Normal Models

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Normal Models

In Statistics, no model gets more attention than the Normal Model.

This is partly historical, partly pedagogical, and partly because it's actually quite useful!

We will keep learning more about it as we progress through the semester.

For now, what to know

Normal Models

- σ is the population standard deviation
- s is the sample standard deviation
- s is actually an estimator for σ
- s is not the standard deviation of the sample itself

Common parameters and statistics

Parameters (Population)

- σ standard deviation
- μ mean
- p proportion

Statistics (Sample)

- s standard deviation
- $\bar{x}$ mean
- $\hat{p}$ proportion

Calculating σ

- Find the mean of the data.
- Write data in a column.
- Next column: subtract mean from data
- Next column: square previous column
- Add all squared values.
- Divide this sum by n, number of data elements. (This is σ^2.)
- Note that σ^2 is called the variance.
- Take the square root of the variance to get the standard deviation.

Calculating σ

We can do this by hand for small data sets: $\{1, 2, 3, 4, 5\}$.

1		
2		
3		
4		
5		

Calculating σ

We can do this by hand for small data sets: $\{1, 2, 3, 4, 5\}$.

1	-2	
2	-1	
3	0	
4	1	
5	2	

Calculating σ

We can do this by hand for small data sets: $\{1, 2, 3, 4, 5\}$.

1	-2	4
2	-1	1
3	0	0
4	1	1
5	2	4

Calculating σ

1	-2	4
2	-1	1
3	0	0
4	1	1
5	2	4

Add: $4+1+0+1+4 = 10$

Calculating σ

Add: $4+1+0+1+4 = 10$

Divide: $10/5 = 2$ (This is σ^2, the variance.)

Calculating σ

Add: $4+1+0+1+4 = 10$

Divide: $10/5 = 2$ (This is σ^2, the variance.)

Square root: $\sigma = \sqrt{2} \approx 1.4142$

Calculating s

Finding s is almost the same as finding σ, except that we divide by $n - 1$.

Calculating s

- Find the mean of the data.
- Write data in a column.
- Next column: subtract mean from data
- Next column: square previous column
- Add all squared values.
- Divide this sum by $n - 1$. (This is s^2.)
- You guessed it! s^2 is called the variance.
- Take the square root of the variance to get the standard deviation.

Calculating s

We can do this by hand for small data sets: $\{1, 2, 3, 4, 5\}$.

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Calculating s

We can do this by hand for small data sets: $\{1, 2, 3, 4, 5\}$.

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Add: $4+1+0+1+4 = 10$

Calculating s

Add: $4+1+0+1+4 = 10$

Divide: $10/\mathbf{4} = 2.5$ (This is s^2, the variance.)

Calculating σ

Add: $4+1+0+1+4 = 10$

Divide: $10/4 = 2.5$ (This is s^2, the variance.)

Square root: $s = \sqrt{2.5} \approx 1.5811$

s and σ

The value of s will always be larger than the value of σ calculated on thes same data.

This is because s is presuming you have a sample and you want to guess what σ is in the whole population.

However, when you calculate σ, you are only doing on an entire population!

Sometimes, even if your whole population seems to be in front of you, you will imagine it as a sample of a larger population.

Sample or population?

Let's pretend I am doing an experiment. I collect 25 little frogs from the wild and bring them into my house in a fishtank and feed them, give them water, etc. I want to know if they will get bigger or stay the same size.

Was that a sample or a population?

Sample or population?

You could argue that I have the entire set of frogs that I care about, or you could argue that really, I took a sample of frogs, and I am using them to infer what would happen to any of the frogs out there.

If I took the standard deviation of a classroom's worth of exams, I could make the argument that the class is just a sample of all the students who might have taken this course with me but ended up in other sections. So, then it's sample, even though I have all the data I really care about.

Adding a constant

If I were to add 5 to every value in $\{1, 2, 3, 4, 5\}$ and get

$$\{6, 7, 8, 9, 10\}$$

what would happen to the mean (μ or $\bar{x}$)?

What would happen to σ and s?

Answers

You shouldn't bother to recalcualte all that, right?

The mean will shift by the constant you added.

The values of s and σ will stay the same. Why?

Multiplying by a constant

If I were to multiply every value in $\{1, 2, 3, 4, 5\}$ by 10 and get

$$\{10, 20, 30, 40, 50\}$$

what would happen to the mean (μ or $\bar{x}$)?

What would happen to σ and s?

Answers

The mean will multiply by the 10. Why?

The values of s and σ will also multiply by 10. Why?

Calculating s

10	-20	400
20	-10	100
30	0	0
40	10	100
50	20	400

Add: $400+100+0+100+400 = 1000$
This sum is 100 times larger than before!

Divide by 5, take square root: $\sqrt{\frac{1000}{5}} = \sqrt{200} \approx 14.142$

Taking the square root brings the difference to 10.

Basics in formula format

We use formulas to make things easier to remember, because all that discussion is really hard to rehearse each time. Once we can agree a formula is correct, it doesn't take much space, and it's easier to refer to it!

$$\mu_{(x+c)} = \mu_x + c$$

$$\mu_{(Kx)} = K \times \mu_x$$

$$\sigma_{(x+c)} = \sigma_x$$

$$\sigma_{(Kx)} = K \times \sigma_x$$

N(μ,σ)

We use the Normal Distribution so much that we abbreviate it this way:

$$N(\mu, \sigma)$$

Where μ is the mean and σ is the standard deviation.

Shift of Data

If you shift your data using a line, what happens to the mean and standard deviation?

- The mean shifts according to the function which is a line
- The standard deviation is multiplied by the slope only

If you have temperature data in Celcius $N(50, 10)$, what is the distribution in Fahrenheit if $F = \frac{9}{5}C + 32$?

Answers

If your Celcius data look like $N(50, 10)$, your Fahrenheit data will have a distribution of $N(122, 18)$.

Adding means

$$\mu_{(A+B)} = \mu_A + \mu_B$$

Means do what you might expect them to do. We use them in everyday life, so we are familiar with them!

Everyday example of adding means

Let's say you plan to shop at Target, and expect to spend $N(100, 12)$. Then, you plan to stop at a grocery store and spend $N(50, 5)$. How much do you expect to spend overall?

Of course, you expect to spend \$150 on average, right?

But what about the standard deviation?

But what if you want the standard deviation?

Answer: Then you're thinking about the wrong thing!

Variances add.

Variances add!!!
STANDARD DEVIATIONS DO NOT ADD!!!

$$\sigma^2_{(A+B)} = \sigma^2_A + \sigma^2_B$$

So what can we do about it?

We know $\sigma_{Target} = 12$ and $\sigma_{grocery} = 5$.

Square them both to get the variances, then add them! Then, square root to get back to the standard deviation you wanted in the first place.

Add variances!

$$\sigma^2_{Target} = 144$$

$$\sigma^2_{grocery} = 25$$

$$\sigma^2_{Target+grocery} = 169$$

$$\sigma_{Target+grocery} = 13$$

But what's the formula?

It is easier, concpetually, to remind yourself that variances are what adds, but sometimes you just want to see a formula, even if the formula makes things harder to understand.

$$\sigma_{(A+B)} = \sqrt{\sigma_A^2 + \sigma_B^2}$$

What if you have more things to add?

What if you are visiting three stores?

You still go back to variances, add them as you wish, then take the square root of all of that!

Your turn

You are going to a movie at a mall. (Yes, malls still exist!) You think parking will cost about $N(10, 3)$, the movies will cost about $N(25, 4)$ and you plan to pick up something at the mall so maybe $N(120, 12)$. Assume the variables (purchases) are each independent and don't interact in any way.

Determine your overall expected expenses, then figure out the standard deviation for them.

Answer:

The mean is $10+25+120 = 155$ as you would expect.

The variance is $3^2 + 4^2 + 12^2$ or $9 + 16 + 144$ which is 169.

So the standard deviation is the square root of this, or 13.

Why does that work?

If you are unconvinced that this is the way to deal with adding up variation, that's ok. You would need to do out several examples by hand before it would make intuitive sense, but let me try to explain.

If you try to simply add the standard deviations together, you would not get the benefit of the fact that two variables are just as likely to wind up on the same sides of their means as they are to wind up on opposite sides of them. This is all held together by **independence** of variables. If they are connected somehow, none of this works, and we need other formulas!

Adding the same thing repeatedly

You have a pile of apples and you are putting 9 at a time into some bags. The distribution of the apples' weights are $N(6, 2)$ ounces. What will the distribution of the bags' weights be?

Apples question

You know that 9 apples at 6 ounces would be 54 ounces typically. (This is 3 pounds 6 ounces if you prefer it that way.)

For the standard deviation, you have to think in terms of variances first!

$$\sigma^2 = 4 + 4 + 4 + 4 + 4 + 4 + 4 + 4 + 4 = 36$$

$$\sigma = \sqrt{36} = 6$$

Notice that you can shortcut this process: Multiply the original σ by the square root of of 9, since you are bagging 9 apples. $2 \times \sqrt{9} = 2 \times 3 = 6$.

Another surprise

$$\sigma_{(A+B)} = \sqrt{\sigma_A^2 + \sigma_B^2}$$

$$\sigma_{(A-B)} = \sqrt{\sigma_A^2 + \sigma_B^2}$$

Even if you are subtracting, if you have independence, you still add the variances! (Don't worry, means do subtract, just like you expect!)

This is because the *noise* or *variation* is just as likely to go high or go low. This is true whether you are adding or subtracting two things.

Standardizing data

Since all normal models are really the same except for adding and multiplying, we often *normalize* our data so we can refer to them with common language. We use *z-scores* to do this.

$$z = \frac{x - \mu}{\sigma}$$

Comparing standardized test scores

Alan received a 1025 on his SAT which had a distribution of $N(1000, 500)$ that year. Betty received a 21 on her ACT which had a distribution of $N(20, 5)$ that year. Who did better? Who had the higher z-score?

$$z = \frac{x - \mu}{\sigma}$$

Find the z-score for each student.

Answers:

Alan's z-score is 0.05, while Betty's is 0.2, so Betty did better.

Getting back to raw values

To reverse this process, use

$$x = \mu + z\sigma.$$

Marco received a $z = 1.2$ on his test which had a distribution of $N(80, 10)$. Find his raw score.

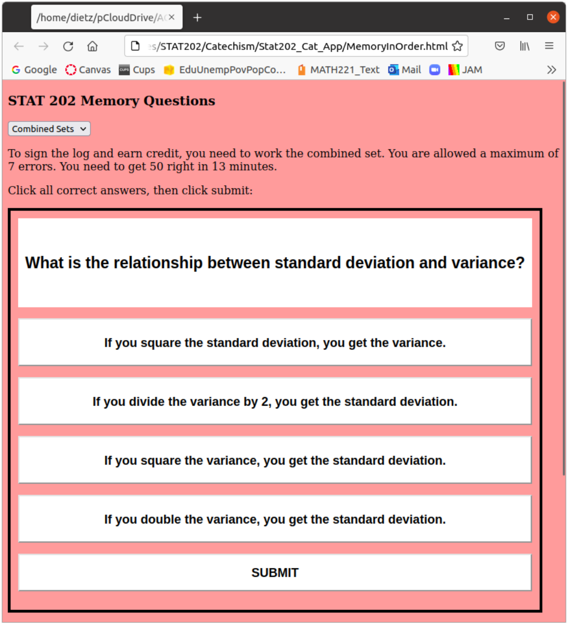
Answer:

Marco's z-score is

$$80 + 1.2 \times 10 = 92.$$

MEMORY QUESTIONS

Just 21 today!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Combined Sets
To sign the log and earn credit, you need to work the combined set. You are allowed a maximum of 7 errors. You need to get 50 right in 13 minutes.
Click all correct answers, then click submit:
What is the relationship between standard deviation and variance?
If you square the standard deviation, you get the variance.
If you divide the variance by 2, you get the standard deviation.
If you square the variance, you get the standard deviation.
If you double the variance, you get the standard deviation.
SUBMIT

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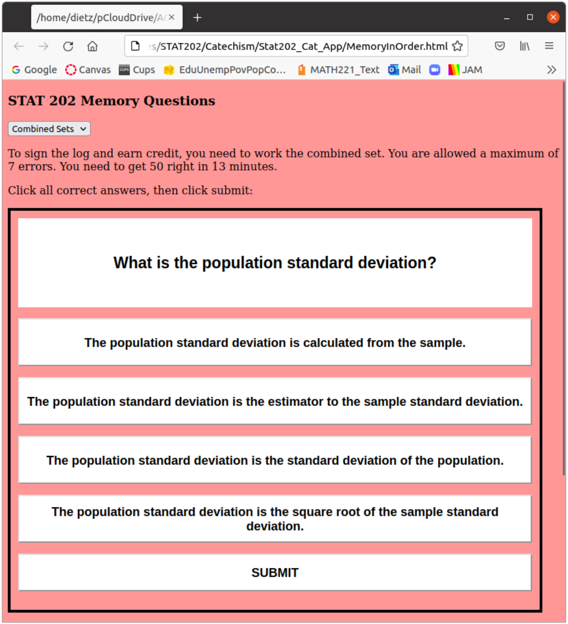
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What is the population standard deviation?
The population standard deviation is calculated from the sample.
The population standard deviation is the estimator to the sample standard deviation.
The population standard deviation is the standard deviation of the population.
The population standard deviation is the square root of the sample standard deviation.
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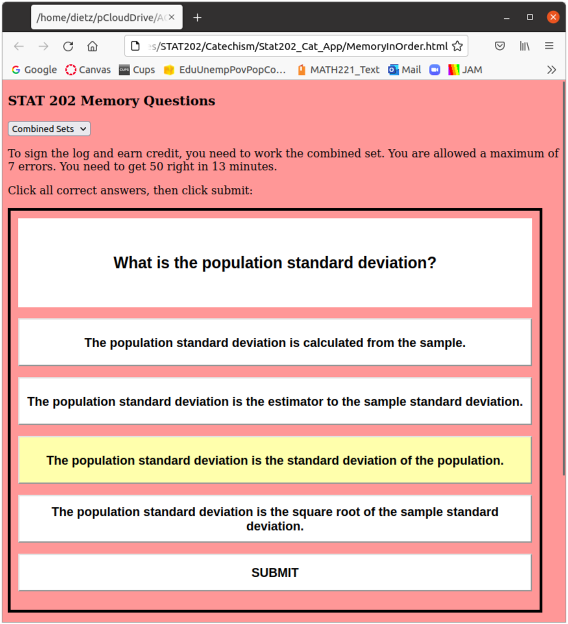
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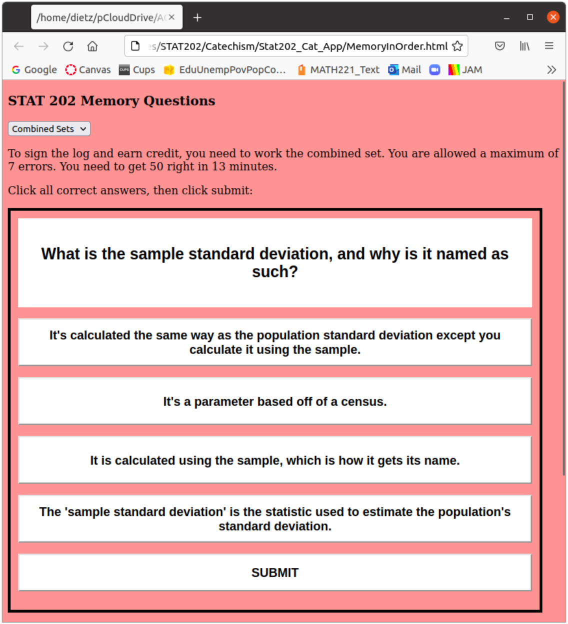
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What is the sample standard deviation, and why is it named as such?
It's calculated the same way as the population standard deviation except you calculate it using the sample.
It's a parameter based off of a census.
It is calculated using the sample, which is how it gets its name.
The 'sample standard deviation' is the statistic used to estimate the population's standard deviation.
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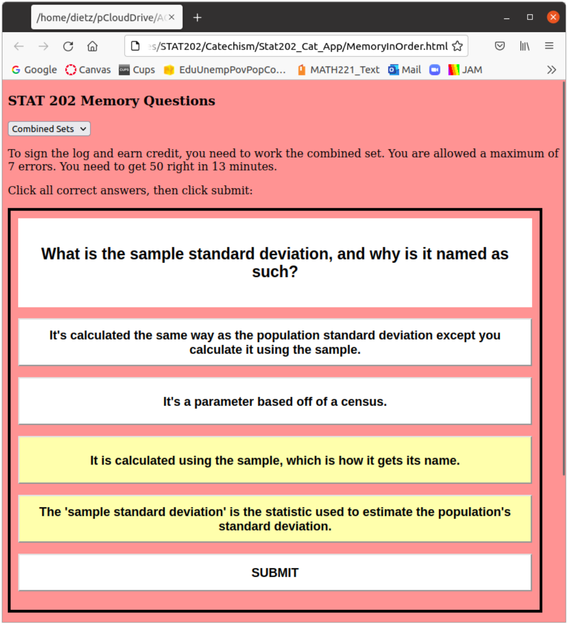
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Click all correct answers, then click submit:

In software, which standard deviation is usually calculated on a collection of data, and why?

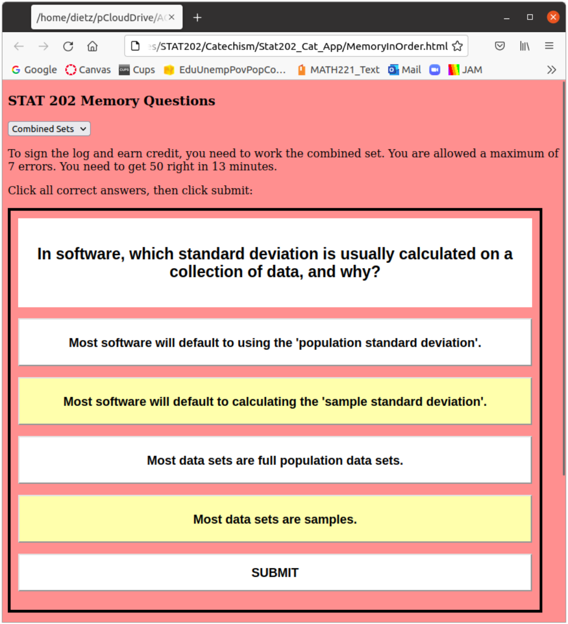
Most software will default to using the 'population standard deviation'.

Most software will default to calculating the 'sample standard deviation'.

Most data sets are full population data sets.

Most data sets are samples.

SUBMIT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What is a parameter?

It is a numerical (or non-numerical) value that represents a population.

You can only find it if you have a census.

It is a numerical (or non-numerical) value that is calculated from a sample.

It's a value calculated from multiple samples.

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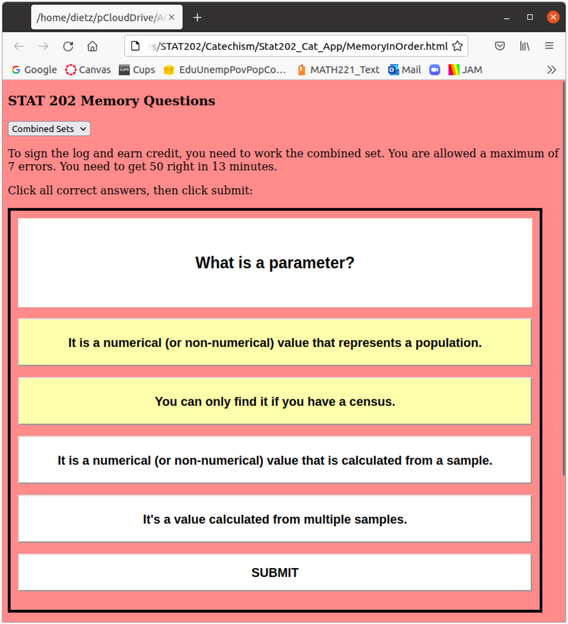

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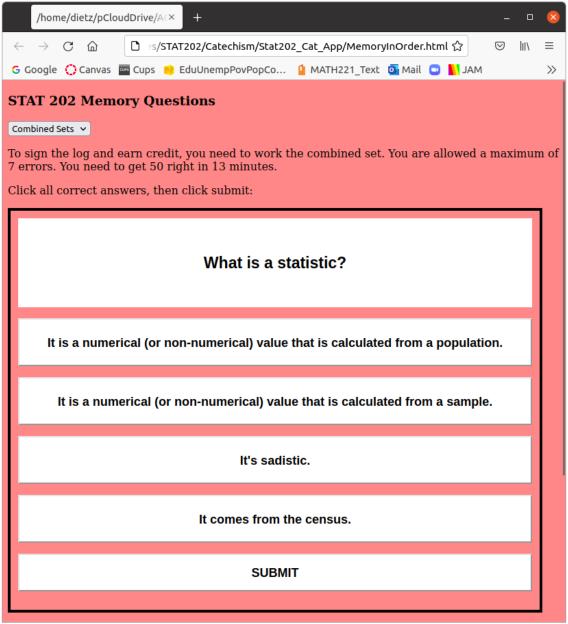
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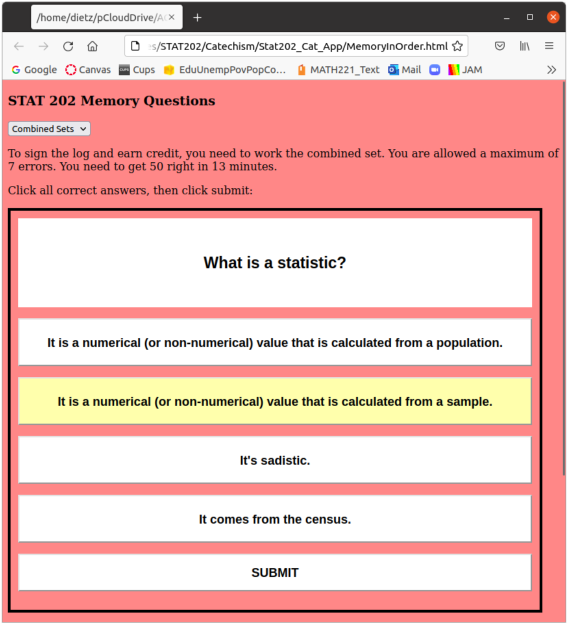
What is a statistic?
It is a numerical (or non-numerical) value that is calculated from a population.
It is a numerical (or non-numerical) value that is calculated from a sample.
It's sadistic.
It comes from the census.
SUBMIT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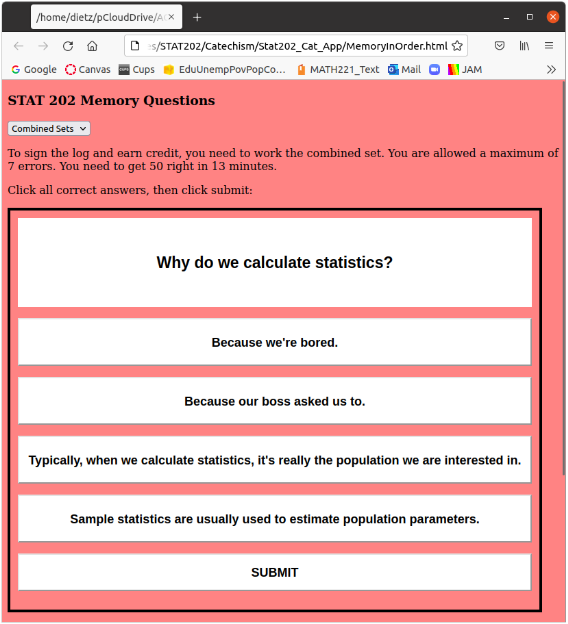
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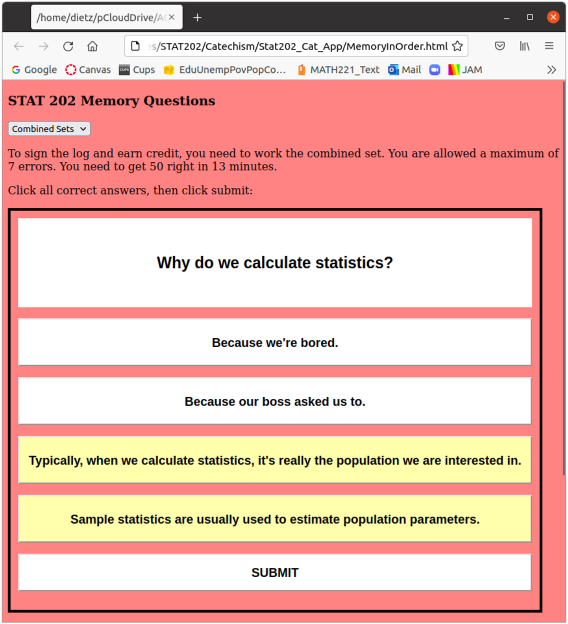
Click all correct answers, then click submit:
Why do we calculate statistics?
Because we're bored.
Because our boss asked us to.
Typically, when we calculate statistics, it's really the population we are interested in.
Sample statistics are usually used to estimate population parameters.
SUBMIT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Why use biased estimations at all?

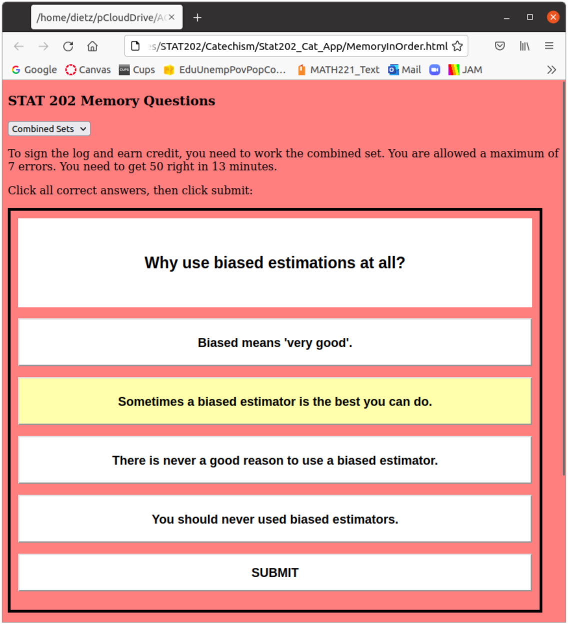
Biased means 'very good'.

Sometimes a biased estimator is the best you can do.

There is never a good reason to use a biased estimator.

You should never used biased estimators.

SUBMIT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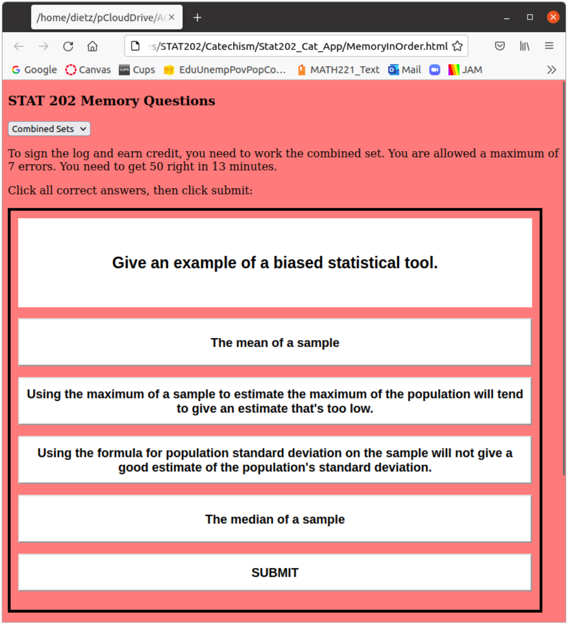
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Give an example of a biased statistical tool.
The mean of a sample
Using the maximum of a sample to estimate the maximum of the population will tend to give an estimate that's too low.
Using the formula for population standard deviation on the sample will not give a good estimate of the population's standard deviation.
The median of a sample
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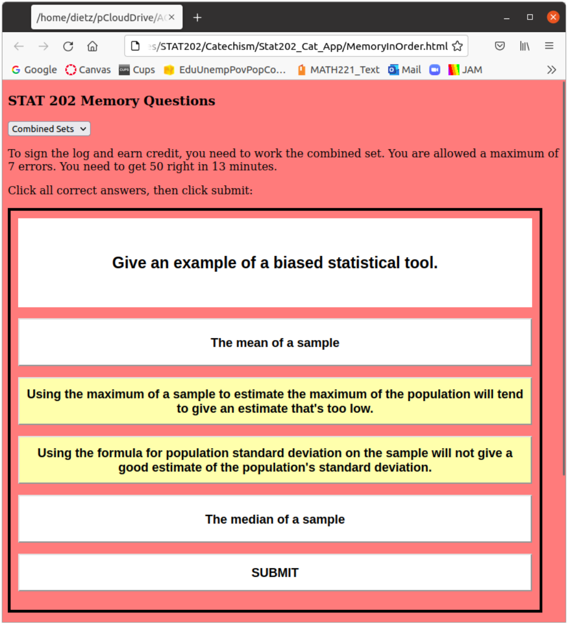
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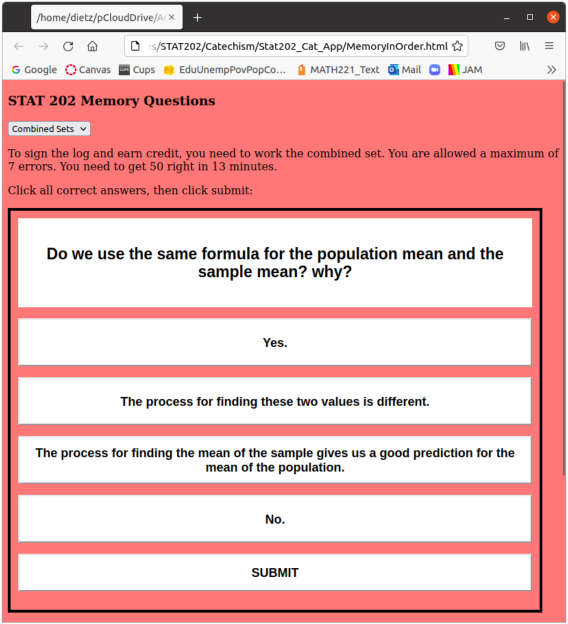
STAT 202 Memory Questions
Combined Sets
To sign the log and earn credit, you need to work the combined set. You are allowed a maximum of 7 errors. You need to get 50 right in 13 minutes.
Click all correct answers, then click submit:
Give an example of a biased statistical tool.
The mean of a sample
Using the maximum of a sample to estimate the maximum of the population will tend to give an estimate that's too low.
Using the formula for population standard deviation on the sample will not give a good estimate of the population's standard deviation.
The median of a sample
SUBMIT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Click all correct answers, then click submit:
Do we use the same formula for the population mean and the sample mean? why?
Yes.
The process for finding these two values is different.
The process for finding the mean of the sample gives us a good prediction for the mean of the population.
No.
SUBMIT

STAT 202 Memory Questions

Combined Sets

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Click all correct answers, then click submit:

Do we use the same formula for the population mean and the sample mean? why?

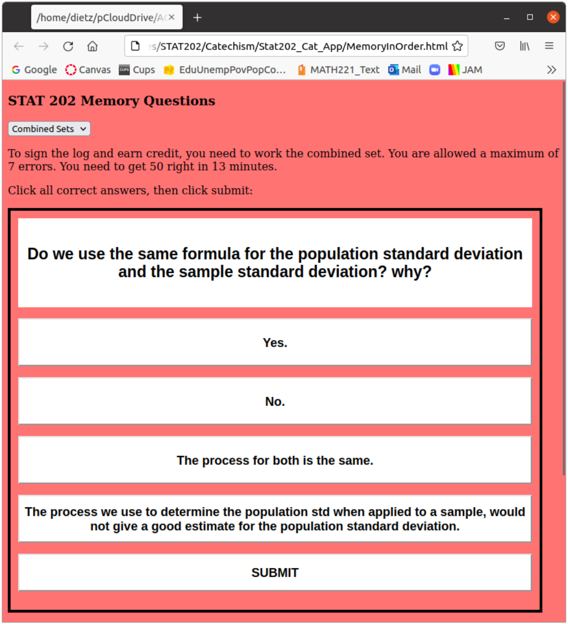
Yes.

The process for finding these two values is different.

The process for finding the mean of the sample gives us a good prediction for the mean of the population.

No.

SUBMIT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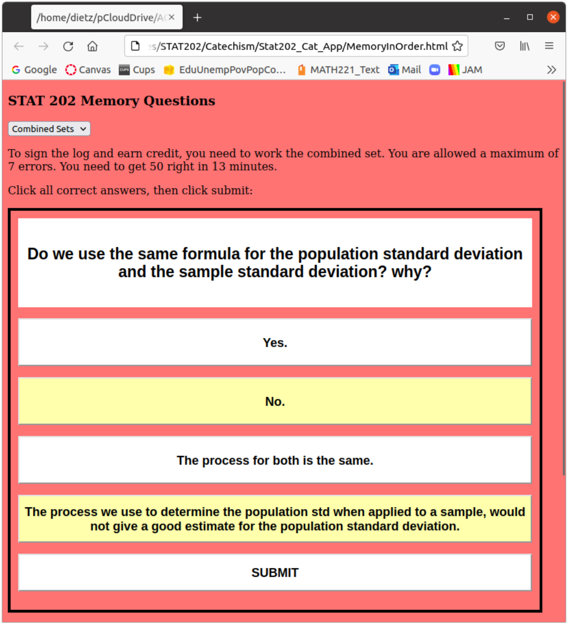
Click all correct answers, then click submit:
Do we use the same formula for the population standard deviation and the sample standard deviation? why?
Yes.
No.
The process for both is the same.
The process we use to determine the population std when applied to a sample, would not give a good estimate for the population standard deviation.
SUBMIT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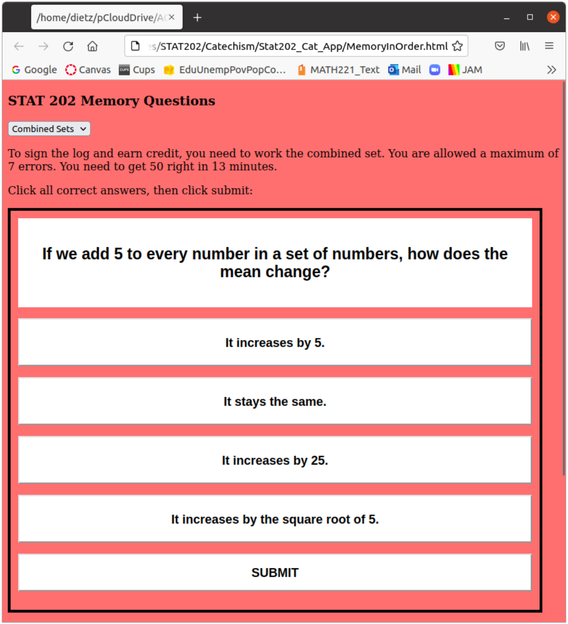
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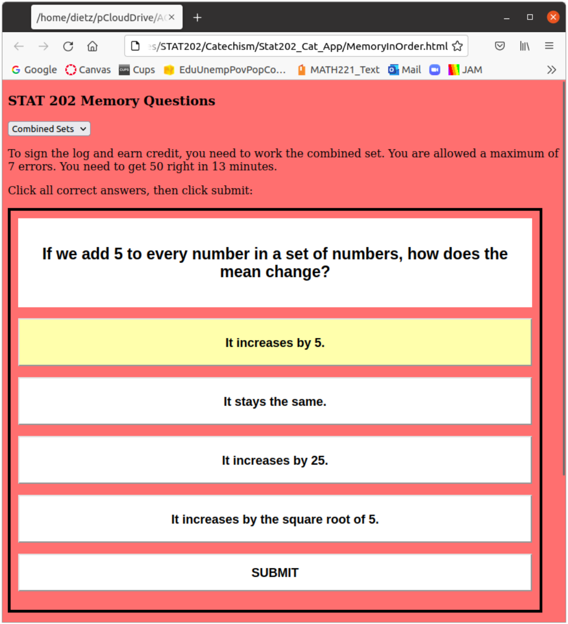
Click all correct answers, then click submit:
If we add 5 to every number in a set of numbers, how does the mean change?
It increases by 5.
It stays the same.
It increases by 25.
It increases by the square root of 5.
SUBMIT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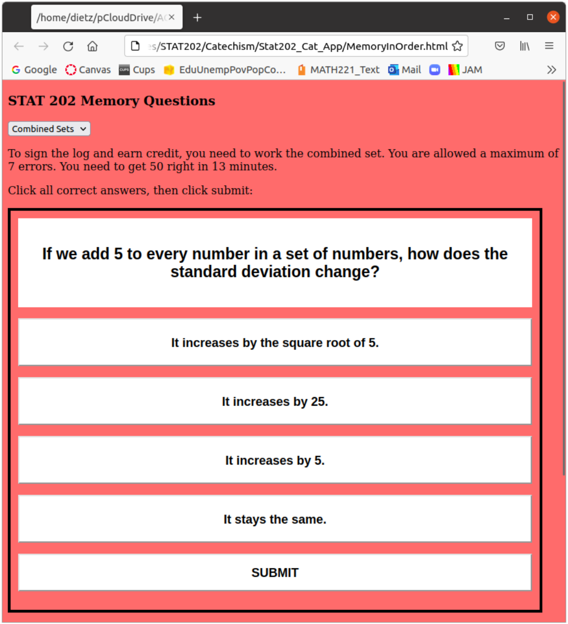
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If we add 5 to every number in a set of numbers, how does the standard deviation change?
It increases by the square root of 5.
It increases by 25.
It increases by 5.
It stays the same.
SUBMIT

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It increases by 25.

It increases by 5.

It stays the same.

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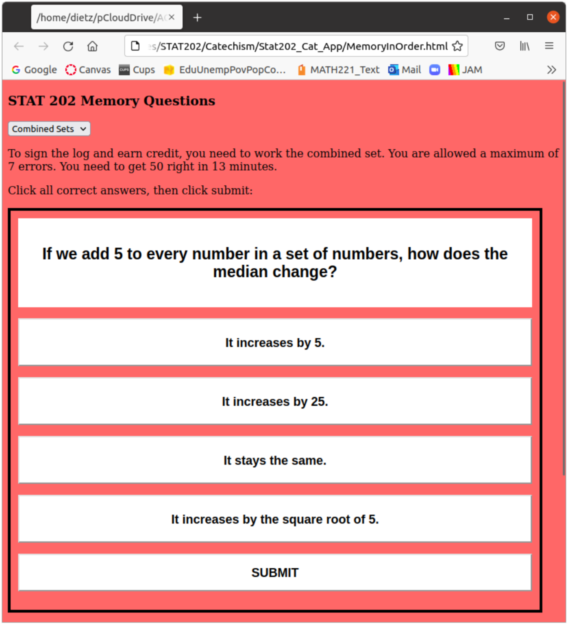
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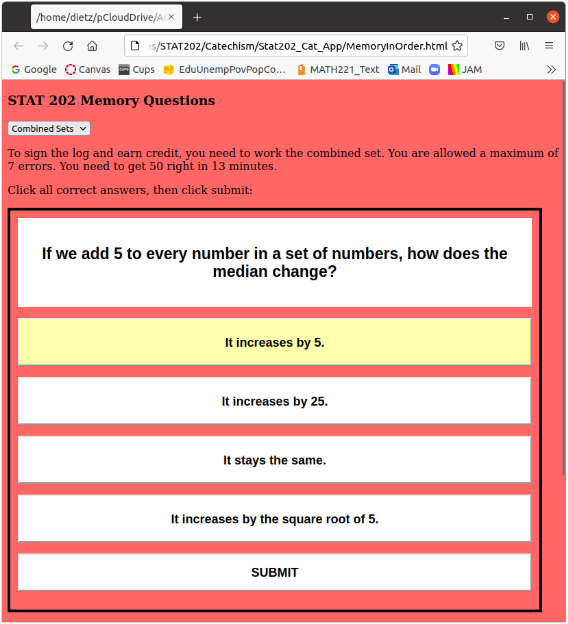
Click all correct answers, then click submit:
If we add 5 to every number in a set of numbers, how does the median change?
It increases by 5.
It increases by 25.
It stays the same.
It increases by the square root of 5.
SUBMIT



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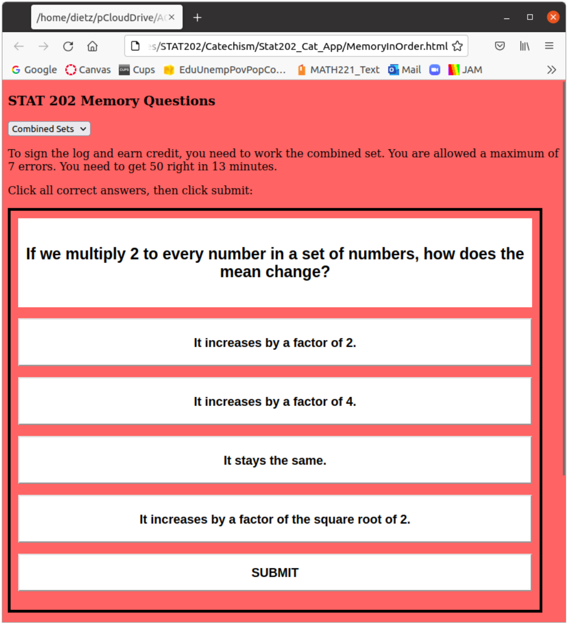
It increases by 5.

It increases by 25.

It stays the same.

It increases by the square root of 5.

SUBMIT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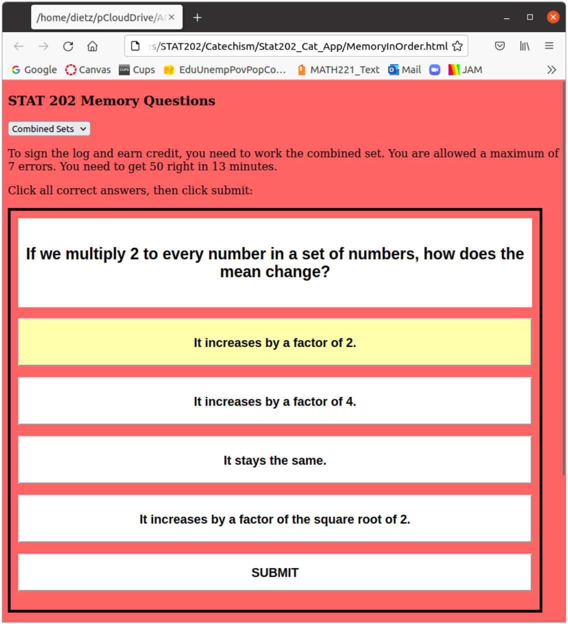
Click all correct answers, then click submit:
If we multiply 2 to every number in a set of numbers, how does the mean change?
It increases by a factor of 2.
It increases by a factor of 4.
It stays the same.
It increases by a factor of the square root of 2.
SUBMIT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It increases by a factor of 4.
It stays the same.
It increases by a factor of the square root of 2.
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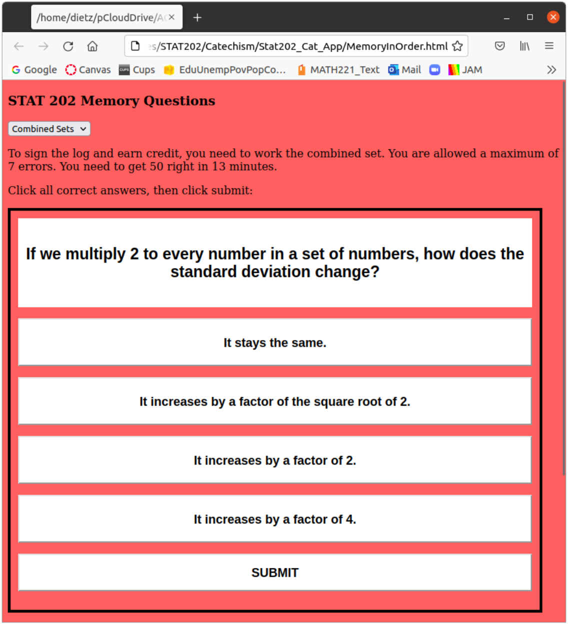
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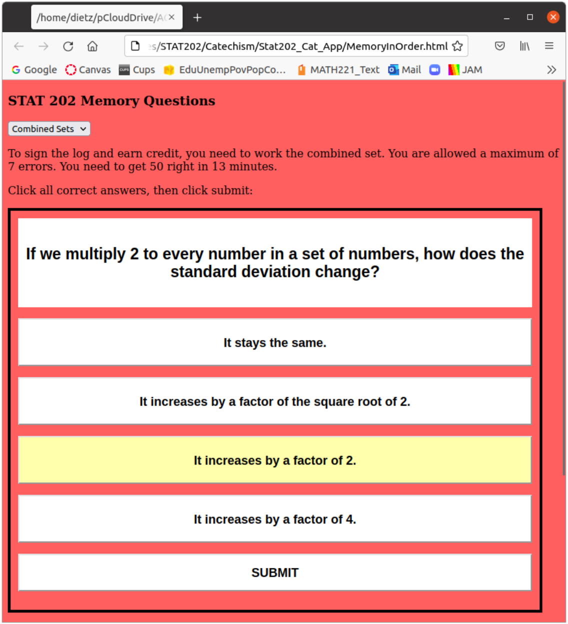
Click all correct answers, then click submit:
If we multiply 2 to every number in a set of numbers, how does the standard deviation change?
It stays the same.
It increases by a factor of the square root of 2.
It increases by a factor of 2.
It increases by a factor of 4.
SUBMIT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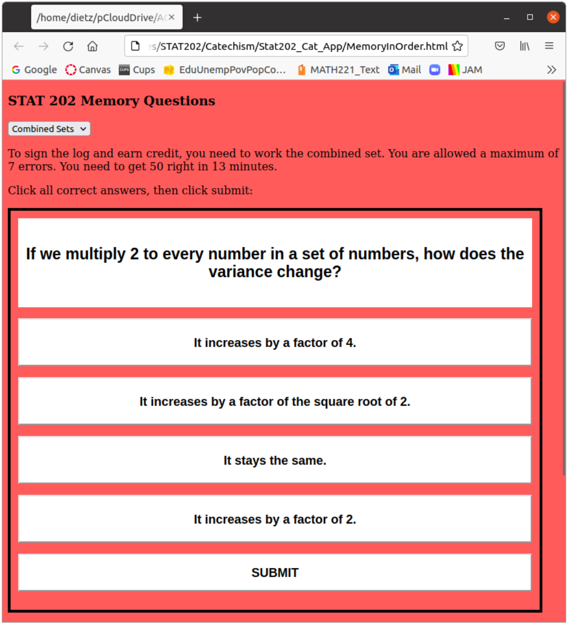
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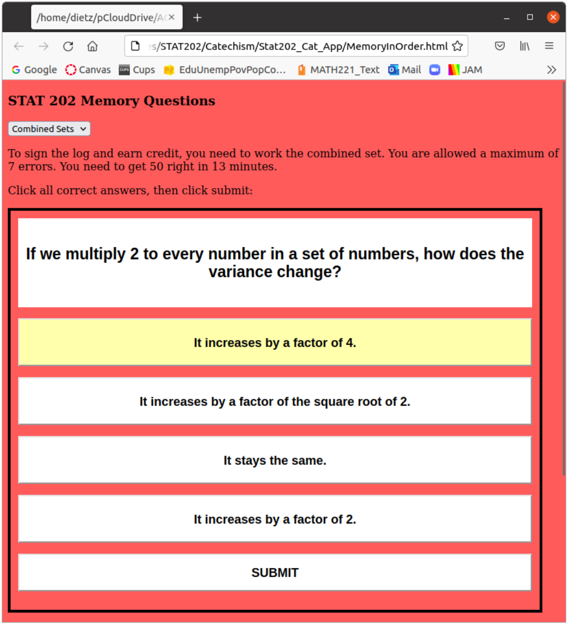
Click all correct answers, then click submit:
If we multiply 2 to every number in a set of numbers, how does the variance change?
It increases by a factor of 4.
It increases by a factor of the square root of 2.
It stays the same.
It increases by a factor of 2.
SUBMIT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If we multiply 2 to every number in a set of numbers, how does the variance change?
It increases by a factor of 4.
It increases by a factor of the square root of 2.
It stays the same.
It increases by a factor of 2.
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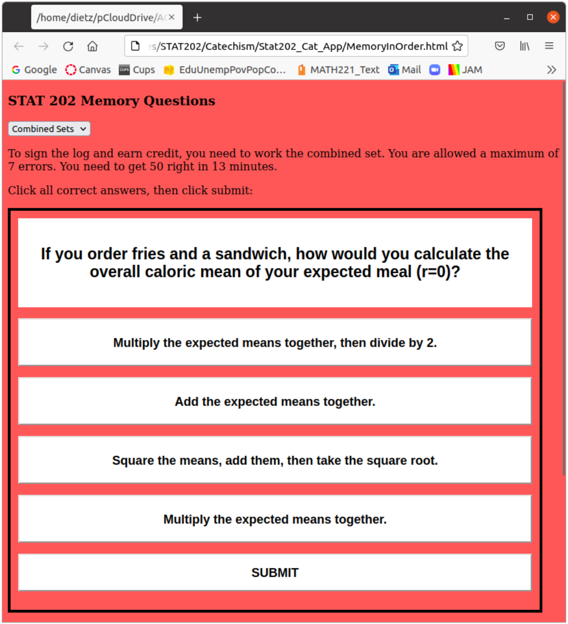
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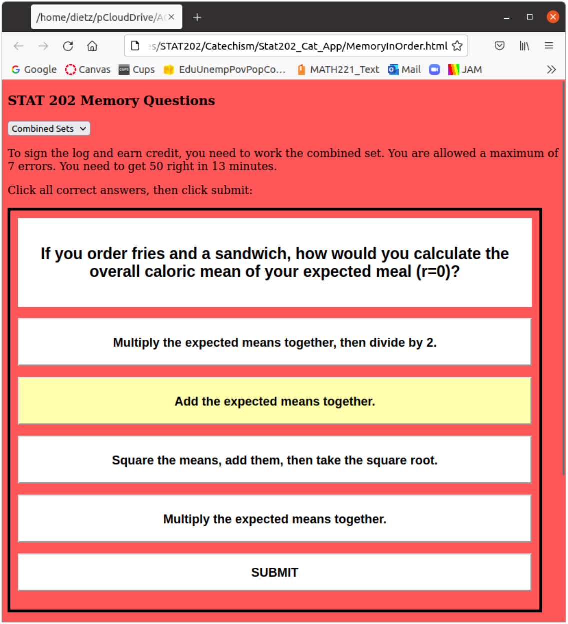
Combined Sets
To sign the log and earn credit, you need to work the combined set. You are allowed a maximum of 7 errors. You need to get 50 right in 13 minutes.
Click all correct answers, then click submit:
If you order fries and a sandwich, how would you calculate the overall caloric mean of your expected meal (r=0)?
Multiply the expected means together, then divide by 2.
Add the expected means together.
Square the means, add them, then take the square root.
Multiply the expected means together.
SUBMIT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Add the expected means together.
Square the means, add them, then take the square root.
Multiply the expected means together.
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Click all correct answers, then click submit:

If you order fries and a sandwich, how would you calculate the overall caloric variance of your expected meal (r=0)?

Add the expected variances together.

Square the variances, add them, then take the square root.

Multiply the variances together.

Multiply the expected variances together, then take the square root.

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Add the expected variances together.

Square the variances, add them, then take the square root.

Multiply the variances together.

Multiply the expected variances together, then take the square root.

SUBMIT

STAT 202 Memory Questions

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Click all correct answers, then click submit:

If you order fries and a sandwich, how would you calculate the overall caloric standard deviation of your expected meal (r=0)?

Multiply the standard deviations together.

Take the square root of the expected variance.

Add the standard deviations together.

Take the average of the standard deviations.

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Take the average of the standard deviations.

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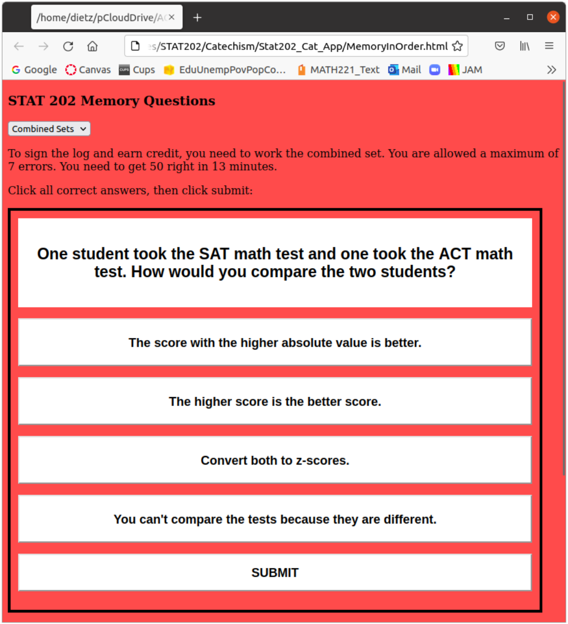
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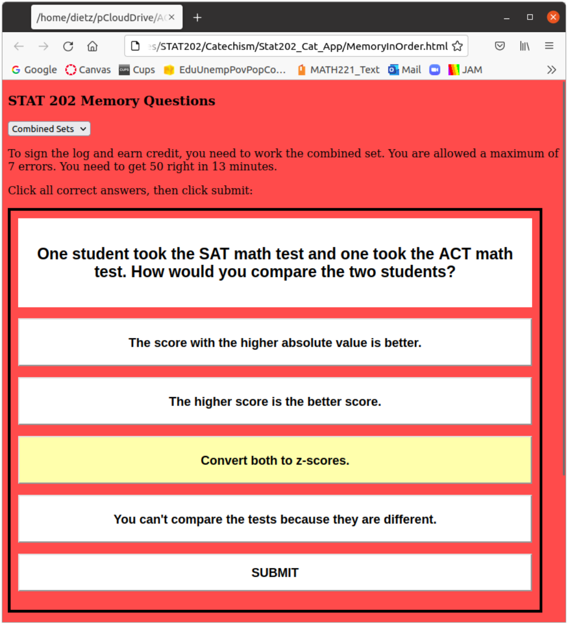
Click all correct answers, then click submit:
One student took the SAT math test and one took the ACT math test. How would you compare the two students?
The score with the higher absolute value is better.
The higher score is the better score.
Convert both to z-scores.
You can't compare the tests because they are different.
SUBMIT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The higher score is the better score.
Convert both to z-scores.
You can't compare the tests because they are different.
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