MATH AND SCIENCE @ WORK

AP* STATISTICS Student Edition

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THE INTEGRATED MEDICAL MODEL

Background

The National Aeronautics and Space Administration (NASA) has been placing humans in reduced gravity environments for over 50 years. Despite this extensive history, only now, are advances in technology and the acquisition of reliable, aggregate data enabling researchers and statisticians to fully evaluate the medical risks and dangers associated with short and long term exposure to reduced gravity.

As NASA is designing a new spacecraft capable of taking humans into deep space, and with the future advent of commercial spaceflight, a deeper and better understanding of medical risk has become even more vital for maintaining spaceflight safety and health for humans.

To address these critical issues, NASA's Human Research Program (HRP) is addressing the medical hazards using a formalized risk management approach—to effectively identify and reduce acute and chronic medical risks to human spaceflight.

Figure 1: Artist concept of astronauts on the Mars surface

One of HRP's tools to assess the relative impact of medical events to astronauts and the mission is the Integrated Medical Model (IMM). The IMM is a simulation-based tool designed to quantify the probability of the medical risks and potential consequences that astronauts could experience during a mission.

The IMM incorporates "best evidence" with data from past missions, computer models, and comparable populations on Earth, to provide a quantifiable assessment of medical risk for a given mission scenario.

The IMM also identifies medical resources, such as equipment and supplies, which are necessary for treating the medical conditions most likely to occur during the mission.

Using the Monte Carlo simulation technique (a random sampling of the data inputs as described by their statistical distribution), the IMM can forecast medical outcomes, helping to provide more appropriate medical support for flight crews. The medical risks addressed by the IMM range from minor conditions (such as headaches and nasal congestion) to more serious conditions (such as sudden cardiac arrest and kidney failure).

Problem

On the TI-Nspire™ Handheld, open the document, *Medical Model*, follow the instructions on pages 1.1–1.3 to seed the calculator, then read through the problem set-up (page 2.1) and complete the instructions and questions embedded within the document.

A. Follow the instructions and answer the questions on pages 2.4–2.6 to estimate the number of crewmembers (from a 10–person crew) that will experience a headache on that mission.

   2.4. What assumptions should be made in order to use a binomial approximation?

   2.5. The randBin command can be used to randomly simulate this binomial experiment. Enter the command **randBin(10,0.732)** in the calculator. Record your results.

   2.6. The result of your randBin command is the number of crewmembers in your simulation that experienced a headache on the mission. Compare with other students' results. Are the results the same? Why or why not?

B. Enter the command to simulate a 100–person crew below. Then enter the command to simulate a 1–person crew. Record both of your results.

C. The command **randBin(10,0.732,5)** simulates a 10–person crew on five different missions. Enter the command. Record your results and compare with other students.

   2.9. Discuss the meaning of the results.

D. Enter the command **randBin(10,0.732,100)** in the shaded formula entry cell of the column labeled “headaches” on page 3.2, then view the histogram of headaches created on page 3.3.

3.4. Use your histogram to estimate the probability that at least half the crew will experience headaches on a mission.

E. It is possible for a headache to become severe enough that a crewmember would need to be evacuated. Assume (in the best case) that the probability a headache requires an evacuation is 0.025; and in the worst case, the probability a headache requires an evacuation is 0.075. Assume 3% of all headaches are worst case. What is the probability that an evacuation of a crewmember is needed?

A simulation can be used to estimate this probability. Enter the following commands into the spreadsheet on page 4.3 in order to complete the simulation.

- Enter the command **seq(*x*,*x*,1,200)** in the shaded formula cell of column A. This command simulates 200 crewmembers.
- Enter the command **randBin(1,0.732,200)** in the shaded formula cell of column B. This simulates whether or not each crewmember gets a headache. (1=headache, 0=no headache)
- In cell C1, enter: $=\begin{cases}\textbf{randBin}(\textbf{1},\textbf{0.03}), & \textbf{b1}=\textbf{1}\\ \textbf{0}, & \textbf{b1}=\textbf{0}\end{cases}$.

  This simulates whether each headache is worst case or not. (1=worst case, 0=best case)

  Don't forget the "=" sign. The 2–piecewise function template can be found by pressing the **math template key**, located above the multiplication key.
- Use the fill feature in the data menu to copy cell C1 to the rest of column C. Do this by pressing **Menu** while the cursor is in cell C1. Select **Data > Fill**. Press the **down cursor arrow** until cell C200 is reached, and then press **Enter**.
- In cell D1, enter: $=\begin{cases}\textbf{randBin(1,0.075)}, & \textbf{b1}=\textbf{1 and c1}=\textbf{1}\\ \textbf{randBin(1,0.025)}, & \textbf{b1}=\textbf{1 and c1}=\textbf{0}\\ \textbf{0}, & \textbf{b1}=\textbf{0}\end{cases}$.

  This simulates whether each headache case requires evacuation (1=evacuation, 0=no evacuation).
- Don’t forget the “=” sign before the template. The *n*–piecewise function can be found by pressing the **math template key**. Once you select the template, choose “3” as the number of function pieces.
- Use the fill feature in the data menu to copy cell D1 to the rest of column D.

4.4. Enter **sum(evac)** to find the total number of evacuations. What is your estimate of the probability of evacuation?

F. What is the probability that out of 200 crewmembers, 5 or more will need to be evacuated?

To answer this question, combine the total number of evacuations found on page 4.4 with the results of the other students in the class.

References

Fitts, M. A.; Kerstman, E.; Butler, D. J.; Walton, M. E.; Minard, C. G.; Saile, L. G.; Toy, S.; Myers, J. "The Integrated Medical Model: Statistical Forecasting of Risks to Crew Health and Mission Success." Internet Archive. NASA Technical Documents. 4 Feb 2008. Retrieved 19 Sept 2011.

Myers, J; Lewandowski, B; Brooker, J; Weaver, S. "Assessing the Likelihood of Rare Medical Events in Astronauts." IEEE Xplore Digital Library. Reliability and Maintainability Symposium (RAMS), Lake Buena Vista, FL. 24-27 Jan 2011. Retrieved 19 Sept 2011.