

IS POPCORN NORMAL?

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Introduction

The following question, posed by William A. Massey, appeared in Chance News January 1996. [1]

"When you are listening to corn pop,
are you listening to the Central Limit Theorem?"

This talk describes a simple experiment to answer this question in an introductory statistics class.

The experiment is motivated by the belief that in general a classroom demonstration will:

- Improve student motivation, comprehension, and retention.
- Encourage discussion of difficult material.
- Provide connections for students between abstract concepts (such as the Central Limit Theorem) and their practical implications (such as why popcorn might be normal).

The first issues for a classroom experiment is to define the terms in the quote and fundamentally, the Central Limit Theorem (CLT) justifies the use of the word Normal or Standard for the bell-shaped distribution

$$\frac{\exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)}{\sqrt{2\pi}\sigma}$$

In essence the CLT states that the average of a large number of independent random measurements is Normal. The popular science book by Bennet [2] has an interesting history of the development of CLT and Normal distribution.

Of course, the original question requires interpretation for most students in an Introductory Statistics course. The question can be restated as

"Are popcorn pops normally distributed?"

Or more colloquially

"Is popcorn normal?"

Testing to see if a sample could plausibly come from a normal distribution is central to a standard Statistics course. The classroom presentation, experiment, and worksheets (developed by the undergraduate authors Clark, Edman, and Huff as part of a senior

project) would fit nicely at the start of an introductory course. The materials are designed to be flexible and provide numerous options for the instructor.

The first question to be addressed is why popcorn might be normal. Basically, the Central Limit Theorem implies that the time for an individual kernel of popcorn to pop should be normally distributed if all of the following are true:

- A. The failure (pop) is caused by a large number of independent factors.
- B. All the kernels experience similar conditions.
- C. The experimental conditions are the same throughout the experiment.
- D. The failure (pop) of one kernel does not influence the failure of another.

Of course, any or all of the conditions A-D may not be true. As examples:

- A. The failure (pop) might be caused by a single, non-normally distributed critical factor e.g. moisture content.
- B. Kernels may be unevenly heated.
- C. With microwave corn steam accumulates in the bag with microwave corn.
- D. The failure (pop) of one kernel may trigger subsequent pops in a chain reaction.

A quick Google search on popcorn and normal distribution(s) will produce a variety of interesting web sites:

- Bang Corn [3] is a semi-serious discussion board concerning improving popcorn popping by improving the sorting and grading processes.
- Heat and Popcorn [4] suggests an audio-based experiment to answer the question.
- The abstract of a pedagogical paper [5] describing a manual classroom experiment that claims to demonstrate that popcorn is normal.

The experiment described in [5] is simple. The author has students in her Chemical Engineering class collect the kernels which pop during short intervals and manually count the popped kernels from a hot air popper. The representative results reported in the paper are similar to the histogram shown in Figure 1.

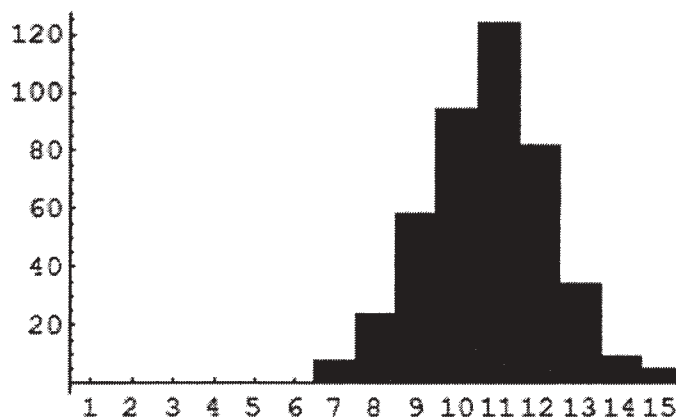


Figure 1. Experimental Results from Jones [5]

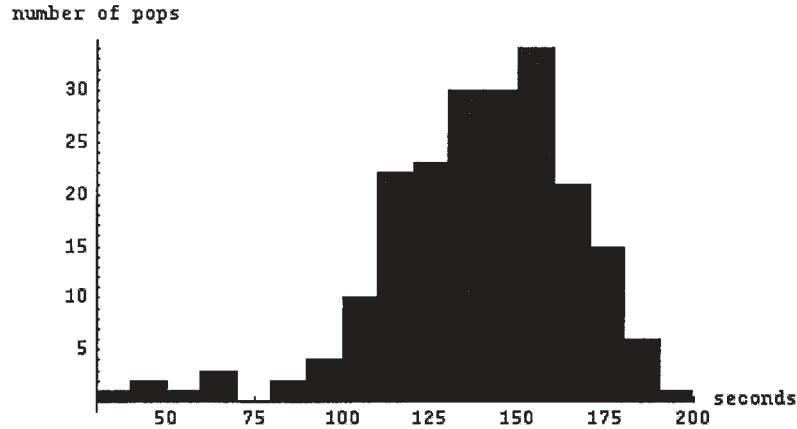


Figure 2. Microwave Popcorn.

A standard analysis (using summary statistics) shows formally that this data set is significantly skewed and non-normal. The simplest visual evidence for or against normality of a data set is a normal plot. Figure 3. is a normal plot of the microwave popcorn data.

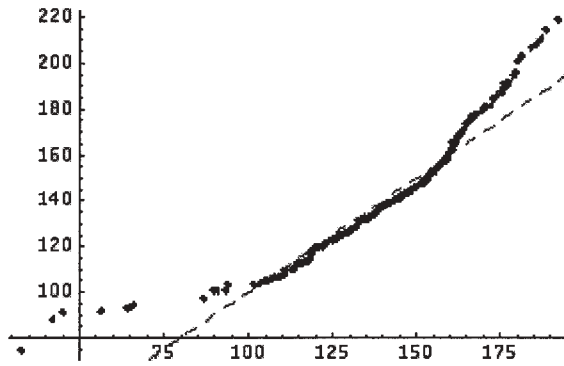


Figure 3. Normal Plot of Microwave Popcorn

If the data were normal the data (dots) would match the dashed reference line. Since it does not match we should conclude that the data is not normal.

One interesting feature of this data is that the distribution of gaps (time intervals between successive pops) shows a lot more short intervals than would be expected from a normal distribution. Perhaps one pop does trigger another kernel to pop through a collision or some other mechanism.

Hot air popped popcorn is very similar. Both the microwave popcorn and hot air popcorn experiments are highly repeatable: the same brand and popping technique

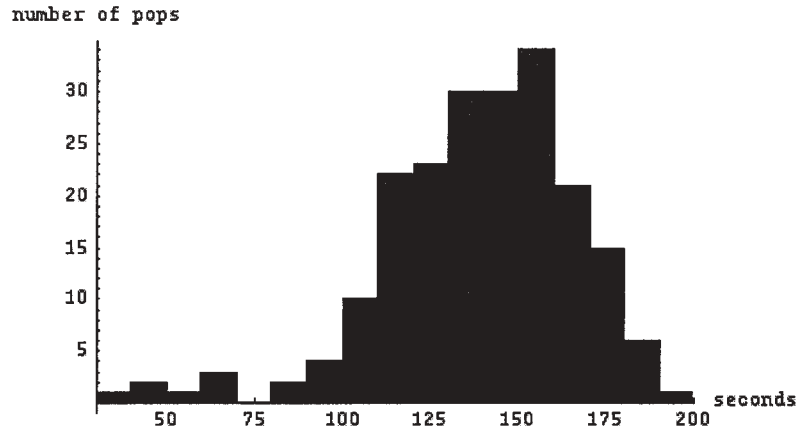


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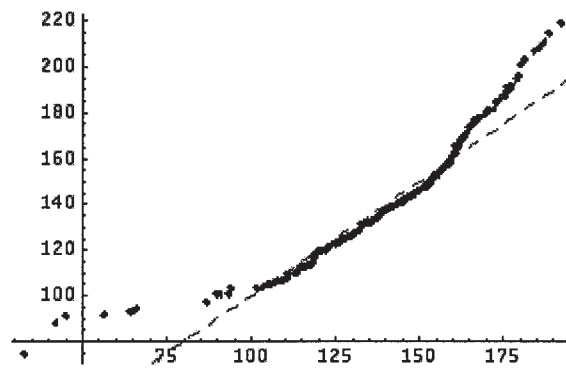


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producing a sample from the same distribution. Other experiments are possible to compare different brands of popcorn and different popping techniques (stovetop, kettle, etc.).

Conclusions

Popcorn is clearly not normal! Although we should collect data and encourage experiments we should not misrepresent skewed data as coming from a normal distribution. Similar audio data collection is possible in other circumstances. Maybe we can find a real example of a "noisy" process that does produce a normal distribution.

References

- [1] Massey, William A., Chance News, January 9th, 1996.
- [2] Bennet, Deborah J., Randomness, Harvard University Press, Cambridge MA, 1998.
- [3] Bang Corn, October 27th 2003,
"http://www.halfbakery.com/idea/Bang_20Corn.html".
- [4] Heat and Popcorn, October 27th 2003,
"http://www.jimschrempp.com/about_me/rantsraves/popcornpoppin.html".
- [5] Jones, Marjorie A., An easy and effective classroom demonstration of population distributions, Journal of Chemical Education, Volume 76, Number 3, March 1999.