate on some phones’ menus. Sentence A also has a couple of “uncommon” words (“statistics” and “average”) that might not be in a phone’s automated lexicon if word style was utilized.

1g. Students may be stretched a bit here, unless they have studied statistical inference. Some students may think to graph a distribution of the difference scores for reference:

A minus B

Quantiles



100.0%	maximum	49.00
99.5%		49.00
97.5%		48.45
90.0%		23.80
75.0%	quartile	6.75
50.0%	median	2.50
25.0%	quartile	-1.75
10.0%		-5.00
2.5%		-16.93
0.5%		-17.00
0.0%	minimum	-17.00

Moments

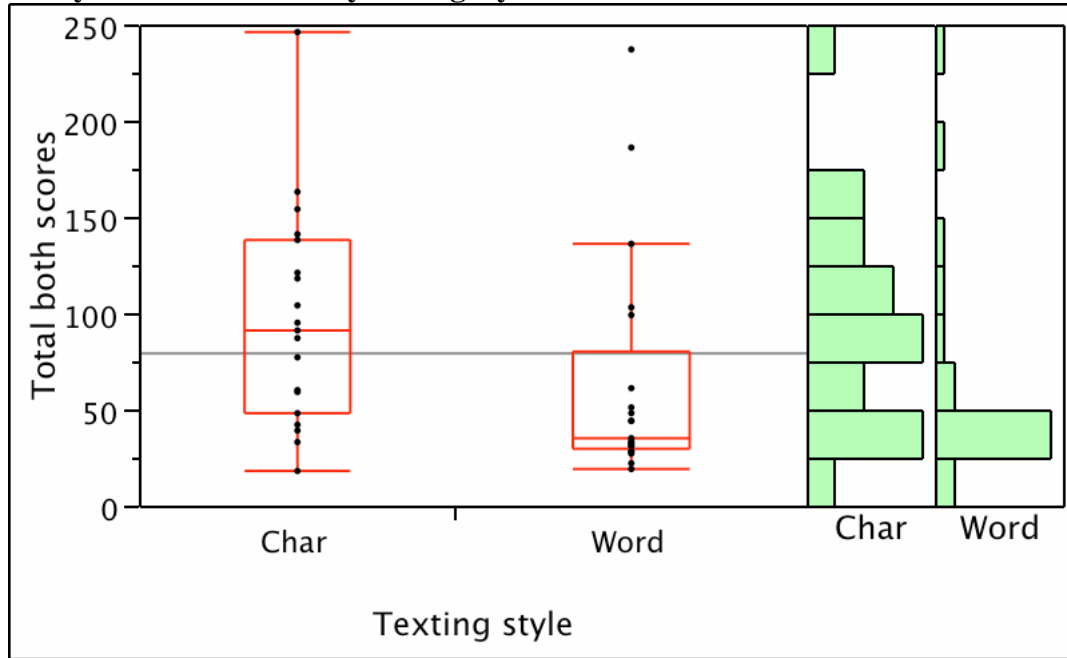
Mean	4.425
Std Dev	11.838415
Std Err Mean	1.8718178
upper 95% Mean	8.2111089
lower 95% Mean	0.6388911
N	40

The distribution of the differences shows a roughly symmetric shape, slightly skewed right, with a few outliers on both sides (4 on the high end). The mean is 4.425 seconds, and the standard deviation is 11.84 seconds. If there really was **no** difference, then they might figure that the mean of the distribution would have been zero seconds with a standard deviation of (perhaps) the same (11.84 seconds). So the question might be, is a mean of 4.425 far enough away from zero to be a **real** difference? Student opinions should be welcomed here, and discussed thoroughly. This is a great opportunity for students to struggle with their comprehension and articulation of statistical concepts. You might even want to let them struggle with this question **without** stepping in and answering it with authority. The answer will lie in the latter portion of the course when statistical inference is taught (analysis that leads to a **decision**).

(By the way, a one-sample t -test on a hypothesized mean of $\mu_0 = 0$ produces a t -score of 2.364 and a p -value $\approx .012$, so the difference **is** statistically significant. But is it **practically** significant? This is yet another angle on the problem that could be discussed with students.)

2a.

Analysis of Total score By texting style



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
c	18	33	48	91	138	163	246
w	19	23	29.5	35	80	176	237

Subjects who used word style have a considerably lower score than those who used character style. The median of the word texters is 35—a dramatically lower score than the median of 91 for the character texters. Both distributions are skewed to the right. The word-style texters have two high outliers at 186 and 237.

2b. The means of each gender in each style:

Mean total score of female (word style) = 32.2 seconds

Mean total score of male (word style) = 91.5 seconds

Mean total score of female (character style) = 89.8 seconds

Mean total score of male (character style) = 102.6 seconds

2c. The mean texting score for word style is 63.24 seconds.

The mean texting score for character style is 96.53 seconds.

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Char	19	96.5263	56.2557	12.906	69.412	123.64
Word	21	63.2381	58.1721	12.694	36.758	89.72

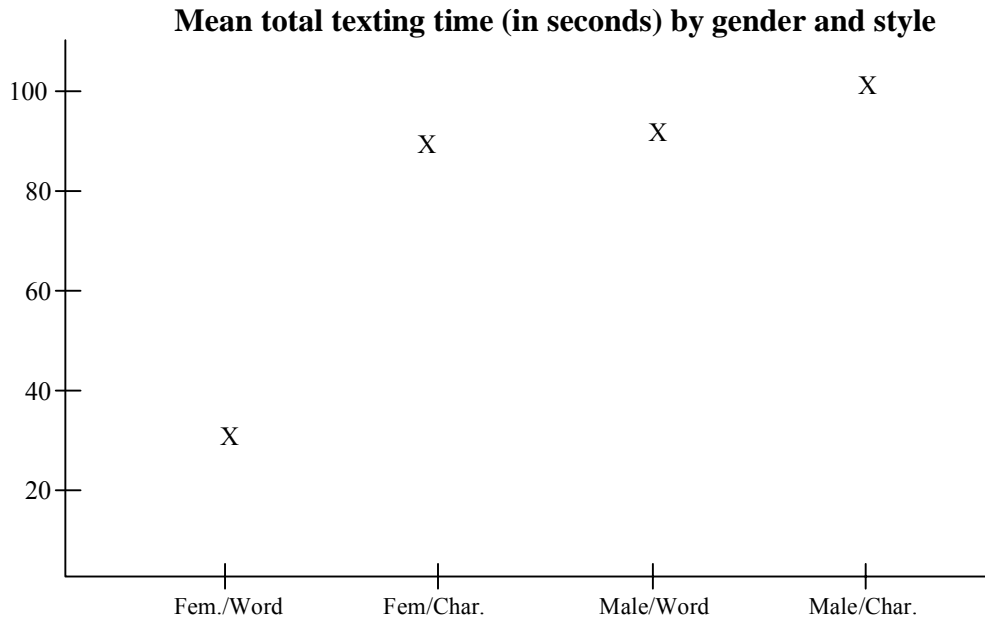
Again, this may stretch students who have not yet studied statistical inference. So the emphasis here should be on good reasoning and communication. A cursory look at parallel box plots should reveal that word speeds were faster (shorter) in general than character speeds. More than half of the word speeds are below the first quartile of character speeds. (See graph and data for 2a.)

Another argument could be made based on the lower limit of texting speed. There obviously is a lower limit on texting scores (some textbooks call this a “wall”). Zero seconds would be impossible, as well as 1, 2, and 3 seconds, and so on. So **wherever** this wall is, there are far more word texters’ scores pressed up against this wall than character scores. This would seem to indicate once again that word texters are faster in general than character texters.

This “scrunching factor” can be seen in the parallel histograms above.

Teachers might also find this a good place to ask probing questions of students like: How many seconds would constitute a significant difference in scores? Are there outliers, and do they make a difference? Justify your claim with practical reasoning. How many seconds would be a practical difference for users of text messaging? Would it really matter to text messagers if they saved a second on every text message with one method over the other? To whom would it matter the most? Would the cost of text messaging be a factor? Would battery life? Would one style perhaps have a steeper “learning curve” than another, but pay off in the long run (with time and/or battery life saved)?

2d.



2e. It appears from the graph that females generally have quicker (lower in seconds) mean texting speeds regardless of the texting style. It also appears that in each gender the mean speed for character style is slower (higher in seconds) than the mean speed for word/T9 style.

A potential confounding variable is the experience factor for each gender. If females have generally been texting longer (or more frequently per day) than males, then perhaps the experience/practice factor accounts for the difference in texting speeds, rather than sheer supremacy in “thumb dexterity.”

3a. Comparisons can be made on either thumb’s length, but another reasonable calculation would be to average each student’s two thumb lengths and create a new list of data: average thumb lengths. Several different justifications can be made using different graphs and statistics, using means, medians, modes, spreads, and outliers of the gender distributions of average thumb lengths. It would appear that males generally have larger thumb lengths, as their medians, means, and modes are all higher than females’. The box plots of the two genders show that at least three-fourths of males’ average thumb lengths are longer than the females’ median thumb average.

However, here are the statistics:

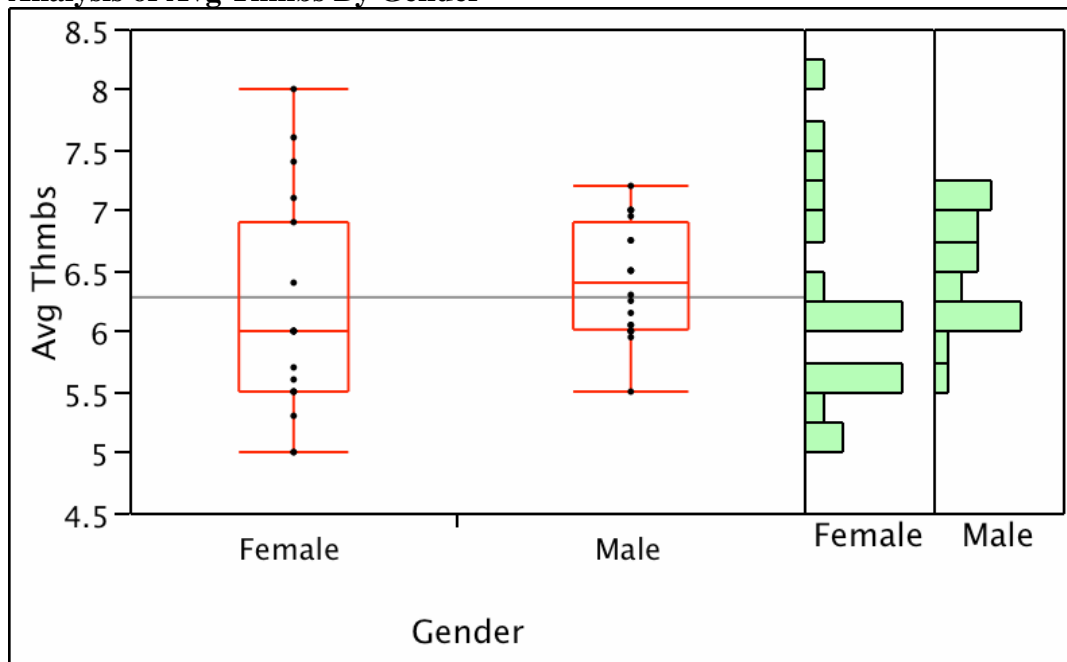
Average thumb lengths			
Female mean:	6.13 cm	Female median:	6 cm
Male mean:	6.42 cm	Male median:	6.4 cm

So the difference in the centers is around .3 to .4 centimeters, which may not be a significant difference in thumb length (but then again, maybe it is—thumbs are not that long to begin with!)

(Once again, a more definitive answer will be possible later in the course when statistical inference is discussed. A two-sample *t*-test on the mean average thumb length produces a *p*-value of 11 percent.

So assuming the conditions are met for a two-sample t -test, the difference in mean thumb length is not statistically significant at the $\alpha = .05$ level.)

Analysis of Avg Thumbs By Gender



Quantiles

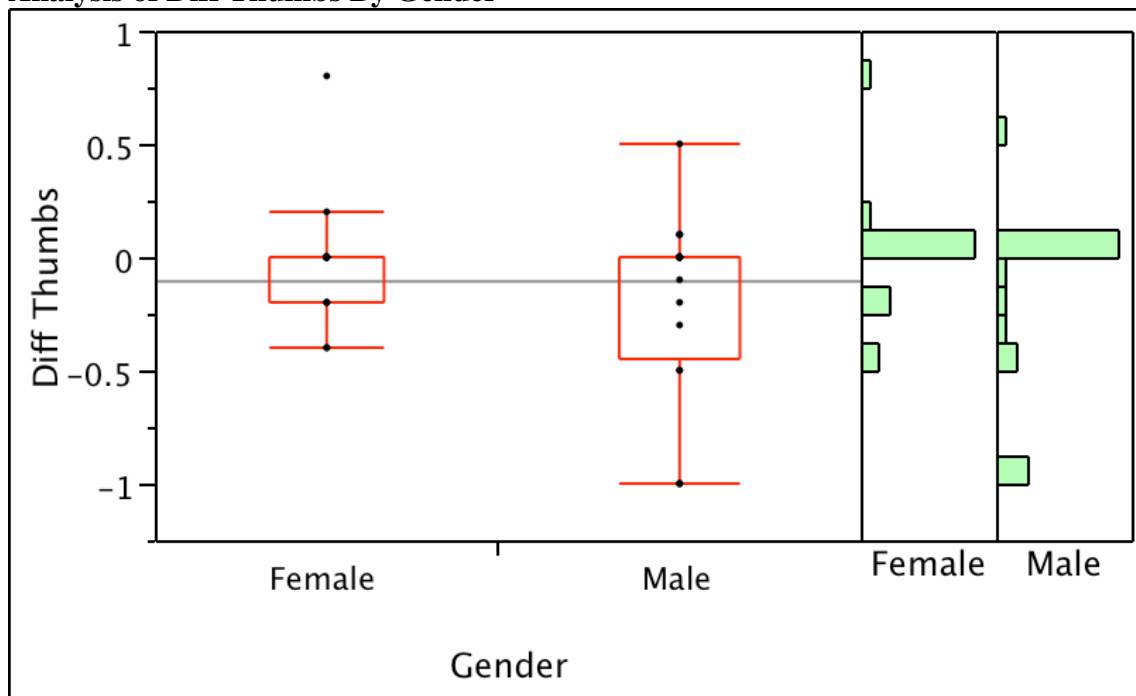
Level	Minimum	10%	25%	Median	75%	90%	Maximum
Female	5	5	5.5	6	6.9	7.6	8
Male	5.5	5.955	6.0125	6.4	6.9	7	7.2

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Female	19	6.13158	0.877530	0.20132	5.7086	6.5545
Male	20	6.42000	0.465776	0.10415	6.2020	6.6380

3b. The graphs seem to show that the mean, median, and mode of both genders' thumb length differences are all very close to zero, which would seem to be reasonable. There also appears to be several students of both genders who have noticeable variations in their two thumb lengths. But since they are on both sides of zero, it would be reasonable to conclude that there is no overall difference in the centers of the distributions. Are these extreme values outliers? Box plots can help answer that question, and yes, there are two outliers.

Analysis of Diff Thumbs By Gender



Quantiles

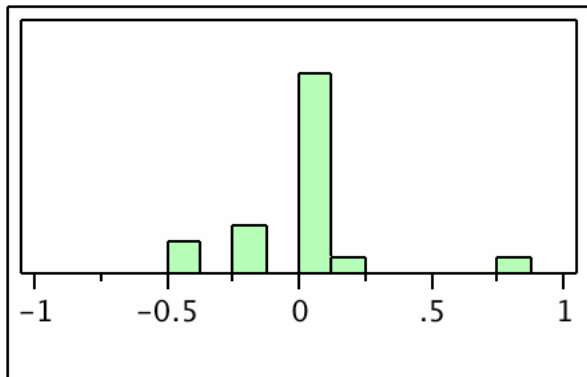
Level	Minimum	10%	25%	Median	75%	90%	Maximum
Female	-0.4	-0.4	-0.2	0	0	0.2	0.8
Male	-1	-1	-0.45	0	0	0.1	0.5

Means and Std Deviations

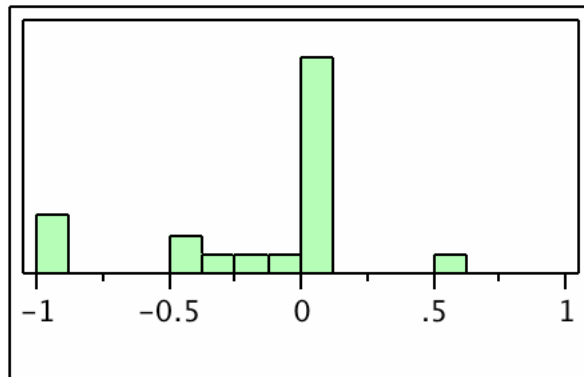
Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Female	19	-0.02105	0.248504	0.05701	-0.1408	0.09872
Male	20	-0.19000	0.410263	0.09174	-0.3820	0.00201

3c. If you try to determine the type of skewness of the female thumb differences, the box plot would be confusing. Since there is an extreme outlier on the right, one might be tempted to say the distribution is skewed **right**. But looking at the position of the median relative to the middle 50 percent (the “box”), the median is clearly on the extreme right side of the middle 50 percent. In fact, the median is equal to the third quartile. So this would tend to indicate a skewed **left** distribution. So we must look at another view of the data: a dot plot. The dot plot seems to indicate a relatively symmetric distribution with slight skewness to the **right** because of the lone outlier on the right. It is always a good idea to look at several views of a distribution of data before making conclusions.

**Distributions Gender=Female
Diff Thumbs**

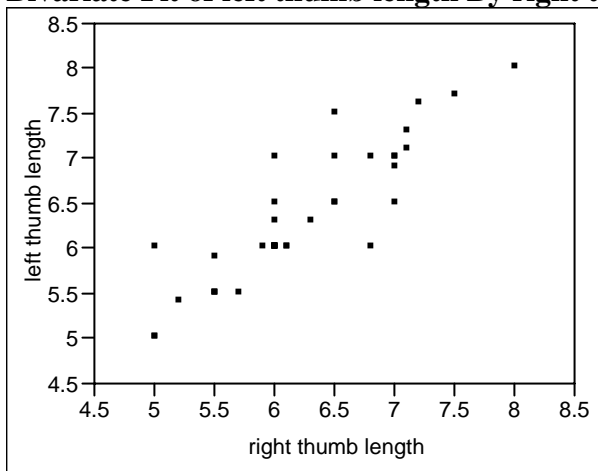


**Distributions Gender=Male
Diff Thumbs**



3d.

Bivariate Fit of left thumb length By right thumb length

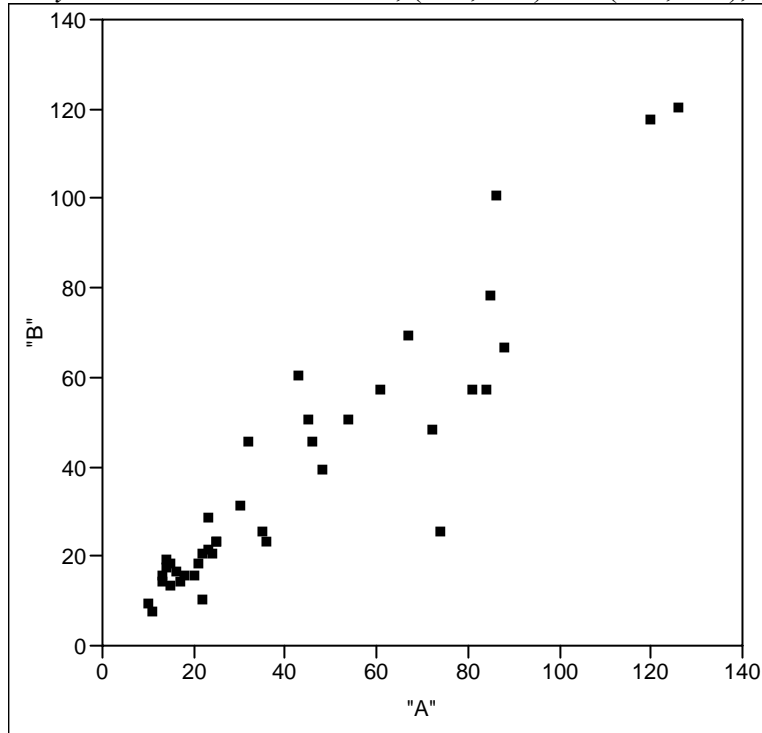


Students could make a scatter plot of one thumb length vs. the other, or a univariate plot of the differences. Most people recorded the same length for both their thumbs. While it is possible that people's thumbs vary by 0.5 cm or so, it seems more likely that there is measurement error—especially when the difference is 1 cm.

4a. It appears from the graph that men tend to send shorter messages, on average, than females, both when females are the recipients and when males are recipients. The shortest mean message lengths are when males send messages to males. In fact, there is not a large difference between female mean message lengths when comparing male and female recipients. But there is a much larger difference in male mean message length when comparing male and female recipients. Male-to-male messages are the shortest on average. Notice that any message type **involving** a female is noticeably longer than male-to-male messages.

Part 3

- 1a. The graph of this data shows a fairly strong, positive, linear relationship between sentence A score and sentence B score (both in minutes + errors). There is one value, (74, 25), that is far from the line in the y-direction and two values, (120, 116) and (125, 120), that are far from the line in the x-direction.



- 1b. $r = .92465$, confirming the fairly strong, positive relationship observed in the graph.

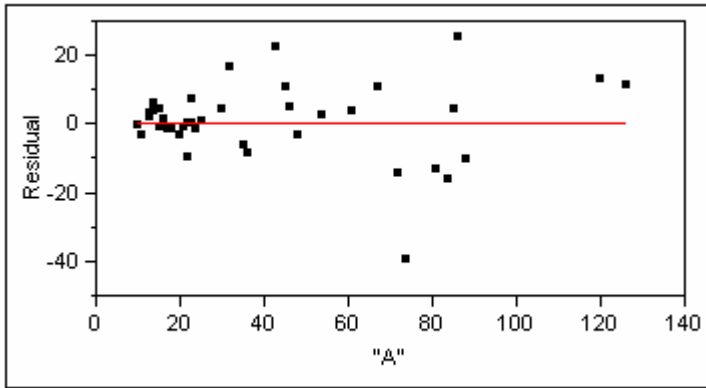
$r^2 = .85498$, indicating that approximately 85 percent of the variation in "B" score can be explained by the linear relationship between "A" score and "B" score.

- 1c. "B" score = $1.5850989 + 0.8563895(\text{"A" score})$

y-intercept: the model predicts a "B" score of 1.585 when the "A" score is 0

slope: for every 1 second + error increase in "A" score, the model predicts an increase of 0.8564 second + error in "B" score

- 1d. The residual plot generally shows random scatter about the line. There is one value, (74, 25), that can be considered an outlier (it has a large residual) and two values, (120, 116) and (125, 120), that can be considered influential.



1e. "B" score = $1.5850989 + 0.8563895(\text{"A" score})$

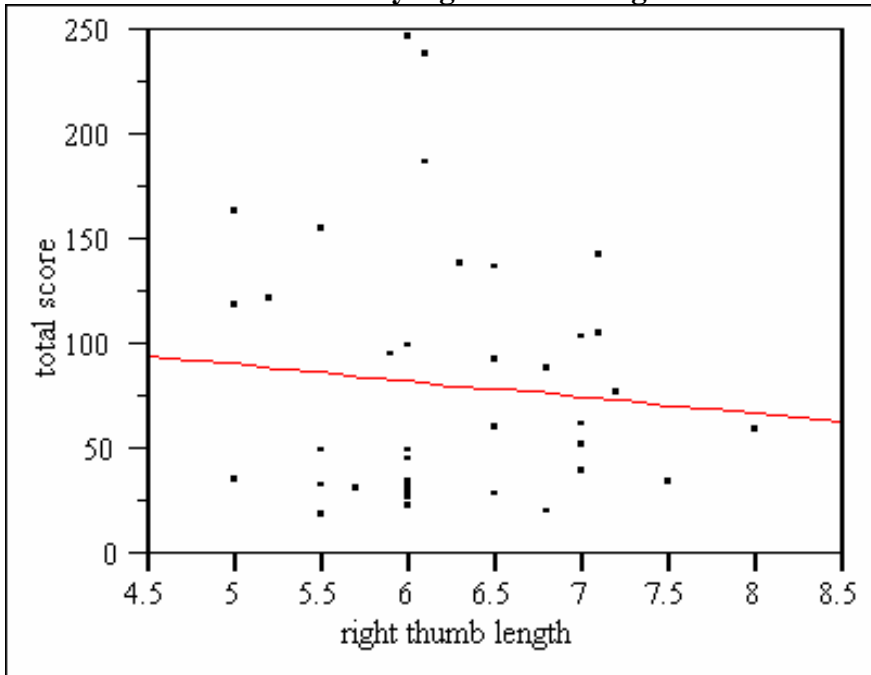
"B" score = $1.5850989 + 0.8563895(22) = 20.4256679$ the model predicts a score of about 20.4 seconds + errors

"B" score = $1.5850989 + 0.8563895(5) = 5.8670464$ the model predicts a score of about 5.9 seconds + errors

The prediction based on the "A" score of 22 is more reliable because 22 is well within the range of the data values for "A" scores. There were no "A" scores as low as 5 (the smallest was 10), so that prediction is an extrapolation and not as reliable.

2 and 3. Answers to these questions will depend on which measures are selected.

Bivariate Fit of total score By right thumb length



Linear Fit

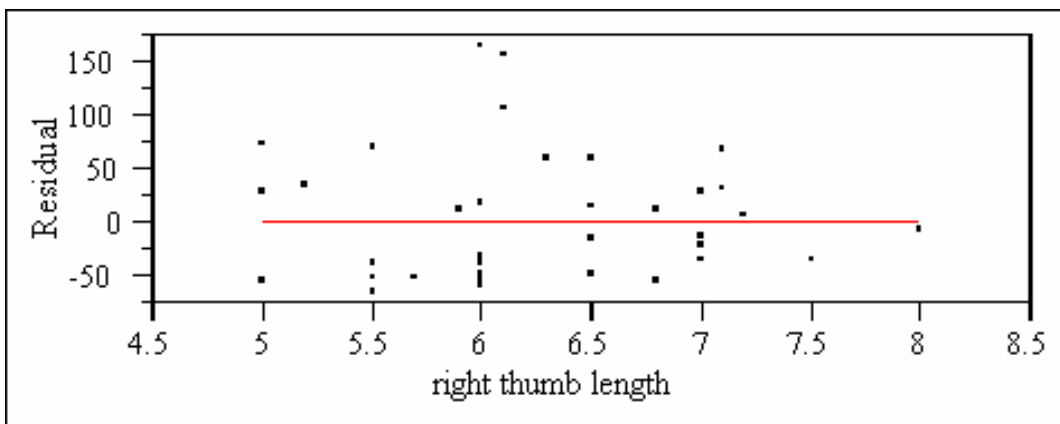
total score = 129.21185 - 7.9047036 right thumb length

Summary of Fit

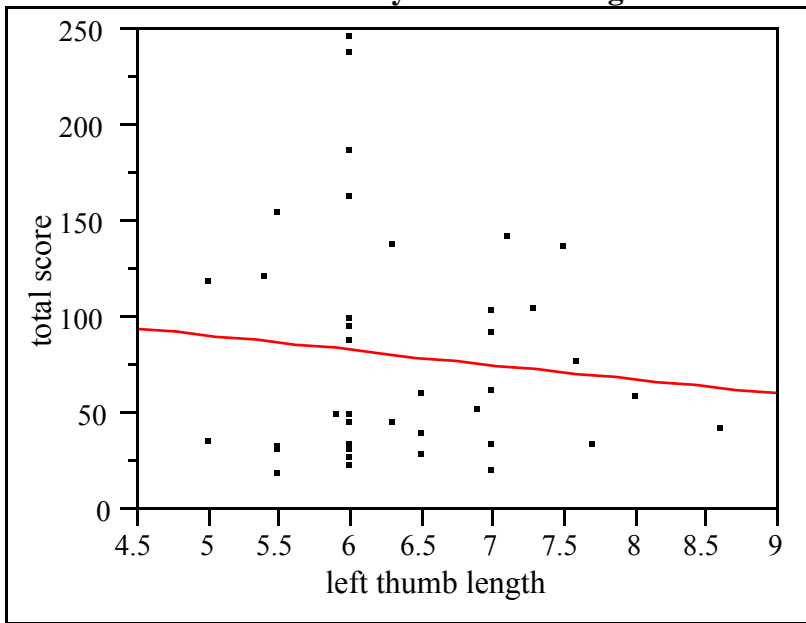
RSquare	0.008959
Mean of Response	80
Observations (or Sum Wgts)	39

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	129.21185	85.63176	1.51	0.1398
right thumb length	-7.904704	13.66791	-0.58	0.5665



Bivariate Fit of total score By left thumb length



Linear Fit

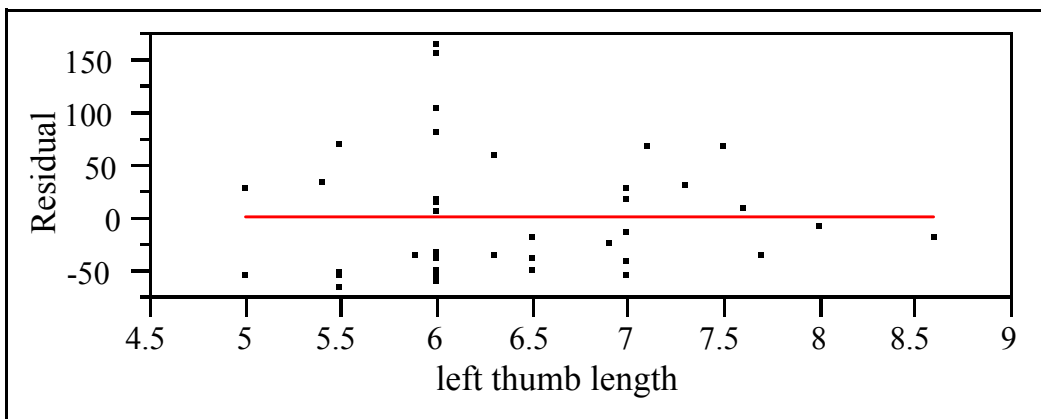
total score = 127.72527 - 7.617413 left thumb length

Summary of Fit

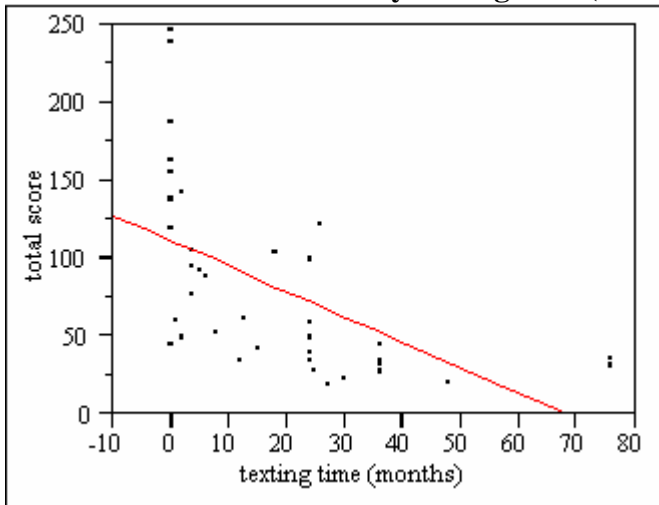
RSquare	0.010962
RSquare Adj	-0.01507
Root Mean Square Error	59.42939
Mean of Response	79.05
Observations (or Sum Wgts)	40

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	127.72527	75.58904	1.69	0.0993
left thumb length	-7.617413	11.73751	-0.65	0.5203



Bivariate Fit of total score By texting time (months)



Linear Fit

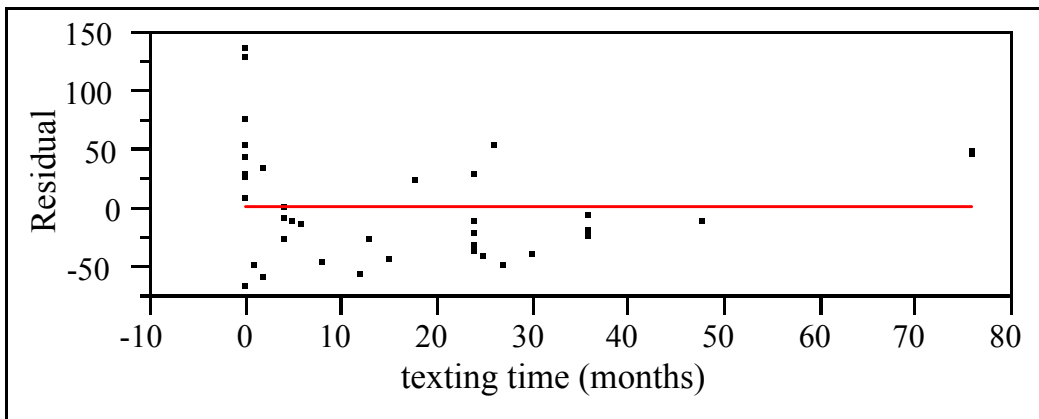
total score = 110.7313 - 1.6288585 texting time (months)

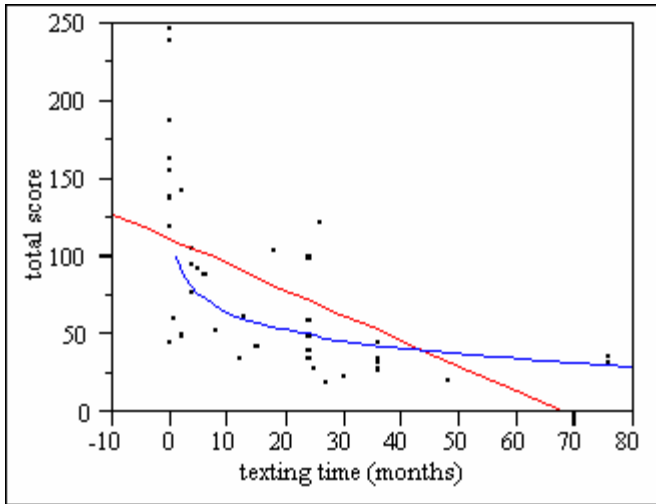
Summary of Fit

RSquare	0.34869
RSquare Adj	0.331551
Root Mean Square Error	48.22681
Mean of Response	79.05
Observations (or Sum Wgts)	40

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	110.7313	10.36737	10.68	<.0001
texting time (months)	-1.628859	0.361131	-4.51	<.0001





Transformed Fit to Log (excluding texting times = 0)

total score = 102.05117 - 16.64636 Log(texting time (months))

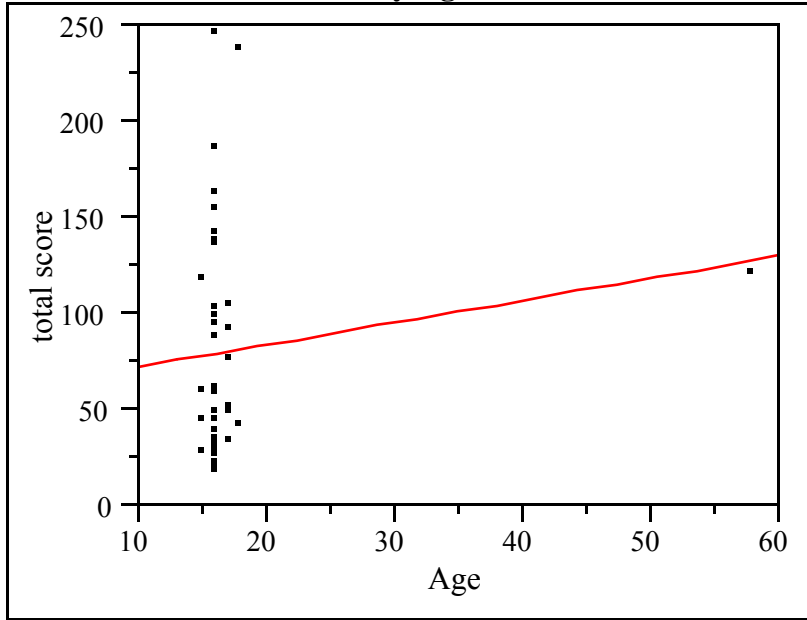
Summary of Fit

RSquare	0.325056
RSquare Adj	0.301782
Root Mean Square Error	27.7234
Mean of Response	56.12903
Observations (or Sum Wgts)	31

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	102.05117	13.25843	7.70	<.0001
Log(texting time (months))	-16.64636	4.454258	-3.74	0.0008

Bivariate Fit of total score By Age



Linear Fit

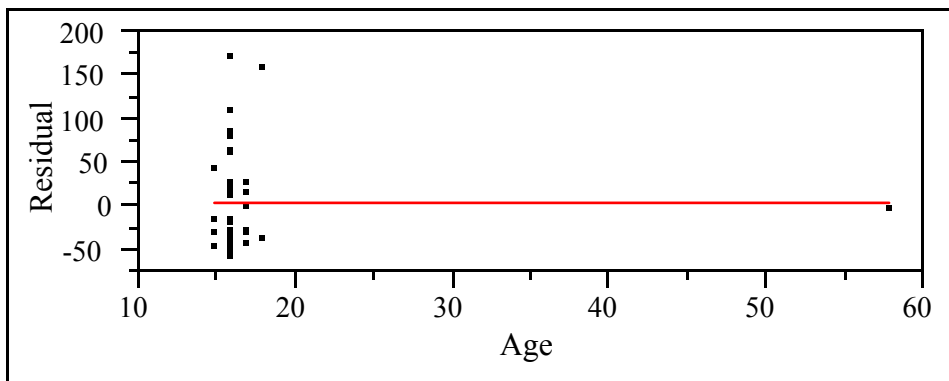
$$\text{total score} = 59.105022 + 1.1595917 \text{ Age}$$

Summary of Fit

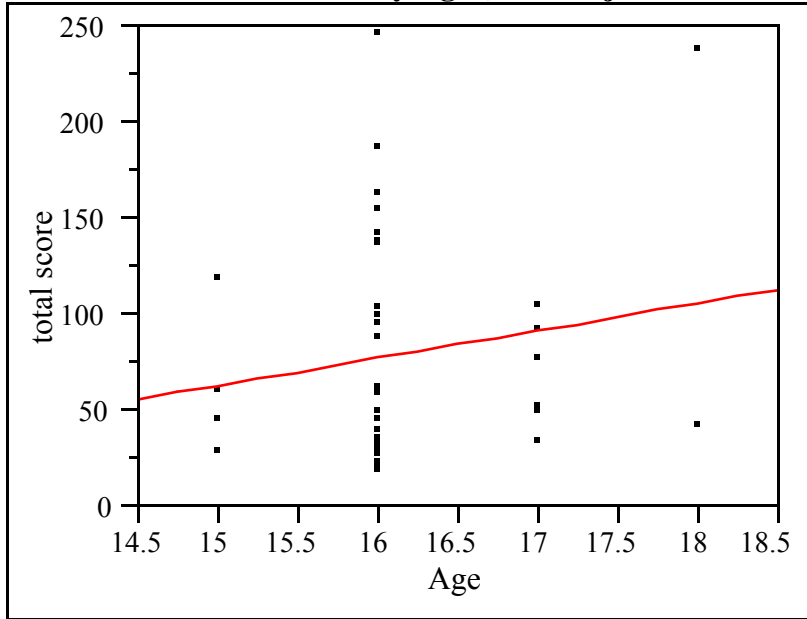
RSquare	0.017087
RSquare Adj	-0.00878
Root Mean Square Error	59.24507
Mean of Response	79.05
Observations (or Sum Wgts)	40

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	59.105022	26.26643	2.25	0.0303
Age	1.1595917	1.426702	0.81	0.4214



Bivariate Fit of total score By Age (with subject #30 excluded)



Linear Fit

total score = -152.982 + 14.297297 Age

Summary of Fit

RSquare	0.026071
RSquare Adj	-0.00025
Root Mean Square Error	59.36653
Mean of Response	77.97436
Observations (or Sum Wgts)	39

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	-152.982	232.2613	-0.66	0.5142
Age	14.297297	14.36603	1.00	0.3261