SPINOFFS

Spinoffs are relatively short learning modules inspired by the LTAs. They can be easily implemented to support student learning in courses ranging from prealgebra through calculus. The Spinoffs typically give students an opportunity to use mathematics in a real world context.

LTA - SPINOFF 18A	Space Exclusion Versus Inclusion
LTA - SPINOFF 18B	Creating a Scaled Room Design

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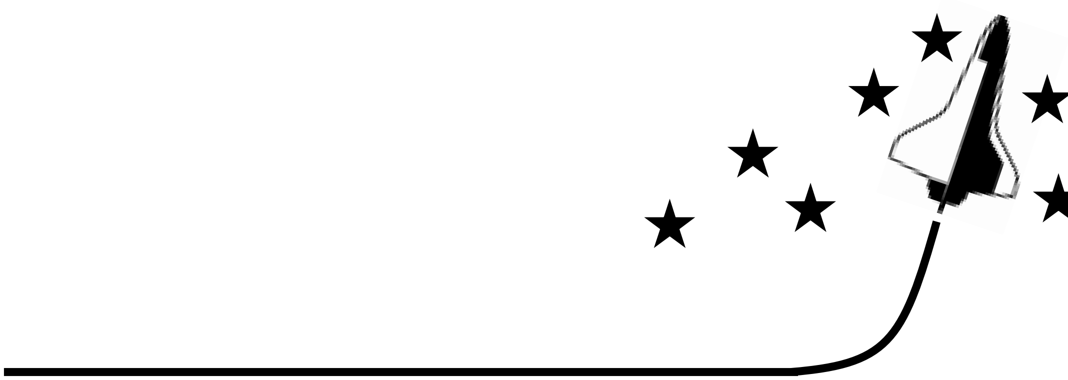

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This project was supported, in part, by the
National Science Foundation
Opinions expressed are those of the authors
and not necessarily those of the Foundation

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SPINOFF 18A

Space Exclusion Versus Inclusion

Oftentimes when dealing with statistics, the most useful piece of information is the mean. When your professor figures your grade, or the college calculates your grade point average, they use the mean. However in most of the work that *human factors engineers* do, using just the mean could cost them their job! When considering the dimensions for designing something a human would use such as a chair, desk, steering wheel, space capsule, or space suit, human factors engineers use other statistical values.

In order to figure out the dimensions, human factors engineers must decide if they are going to use **selection** or **job modification.** Selection is when you fit a person to a job (picking a strong person to move heavy objects) while job modification is when you fit the job to the person (using carts or pulleys to help almost anyone move a heavy object). In the case of selection, a large percent of the population is excluded, while in job modification, a large percent of the population is included.

The percent of people to exclude depends on the trade-off between the seriousness of the exclusion versus the cost of the inclusion. For example, the Air Force has decided to exclude a percentage of the population from becoming pilots because of their size (height and weight). This is due to the fact that redesigning an aircraft to fit one very tall or heavy person is astronomical; therefore, it is better to exclude those persons. However, when the Air Force builds a new barracks, it could make the doorways tall enough to include 99% of the population without incurring a big cost difference relative to making shorter doorways.

The excluded percentile of the population could be an upper or lower percentile, or both. Here are a few examples:

- Upper percentile exclusion – persons in the upper percentile of household income are excluded from certain tax breaks.
- Lower percentile exclusion – persons scoring in the lower percentile on the SAT are excluded from entrance into a college.
- Upper and lower percentile exclusion – persons in the lower or upper percentile of age are excluded from working at a factory.

The following exercises involve questions regarding the distribution of human body dimensions such as height, foot length, hand breadth, etc. Statistics concerning body dimensions depend on the population being considered. However, for any particular population, such as male or female United States adults, the distribution of each dimension can be characterized by the mean and standard deviation. (We shall assume that body dimensions are normally distributed.)

Exercise (Literature Search)

1) Use a library and/or the Internet to locate body dimension statistics (e.g. stature, hand and foot length, hand and foot breadth, head circumference, distances from one part of the

body to another, distances from parts of the body to the floor when standing, distances from parts of the body to the floor when sitting, reach distances) for adult male and female humans. Your information must include the means and standard deviations of the body dimensions. Also, be sure that your information indicates how each dimension is measured. For example, to measure hand length, from what point on the wrist does one start? Sources of statistical information concerning body dimensions include: anthropometry, ergonomics, engineering physiology, OSHA, and MIL STD 1472. Describe how you found the information, and record precisely the source of the information and the population to which it applies.

The areas under the normal curve found in Table 1 at the end of this Spinoff, can be transformed into percentile information. The first **column** indicates the ones and tenths digits of the number of standard deviations from the mean. The first **row** of numbers indicates the hundredths digit of the number of standard deviations from the mean. Each decimal value within the table represents the decimal equivalent of the percent of the population that is within the given number of standard deviations from the mean in a **normal distribution.**

For example, if we wanted to know what percent of the people are between the mean and 2.13 standard deviations above the mean, we would see that by matching 2.1 and 0.03 in Table 1 the decimal value is 0.4834. This would correspond to 48.34%, which also means that 1.66% (50%-48.34%) of the population are more that 2.13 standard deviations above the mean.

From another perspective, we could determine what value corresponds to a certain percentile. As a hypothetical example, assume that the mean and standard deviation of adult male heights are equal to 72 inches and 2 inches respectively. If we wanted to determine the height corresponding to the 90th percentile (90% of the males have height less than this value and 10% have height greater than this value), we would look for 0.4 in the body of Table 1 (50% + 40% = 90%). The number closest to 0.4 in the body of the table is 0.3997, which corresponds to 1.28 standard deviations. Thus, we calculate the height as follows:

Mean + (standard deviation)x(number of standard deviations) = value
72 + 2 x 1.28 = 74.56 inches

Therefore, in this hypothetical example, 90% of adult males have height less than 74.56 inches and 10% have height greater than 74.56 inches.

Exercises (Percentiles)

2) Use the mean and standard deviation (found in Exercise 1) of each of the following dimensions and the table of normal curve areas (Table 1) located at the end of this Spinoff to find:
   a) the, 10th, and 90th percentiles for female height and for male height,
   b) the 5th, and 95th percentiles for female hand length for male hand length, and
   c) the 5th, 10th, 90th, and 95th percentiles for head circumference for males and females.

3) Measure your hand length and hand breadth, and calculate what percentile you are in for each of these two measurements. You will need the mean and standard deviation of height and hand length found in Exercise 1 and a table of normal curve areas (Table 1).
4) Sketch a normal distribution curve for either male height or female height. Include the values of the normal distribution function at each integer standard deviation from –3 to +3.

Exercises (Inclusion vs. Exclusion)

For each of the following situations determine if you would incorporate the **selection** or **job modification** philosophy. State the percentiles you would include, what types of measurements are necessary, and the corresponding range or inclusive values for each measurement:

5) Design a chair for use in the Human Factors Engineering building.
6) Design a seat for astronauts to use in the Space Shuttle.
7) Determine the doorway height and width for the entrance to the cargo bay from the cockpit in the Space Shuttle.
8) Determine the doorway height and width for the women's restroom in the Human Factors Engineering building.
9) Determine the distance an important button is located from the pilots seat (forward) in the Space Shuttle.
10) Determine the height of a light switch in the men's restroom in the Human Factors Engineering building.
11) Determine the adjustable widths of a NASA baseball cap to be sold at the Kennedy Space Center gift shop.

Table 1: Area Under the Normal Curve

Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0064	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2518	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4229	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4995	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4982	0.4984	0.4984	0.9850	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995									
3.4	0.4997									
3.5	0.4998									
3.6	0.4998									
3.7	0.4999									
3.8	0.4999									
3.9	0.5000									
4.0	0.5000									

REFERENCE:

Kroemer, K.H.E., Kroemer, H.B., Kroemer-Elbert K.E. (1994). *Ergonomics How to Design for Ease and Efficiency*: Prentice Hall International Series in Industrial and Systems Engineering W. J. Fabrycky and J. H. Mize, Editors. Englewood Cliffs, NJ: Prentice Hall.