

Smoking Aboard U.S. Navy Submarines

Developed by 2015 Submarine Force Library and Museum STEM –H Teacher Fellows:
Caitlin Kennedy, Math Teacher, Fitch High School, Groton, CT
Robert Mayne, Math Teacher, Chariho Regional High School, Wood River Jct., RI

As recently as 2010 the submarine's commanding officer had discretion to designate smoking areas aboard his submarine within certain guidelines. Unlike surface ships, submarines are closed vessels with no access to the open air. In 2006 the U.S. Surgeon General released a report concluding, "there is no risk free level of exposure to secondhand smoke" and "separating smokers from non-smokers, cleaning the air, and ventilating buildings cannot eliminate exposure to non-smokers to second hand smoke." During sea trials of the *Virginia* Class submarines, nicotine had been identified as a contaminant to submarine atmosphere.

The extent to which non-tobacco using submariners were being exposed to environmental tobacco smoke (ETS) was not quantified but the identification of nicotine presence in submarine's atmosphere during sea trials supported the concern of submariners. The Submarine Force tasked the Naval Submarine Medical Research Laboratory (NSMRL) in Groton, CT to conduct a study on U.S. submarines. Volunteers were recruited from the crews of nine submarines: three *Los Angeles* Class, three *Ohio* Class, two *Virginia* Class and one *Seawolf* Class.

Selected volunteers were asked to provide two urine samples, a pre-deployment sample to measure exposures in the harbor environment and a deployed sample representative of operational exposures. Samples were analyzed for cotinine and additional nicotine metabolites. (Cotinine is currently the most widely accepted biomarker for the assessment of exposure to environmental tobacco smoke.)



Clip from the Warner Bros. movie *Destination Tokyo* (1943)

Understanding Data

Explain the W's of this scenario.

- Who:
- What:
- When:
- Where:
- Why:
- How:

Would these data collected be classified as quantitative or categorical? Explain.

Sampling Techniques

Describe how a simple random sample (SRS) of submariners could be chosen.

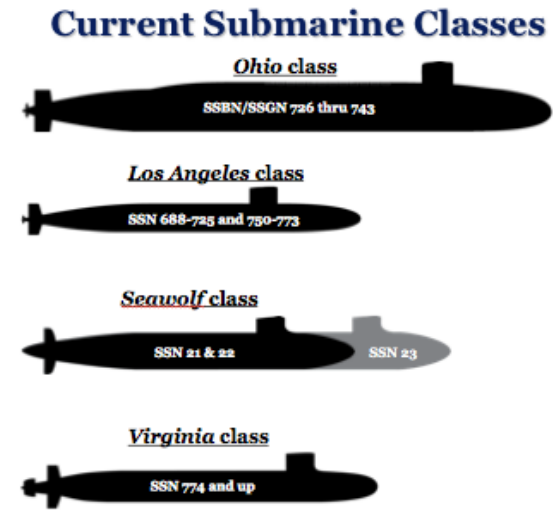
Explain the shortcomings of using SRS in this scenario?

What factors would be important to take into consideration in order to achieve a representative sample of submariners?

Describe a better method than SRS to randomly sample submariners.

Why would it not be feasible (if not immoral) to perform a designed experiment to determine whether smoking on the submarine could adversely affect the health of submariners?

Why would it be important to sample from different classes of submarines? Explain.



What characteristics/demographics of volunteers would make them ineligible to participate in the study? Explain.

Inference Testing

What is the rationale for taking a sample pre-deployment and once deployed? Explain.

What type of hypothesis testing would be used to determine if there is a difference in cotinine levels between pre-deployment and while deployed? Explain.

What assumptions and conditions must be met before testing a hypothesis?

Would this be considered a one-tailed or a two-tailed test? Explain.

When the Naval Submarine Medical Research Laboratory (NSMRL) in Groton, CT performed the analysis of these data, they found that the nearly Normal condition was not met. However, after taking the logarithm of these data, the distribution was roughly unimodal and symmetric.

The summary statistics from this study were as follows: $n = 197$, $\bar{d} = -0.71909$, $s_d = 1.21229$. Determine if there is a statistically significant difference between in port and deployment cotinine levels?

State the null and alternative hypotheses both in words and symbols.

State your assumptions and conditions.

Perform a paired t-test for the mean applied to the differences. Be sure to include any diagrams needed.

State your conclusion based on your hypothesis test.

Create a 95% confidence interval for the differences in cotinine levels between port and deployment.

Create a 90% confidence interval for the differences in cotinine levels between port and deployment.

"Our Sailors are our most important asset(s) to accomplishing our missions. Recent testing has proven that, despite our atmosphere purification technology, there are unacceptable levels of secondhand smoke in the atmosphere of a submerged submarine. The only way to eliminate risk to our non-smoking Sailors is to stop smoking aboard our submarines," said Vice Adm. John J. Donnelly.

Based on your analysis of these data, do you agree with the conclusion of the U.S. Navy Submarine Force to ban smoking on submarines? Be sure to support your conclusion with statistical evidence.



140228-N-TN558-110 GROTON, Conn. (Feb. 28, 2014) The Virginia-class attack submarine USS New Mexico (SSN 779) departs Naval Submarine Base New London for Ice Exercise 2014 (ICEX-2014) in the Arctic Ocean. (U.S. Navy photo by Mass Communication Specialist 1st Class Jason J. Perry/Released)

Lesson Plan Resources: “Smoking Aboard U.S. Submarines”

Developed by 2015 Submarine Force Library and Museum STEM –H Teacher Fellows:

Caitlin Kennedy, Math Teacher, Fitch High School, Groton, CT

Robert Mayne, Math Teacher, Chariho Regional High School, Wood River Jct., RI

Instructional Goals

This lesson is designed to span the high school statistics and probability standards of the Common Core State Standards (Algebra 2 and fourth year course) and the curriculum for AP Statistics. Students will be able to use and apply the concepts of random sampling, designed experiments, observational studies and statistical inference.

Common Core State Mathematic/Literacy Standards:

CCSS.MATH.CONTENT.HSS.CP.A.5

Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. *For example, compare the chance of having lung cancer if you are a smoker with the chance of being a smoker if you have lung cancer.*

CCSS.MATH.CONTENT.HSS.IC.A.1

Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

CCSS.MATH.CONTENT.HSS.IC.B.3

Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

CCSS.MATH.CONTENT.HSS.IC.B.5

Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.

CCSS.MATH.CONTENT.HSS.IC.B.6

Evaluate reports based on data.

CCSS.MATH.CONTENT.HSS.ID.A.4

Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.

CCSS.MATH.CONTENT.HSS.MD.B.7

(+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).

CCSS.MATH.PRACTICE.MP1

Make sense of problems and persevere in solving them.

CCSS.MATH.PRACTICE.MP2

Reason abstractly and quantitatively.

CCSS.MATH.PRACTICE.MP3

Construct viable arguments and critique the reasoning of others.

CCSS.MATH.PRACTICE.MP4

Model with mathematics.

Related Documents & Resources

<http://www.ussnautilus.org> - Submarine Force Museum and Historic Ship Nautilus

http://www.navy.mil/submit/display.asp?story_id=52488 - Smoking To Be Extinguished On Submarines

<http://tobaccocontrol.bmj.com/content/22/e1/e66.abstract> - Evaluating the effectiveness of the US Navy and Marine Corps Tobacco Policy: an assessment of secondhand smoke exposure in US Navy submariners.

<http://www.med.navy.mil/sites/nsmrl/Pages/default.aspx> - Naval Submarine Medical Research Laboratory

<http://www.med.navy.mil/sites/nsmrl/Documents/FactSheet.pdf> - Naval Submarine Medical Research Laboratory

<http://publications.amsus.org/doi/pdf/10.7205/MILMED-D-10-00292> - The Clinical Implications of a Smoking Ban on Submarines in the U.S. Navy

http://www.public.navy.mil/bupers-npc/support/21st_Century_Sailor/nadap/Documents/SECNAVINST510013E.pdf - US Navy and Marine Corps Tobacco Policy (2008)

<http://www.ncbi.nlm.nih.gov/books/NBK44324/> - The Health Consequences of Involuntary Exposure to Tobacco Smoke, A Report of the Surgeon General

<http://www.ncbi.nlm.nih.gov/pubmed/10765410> - Use of environmental tobacco smoke constituents as markers for exposure.

<http://www.navy.mil/viewGallery.asp?id=17> - Gallery photos of US Navy submarines.