Review Exercises
Chapter 6 -- Measurement Error
Pages 104-108

REVIEW EXERCISES (page 104)

Problem 1. Do you only need to measure once?
Answer: NO, no matter how experienced you are. You will NOT get the same result both times: try it yourself -- measure the length of your room to the nearest inch twice; then measure it to the nearest millimeter; then to the nearest micron, then ...

The first probability distributions were devised by the French mathematician and astronomer Laplace in order to examine the uncertainty of astronomical measurements.

Problem 2. Carpenter measures a board with a tape measure.
Cloth tapes might well stretch over time (making old ones less reliable and biased); a steel tape might expand and contract with the temperature (different bias at different seasons).

Problem 3. Bias and chance error.
(a) Bias is NOT a form of CHANCE error, but is a SYSTEMATIC and PREDICTABLE error.
(b) Chance error is NOT a kind of bias, but will exist in ANY measurement.
(c) Measurements are always affected by chance error, but not always (and not usually if done by trained observers) by bias.

Problem 4. Calibrating a yardstick.
The lab presents you with 3 results: 35.96 inches, 36.01 inches, and 36.03 inches. These indicate the yardstick deviates from 36 inches by -0.04, 0.01 and 0.03. Note that the deviations sum to zero, so the best guess so far is that the yardstick is pretty accurate, and the chance error is in the lab's measurement process.

A fourth measurement would most likely have a similar error -- around 0.03 inches. So, presented with a list offering 0.01, 0.03, and 0.06 inches as our choices, we would not expect .01 to be "most likely" (only 1 of the three measurements has a deviation that small), nor would we expect .06 (none of the three measurements so far has a deviation that large).

The SD of the measurements is 0.0294, which also answers our question.

Problem 5. Statistics class measures a table top to three decimal places.
Two unfortunate students (2 and 13) both seem to have foot thick table tops -- and both obviously "misplaced" the decimal point. I would not believe in "chance error" in this case.

Look at just the errors in the other cases: I list measurement 1 and then measurement 2 for all students, with NA for students 2 and 13; I only report the final 2 decimal places, since everyone gets the first two digits (1.3) correct:

```
(bind M1 (list 17 NA 16 16 18 29 32 42 37 NA 33 15 16 21 37 49 20 42 17))
(bind M2 (list 20 NA 35 28 24 36 34 28 42 NA 34 17 18 19 43 36 36 40 18))
```

(make-dataset "Measurements" (list 'm1 'm2)) will group M1 and M2 into datasets, and create casenames which can be related to the plot (click on the dots to see whose measurements we are tracing)

```
(plot m1 m2).
```

Note that there is certainly correlation between the two measurements, \(\text{corr m1 m2} = 0.6769\), which is high. Some students measure on the high side, some on the low side for BOTH measurements. Only two (numbers 3 and 17) have M1 higher than average and M2 lower than average; only 1 has M1 lower and M2 higher than average. Place crosshairs on the plot (press "x") and highlight the points in the upper left and lower right quadrants to see this. (density-plot m1 m2) shows both distributions are bimodal.

(ranking m1 m2) ranks the values of M1 and prints the corresponding M2 value. There are some ties for the first measurement (students 8 and 18 have 1.342) but the ties do not have the same second value in any case.
SPECIAL REVIEW EXERCISES (pages 105-106; problems 1 - 11 only)

Problem 1. Density plot looks like a semi-circle. Is anything wrong?
Scores on a test range from 0 to 100, which is common enough and explains the fact that the density plot will NOT have long tails like a normal curve.
There is no law stating that all distributions must follow the "normal" distribution; the average score of 50 may indicate a difficult test, but there is no law against difficult tests, either.

Problem 2. SD and RMS of zero
Example of a list with SD of zero: (2 2 2 2 2)
If all numbers are the same, the mean will be that number, and the deviations from the mean will be zero.
Example of a list with root mean square of zero: (list 0 0 0)
If we don't take deviations first, the only way to have a RMS of zero is for all numbers to be zero.

ASSIGNED. Problem 3. Personality test and standardized scores.

<table>
<thead>
<tr>
<th>Original score:</th>
<th>79</th>
<th>64</th>
<th>52</th>
<th>72</th>
<th>(c)_______</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standardized</td>
<td>1.8</td>
<td>0.8</td>
<td>(a)____</td>
<td>(b) ____</td>
<td>- 1.4</td>
</tr>
</tbody>
</table>

Fill in the blanks, and explain your computations.

ASSIGNED. Problem 4. Verbal SAT scores
Have mean of 500 and SD of 100; assumed to follow the normal curve.
(a) Percentage of students with scores between 350 and 650?
(b) Of about 1000 students with scores in the range 400-600, how many had scores from 450-550?
   Hint: first find the percentage of students within the range 400-600, then the percentage between 450-550.

Problem 5. Health examination survey of 1960-61
In resurvey of 6,672 subjects a year later, 17 had their gender reversed on the coding sheets.
This is 17 / 6672 = one-quarter of one percent of the subjects.
This seems to be more likely due to coding error than to transgender decisions of a quarter of a percent in a year between 1960 and 1961.
The American Psychological Association estimates the size of the US transgender population in 2008 as 115,000 to 450,000; "Report of the Task Force on Gender Identity and Gender Variance", 2008, p.30; this is 450,000 / 300,000,000 = .0015 or only 0.15 percent of the US population. Much depends on definition, as Lynn Conway points out (lynnconway.com), but her estimate is still less than one-quarter of a percent, and was surely less in 1960-61.

ASSIGNED. Problem 6 and 7. Men, women and math.
At College X, math SAT scores averaged 650 for men and 600 for women.
(6) if there are 500 men and 500 women, the average math SAT for the student body is 0.5 (650) + 0.5 (600) = 625
   Will the SD for the entire student body be higher than for either group individually?
   Explain.
(7) if there are 600 men and 400 women, the average SAT is 0.6 (650) + 0.4 (600) = 390 + 240 = 630.
   The average score moves closer to the male score.
   The SD of the overall group will be greater -- will it be greater than is the case in (6) ?
Problem 8. Reading histogram, p. 102. Note that the histogram has bars going above the normal curve in the range 400-406 that we are asked to look at. The area under the normal curve would UNDERESTIMATE the percentage of data in that range. The data definitely shows leptokurtosis; it is pointier than the normal distribution, and there are more outliers than the normal distribution would predict.

ASSIGNED. Problem 9. Quiz scores. A quiz with 10 questions has an average of 6.4 answers correct and a SD of 2.0. Will the mean and SD for the number of questions INCORRECT be different from 5.5 and 2.0? Explain.

Problem 10. Percentage of left-handed people decrease with age (1980 survey)
Left-handed at 20 years = 10 percent; at 70 years, 4 percent. Data is however cross-section, and not time series -- these are NOT the same people. It could be that when the 70 year olds started school (say at age 6 in 1916) teachers insisted that they write with their right hand; and that in 1965 (when the 20 year olds would have started school) there was less pressure to change hands. Another possibility (Stanley Coren, The Left-Hander Syndrome) is that left-handers do have a higher accidental death rate.

ASSIGNED. Problem 11. Finding percentiles. Given: 25th percentile of height is 62.2 inches; 75th percentile = 65.8 inches.
If the data follows the normal curve, where is the 90th percentile?
Hint: The MEAN of the distribution must be \((62.2 + 65.8) / 2 = 64\) inches. Compute the standard deviation, then work with the formula for standardizing scores to come up with the answer.