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A Brief Overview of

P-Values

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Lecture prepared for

"Open Science in Social Sciences"

BA Blockseminar

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The data and code to generate the figures in this lecture are available at

https://github.com/nbreznau/p_values

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What is a p-value?

- *Almost always*: A statistical test result used to evaluate the **null hypothesis**

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What is a p-value?

- *Almost always*: A statistical test result used to evaluate the **null hypothesis**
  - Can be used to evaluate any hypothesis test (must not be null)
  - Short for **“probability”-value**
  - A test to determine if statistics calculated for a given dataset are likely *different* from some hypothesized value
  - “different” = based on sampling probability
- ‘what is the likelihood of observing this statistic if the hypothesized value is true’

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What is a null hypothesis?

- The claim that something measured in the world is equal to zero
  - For example:
  - That a vaccine has zero impact on infection rates (a controlled experiment)
  - That the average height difference of boys and girls at age 5 is zero (population observation)
  - That there is zero difference in intelligence between immigrants and natives (population observation)
  - That income has zero effect on happiness after adjusting for religious beliefs (population observation, w/ adjustment)

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What is a p-value?

- A statistical test result used to evaluate the **null hypothesis**
- It is based entirely on **probability**

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- A statistical test result used to evaluate the **null hypothesis**
- It is based entirely on **probability**
- It is the **probability of observing the data** assuming the null hypothesis is correct

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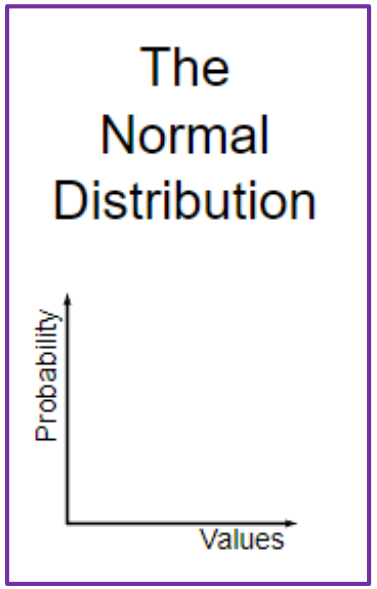
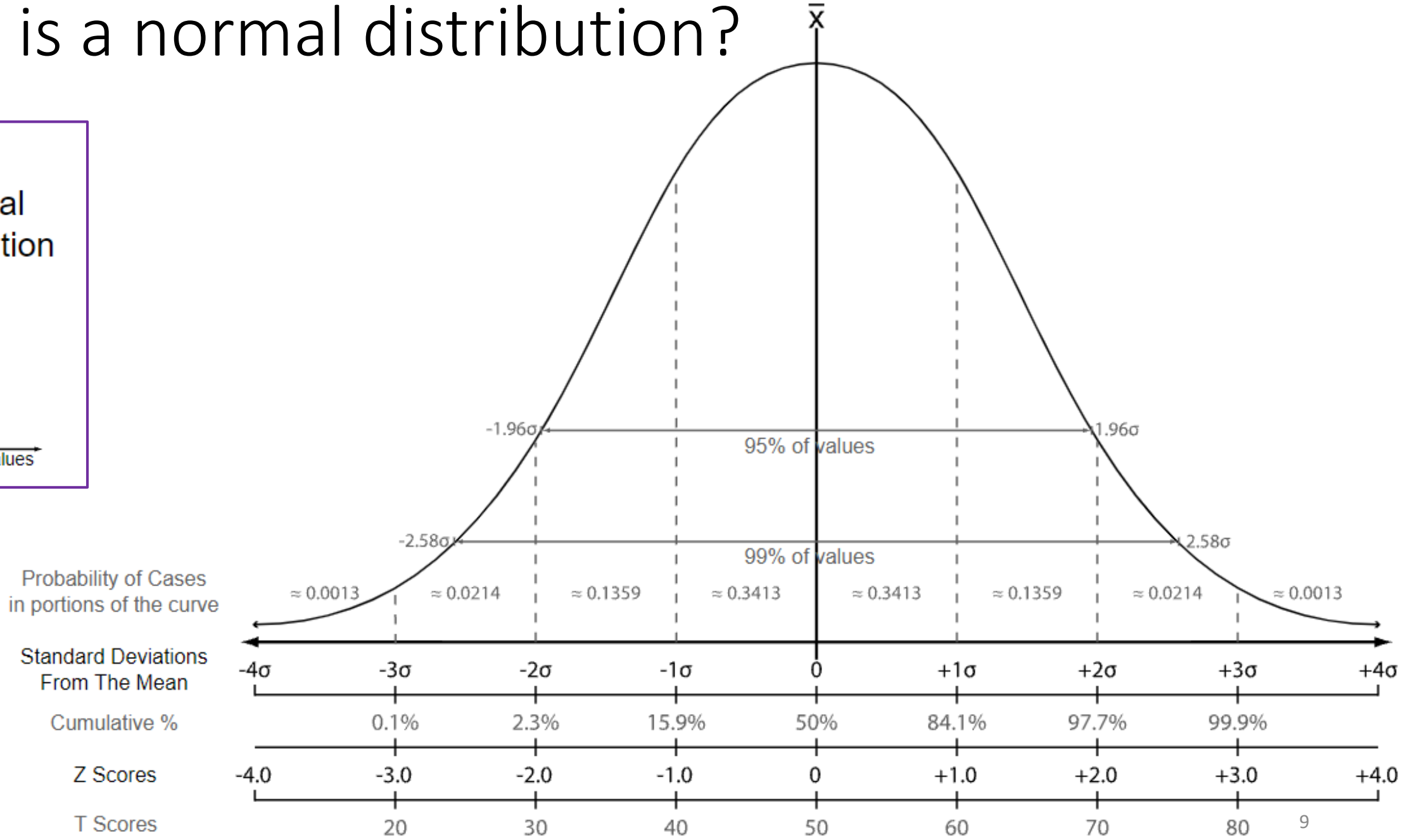
What is a p-value?

- A statistical test result used to evaluate the **null hypothesis**
- It is based entirely on **probability**
- It is the **probability of observing the data** assuming the null hypothesis is correct
  - Assumes that the data were randomly sampled from a population
  - Assumes that the test is properly modeled (e.g., improper: testing if getting sick or not makes one more likely to get a vaccine)
  - Assumes a **normal distribution** of observing the null hypothesis if it were true

What is a normal distribution?





Credit:
Heds 1

What is a p-value?

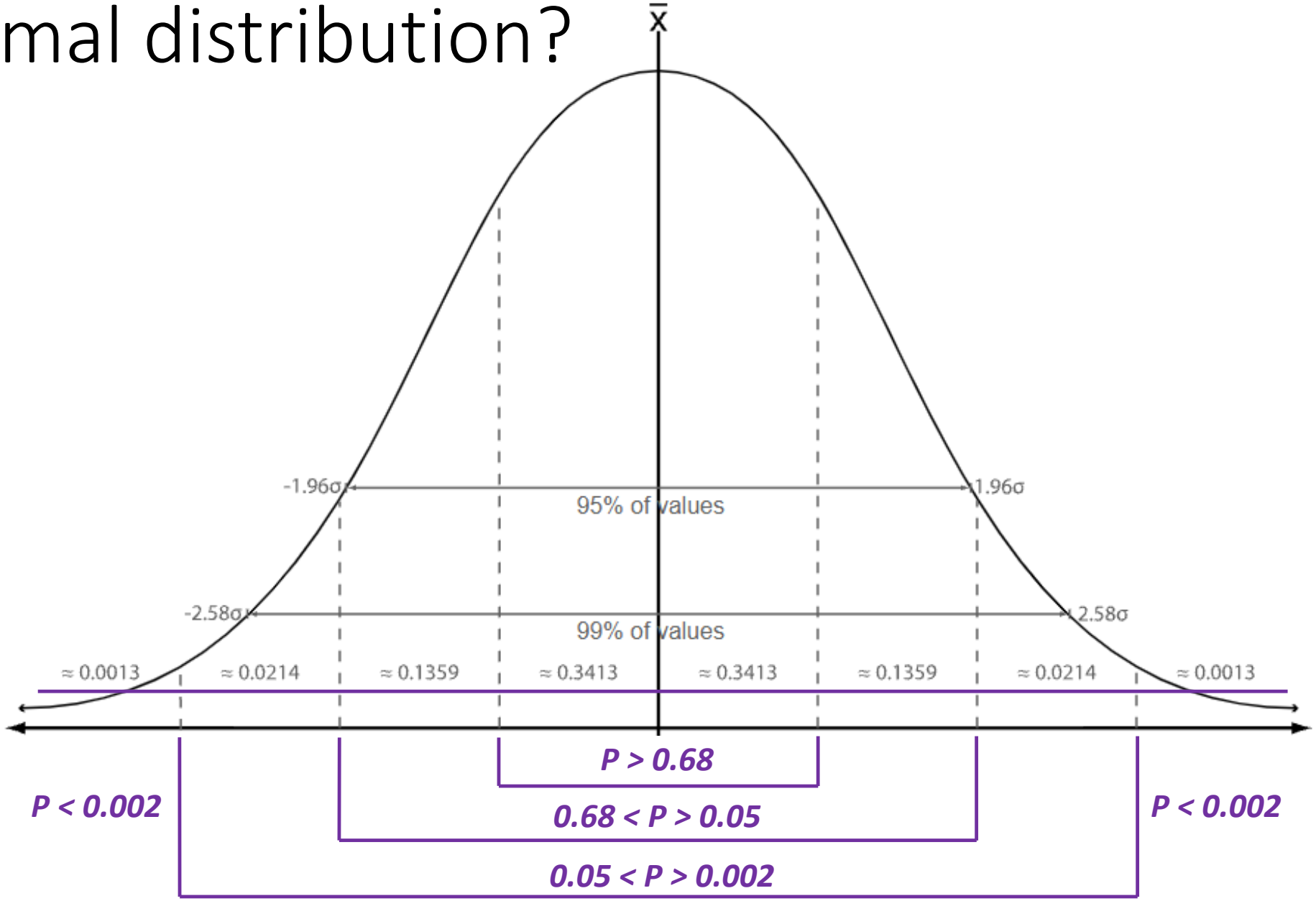
- A statistical test result used to evaluate the **null hypothesis**
- It is based entirely on **probability**
- It is the **probability of observing the data** assuming [illegible] hypothesis is correct
  - Assumes that the data were randomly sampled from a popu[illegible]n
  - Assumes that the test is properly modeled (e.g., improper: testing if getting sick or not makes one more likely to get a vaccine)
  - Assumes a **normal distribution** of observing the null hypothesis if it were true

Also known as "**NHST**" (Null Hypothesis Significance Testing)

What is a normal distribution?

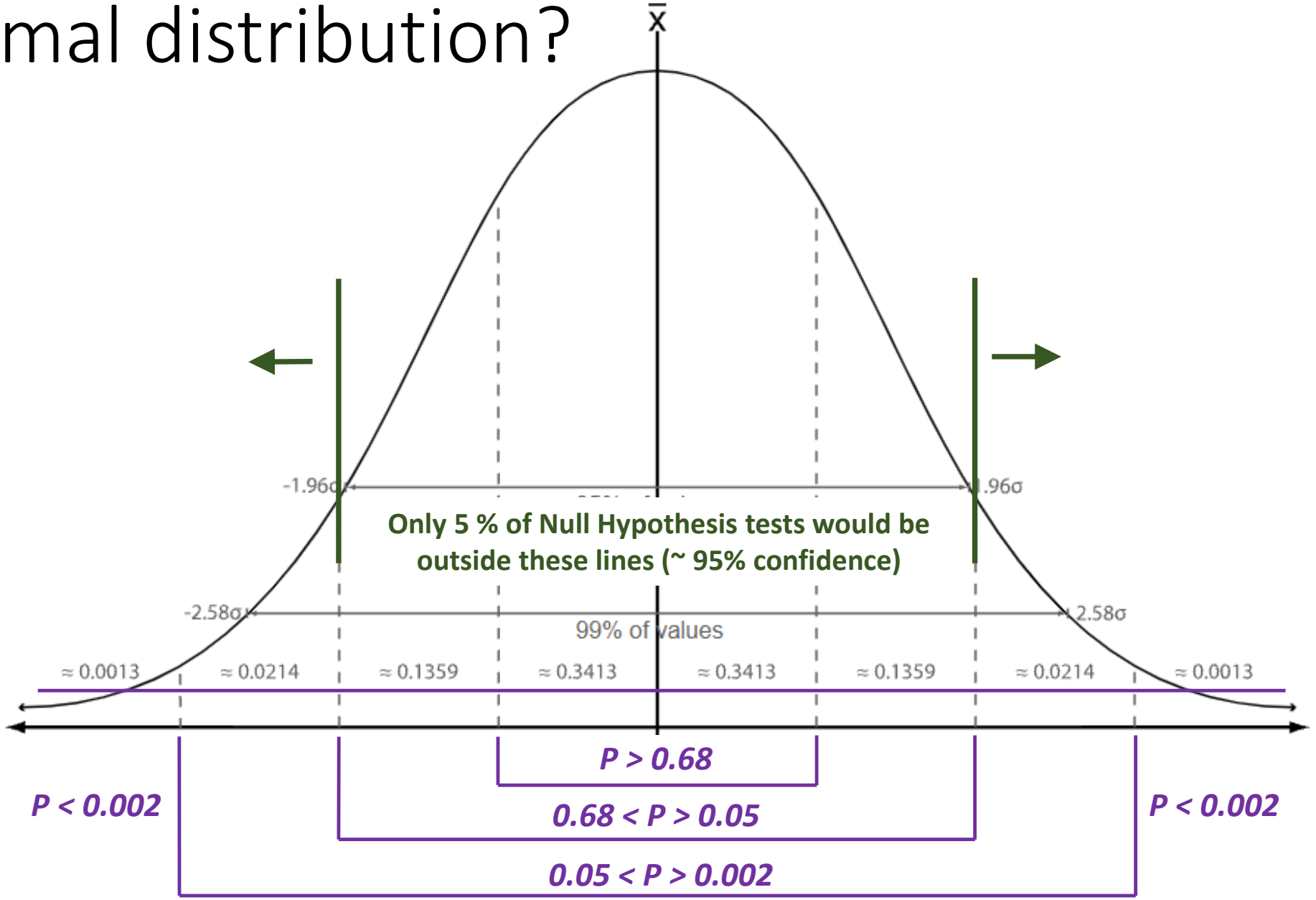
P-Values
(if all assumptions are true)

Probability of Cases in portions of the curve



What is a normal distribution?

P-Values
(if all assumptions are true)



Probability of Cases in portions of the curve

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Example 1. NHST – Comparing Means

Comparing means

- Experiment (randomized controlled trial)
  - Zero difference in infection rates between vaccine and placebo groups
  - Zero difference in employer call-back rates for job candidates with ethnic versus native surnames
- Experiment (intervention)
  - Zero difference between adolescent test scores between schools with the introduction of different teaching techniques

Example 1. NHST – Comparing Means

Comparing means

- Experiment (randomized controlled trial)
  - Zero difference in infection rates between vaccine and placebo groups
  - Zero difference in employer call-back rates for job candidates with ethnic versus native surnames
- Experiment (intervention)
  - Zero difference between adolescent test scores between schools with the introduction of different teaching techniques
- Demographic/population properties (non-experimental)
  - Zero difference between height of girls and boys at age five
  - **Zero difference between happiness between those with high incomes and those with low incomes**

Can Money Buy Happiness?

Example 1. NHST – Comparing Means

How would you test this?

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Example 1. NHST – Comparing Means

One idea:

- Sample from the populations of different countries
- Ask questions about happiness and income
- Compare the average happiness of those with high to those with low incomes

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Example 1. NHST – Comparing Means

World Values Survey

- Up to 80 countries
- 1985-2021 (7 waves)
- Basis for studies of societal values and change
- Roughly 1,000 or more respondents per country

Haerpfer, C., Inglehart, R., Moreno, A., Welzel, C., Kizilova, K., Diez-Medrano J., M. Lagos, P. Norris, E. Ponarin & B. Puranen et al. (eds.). 2020. World Values Survey: Round Seven - Country-Pooled Datafile. Madrid, Spain & Vienna, Austria: JD Systems Institute & WVSA Secretariat. doi.org/10.14281/18241.13

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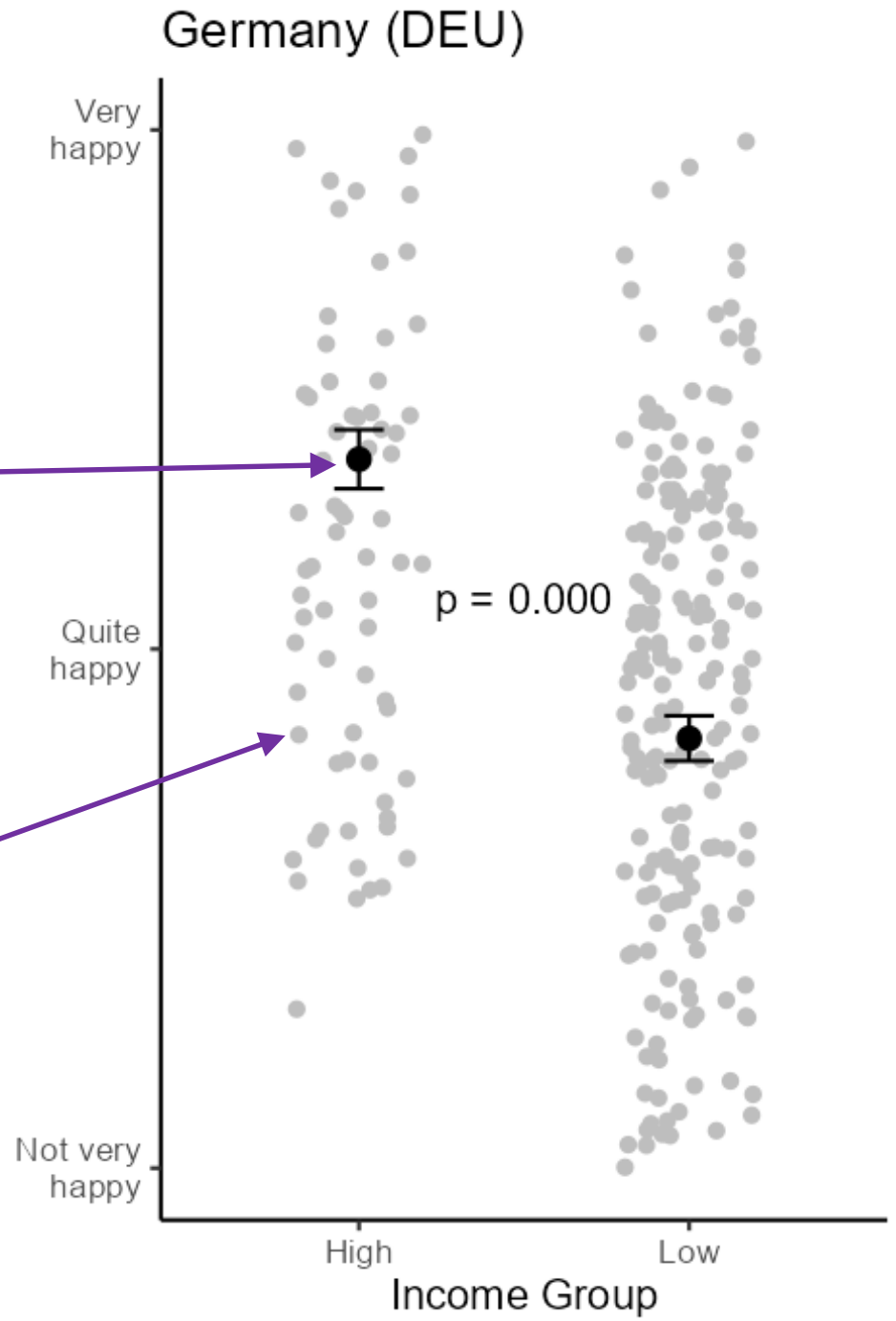
Group average or mean

Individual survey respondent (data point)



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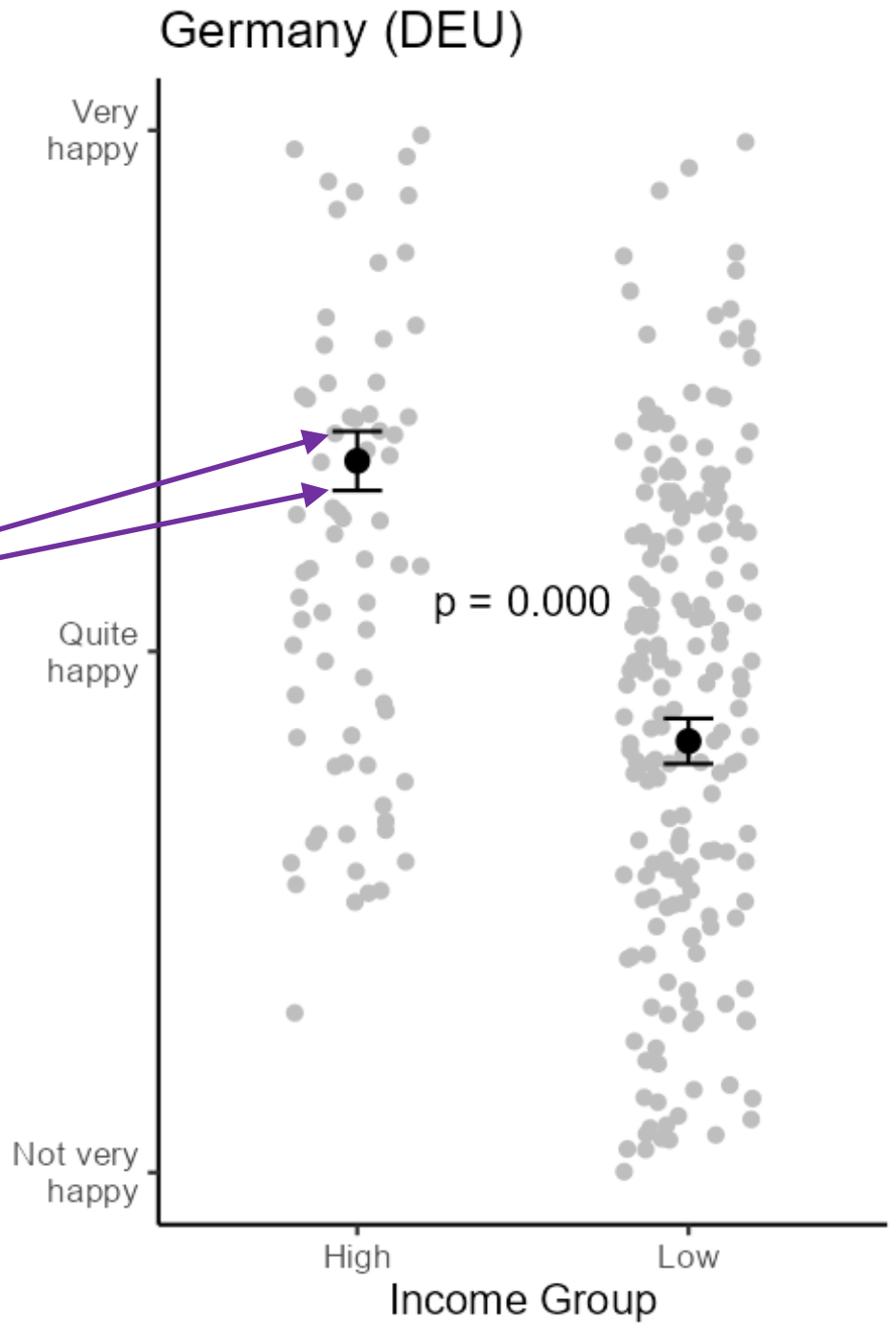
Standard error
=
Standard deviation / square root of sample size



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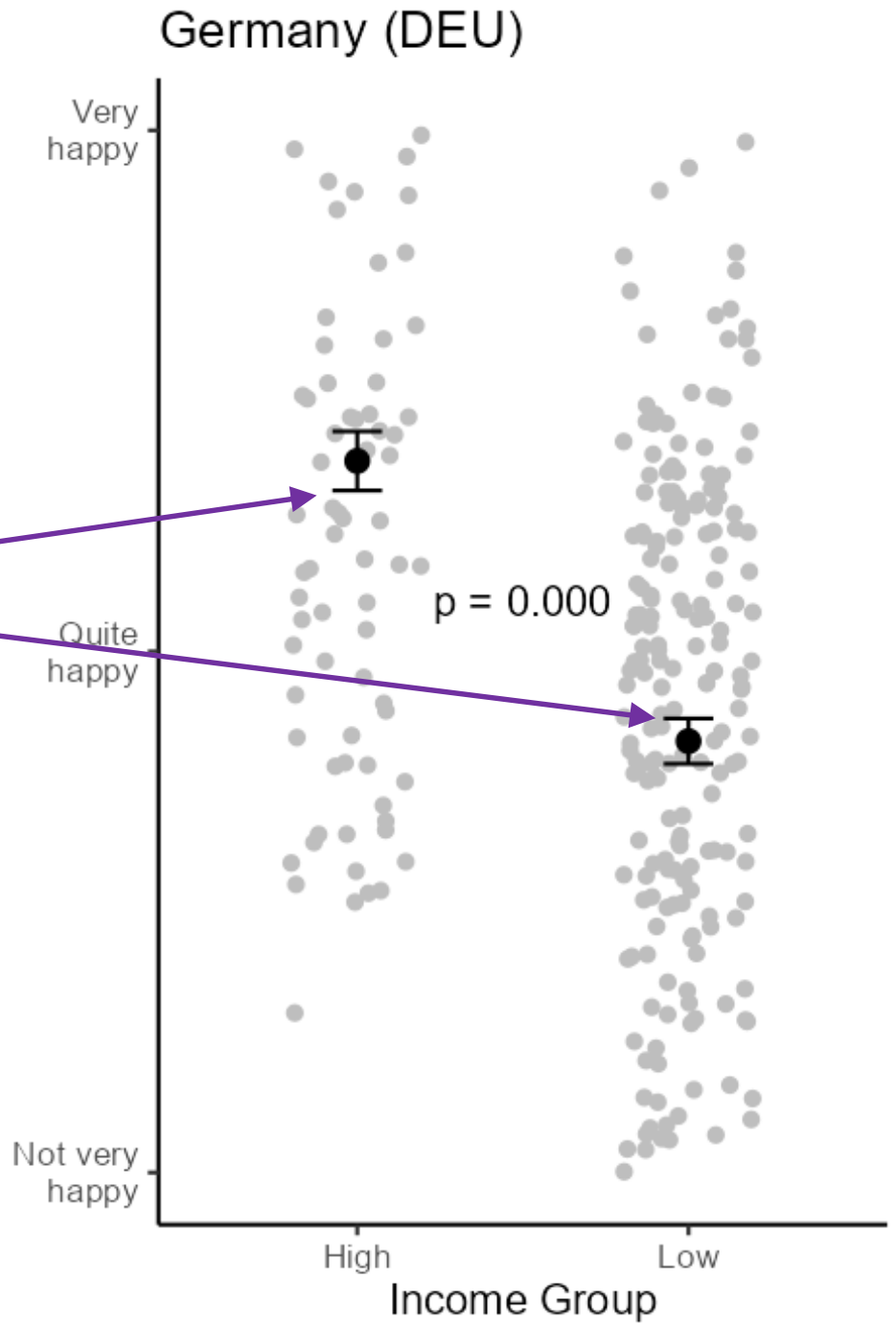
We can see this based on the standard error bars, they do not overlap



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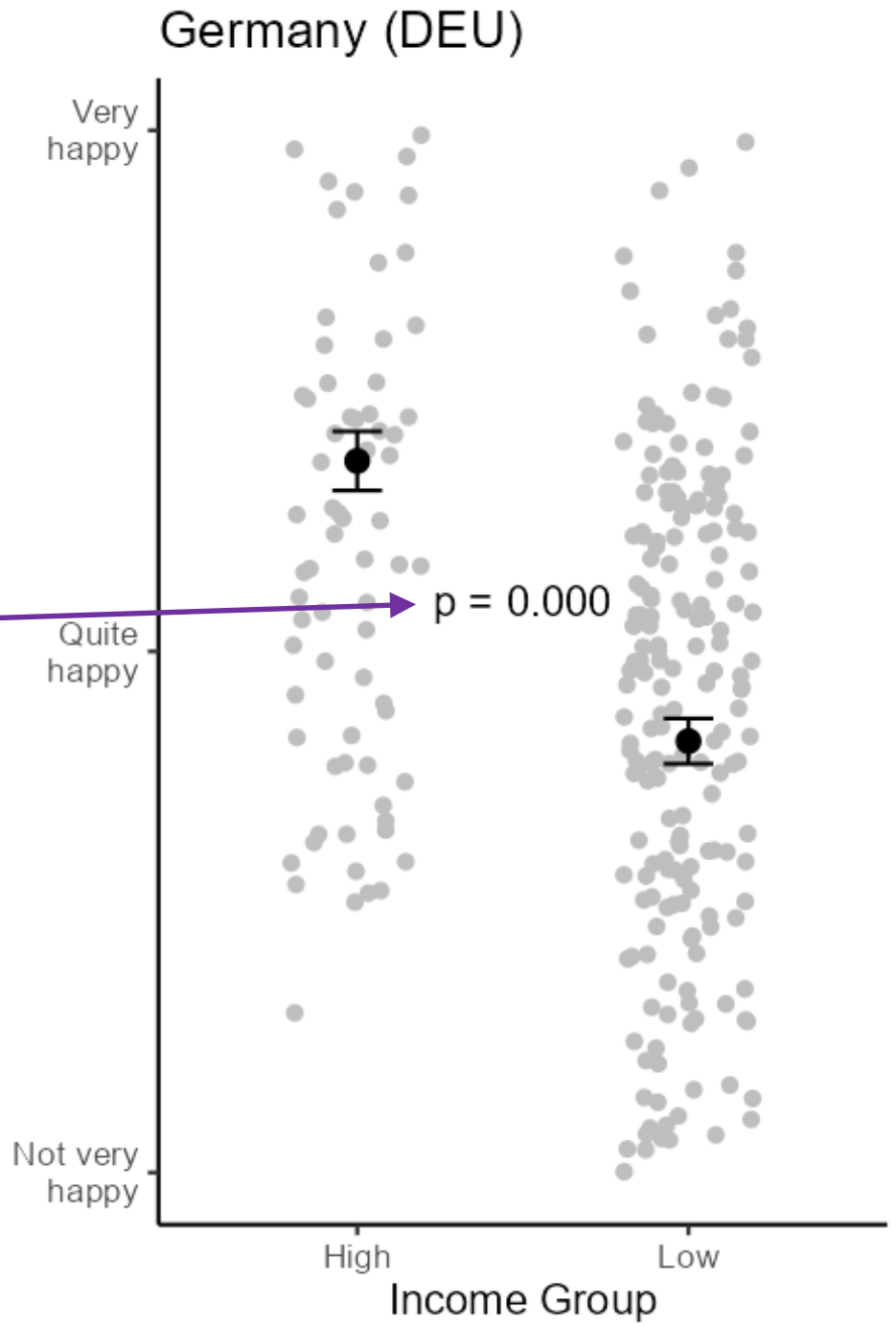
NHST that the difference in happiness between high and low income groups is zero



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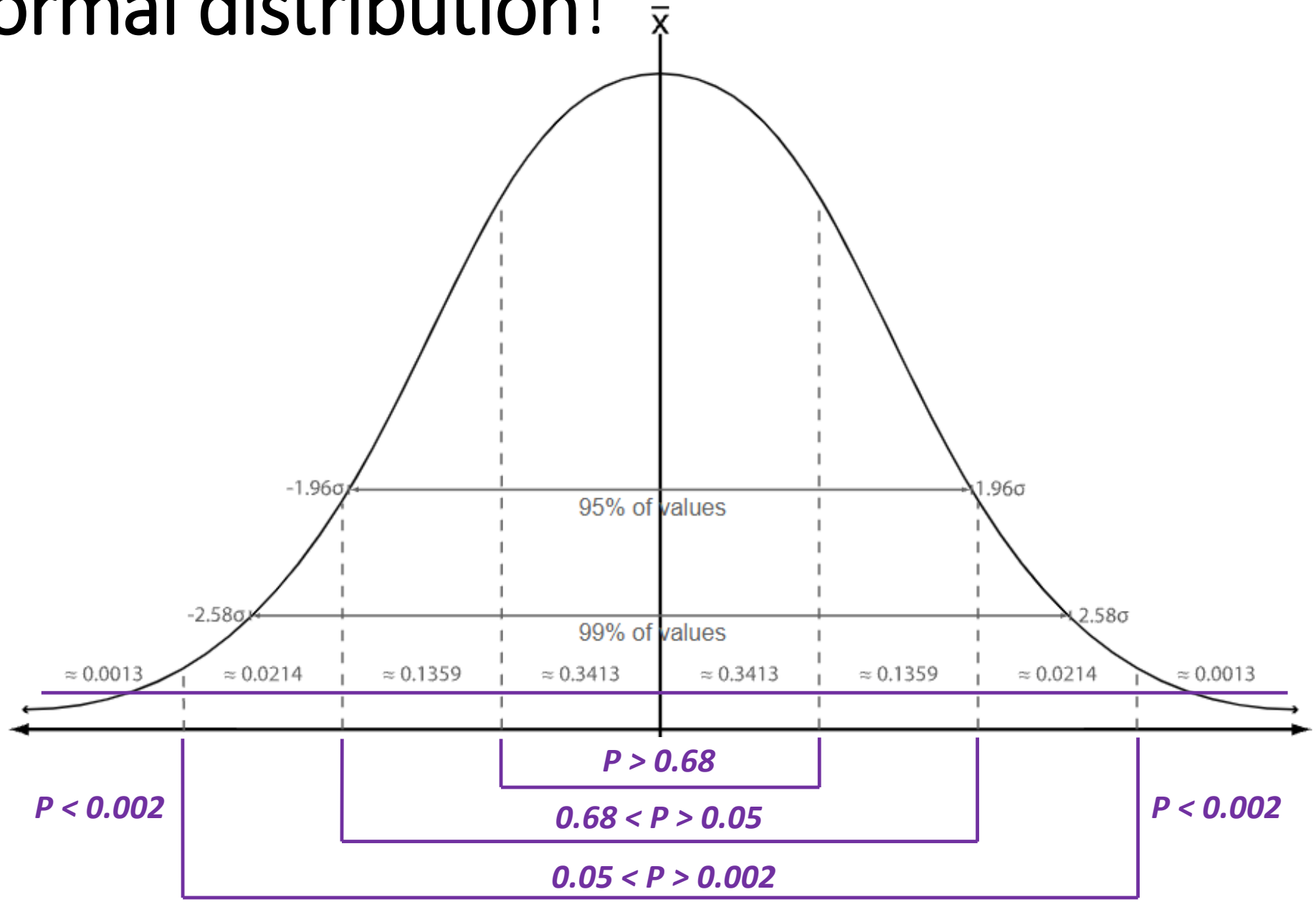
Remember, **normal distribution**!

P-Values
(if all assumptions are true)



Probability of Cases in portions of the curve

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Example 1. NHST – Comparing Means

Group Task

1) Look at different country comparisons in the folder "…results/means_p" at https://github.com/nbreznau/p_values

2) Select two countries to compare, save the two figures on a slide or document

3) Be prepared to meaning of the p-values for each country

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Example 2. NHST – Linear Association

- Compare income and happiness as **continuous** measures.
- WVS has an 8-category income scale (quasi-continuous)
- WVS asks ‘how happy are you’ and ‘how satisfied are you with your life’. Using these two questions we can construct a **scale**.

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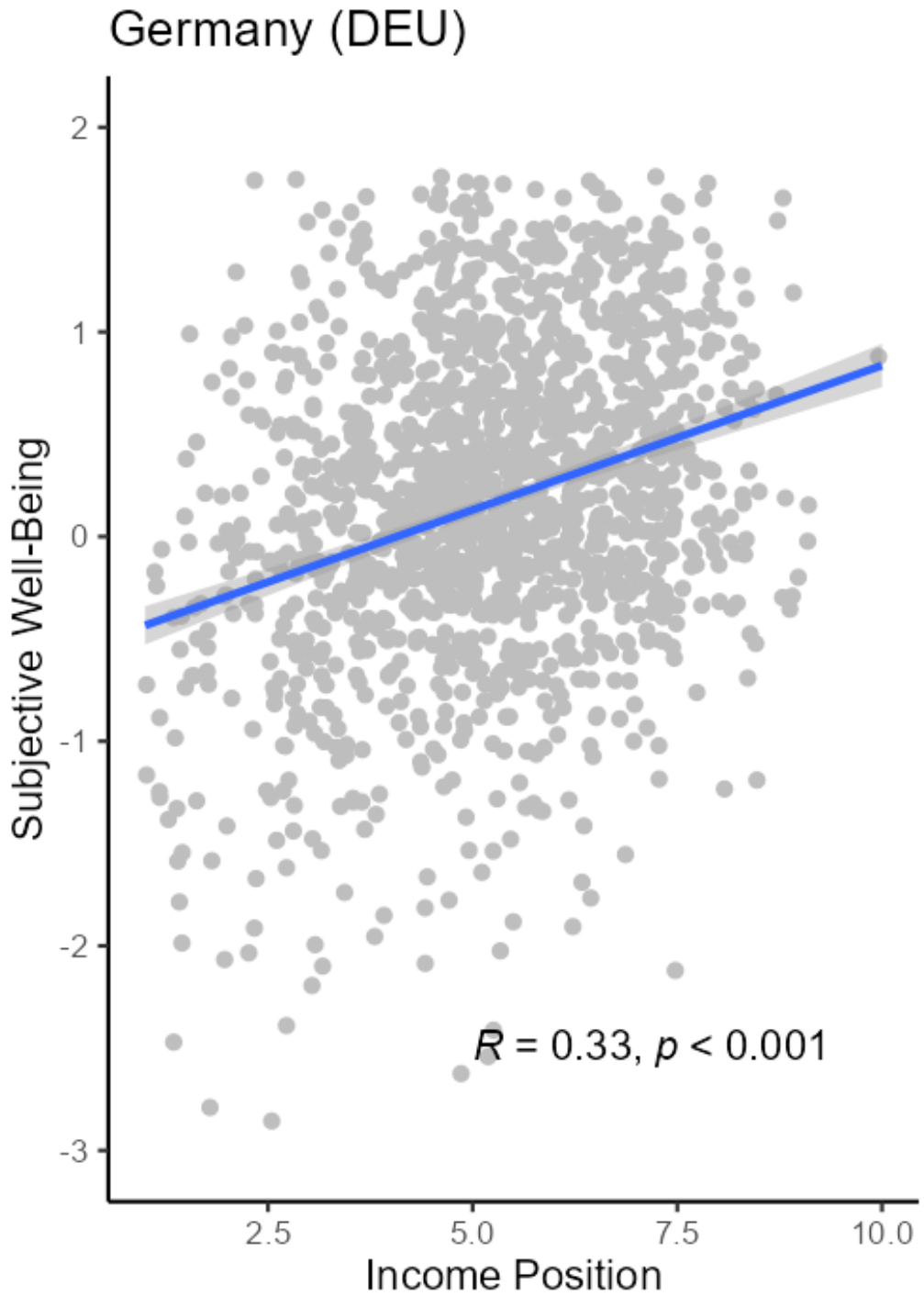
Example 2. NHST – Linear Association



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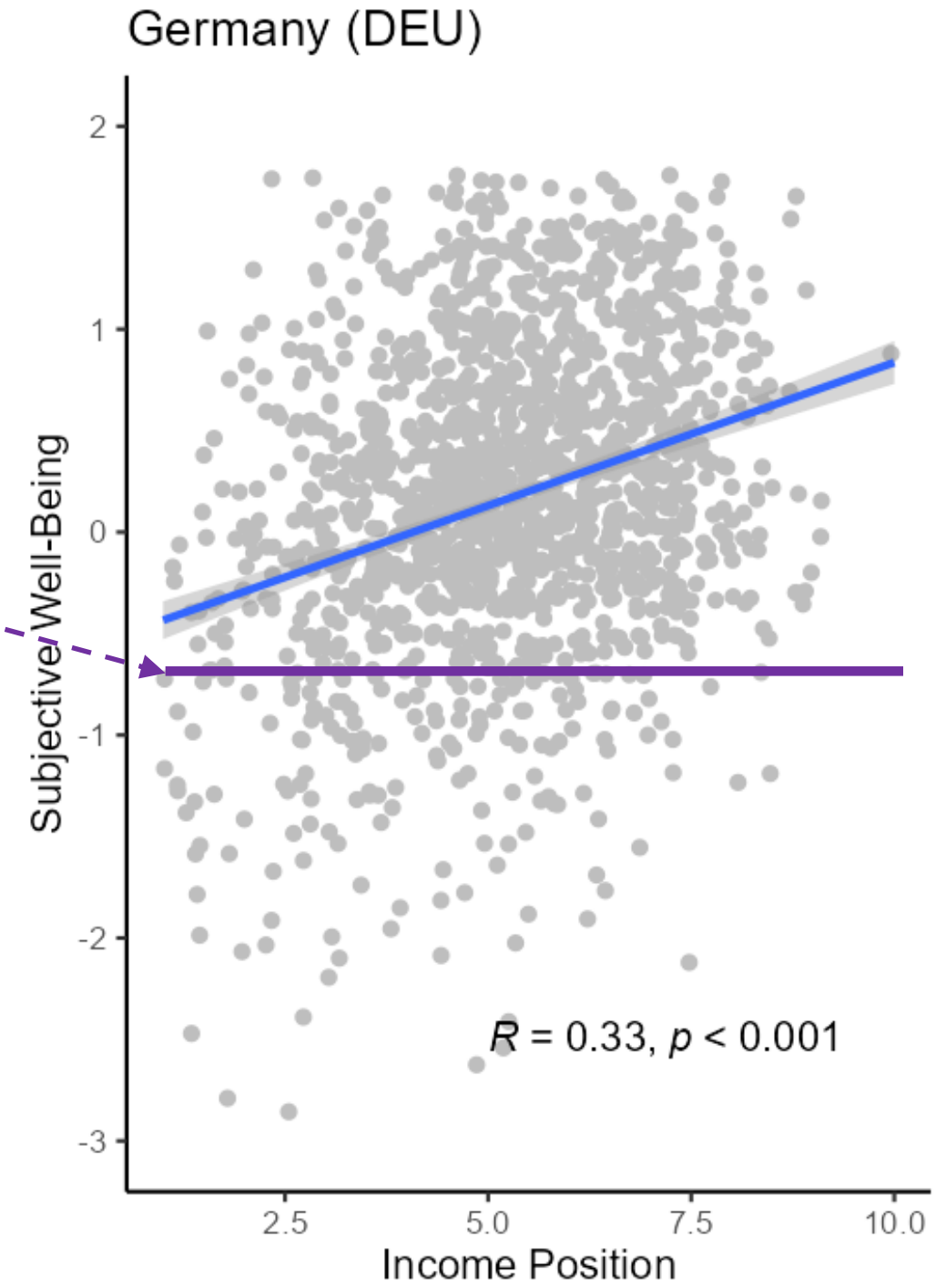
Example 2. NHST – Linear Association

NHST is that the line of best fit has a slope of **zero**



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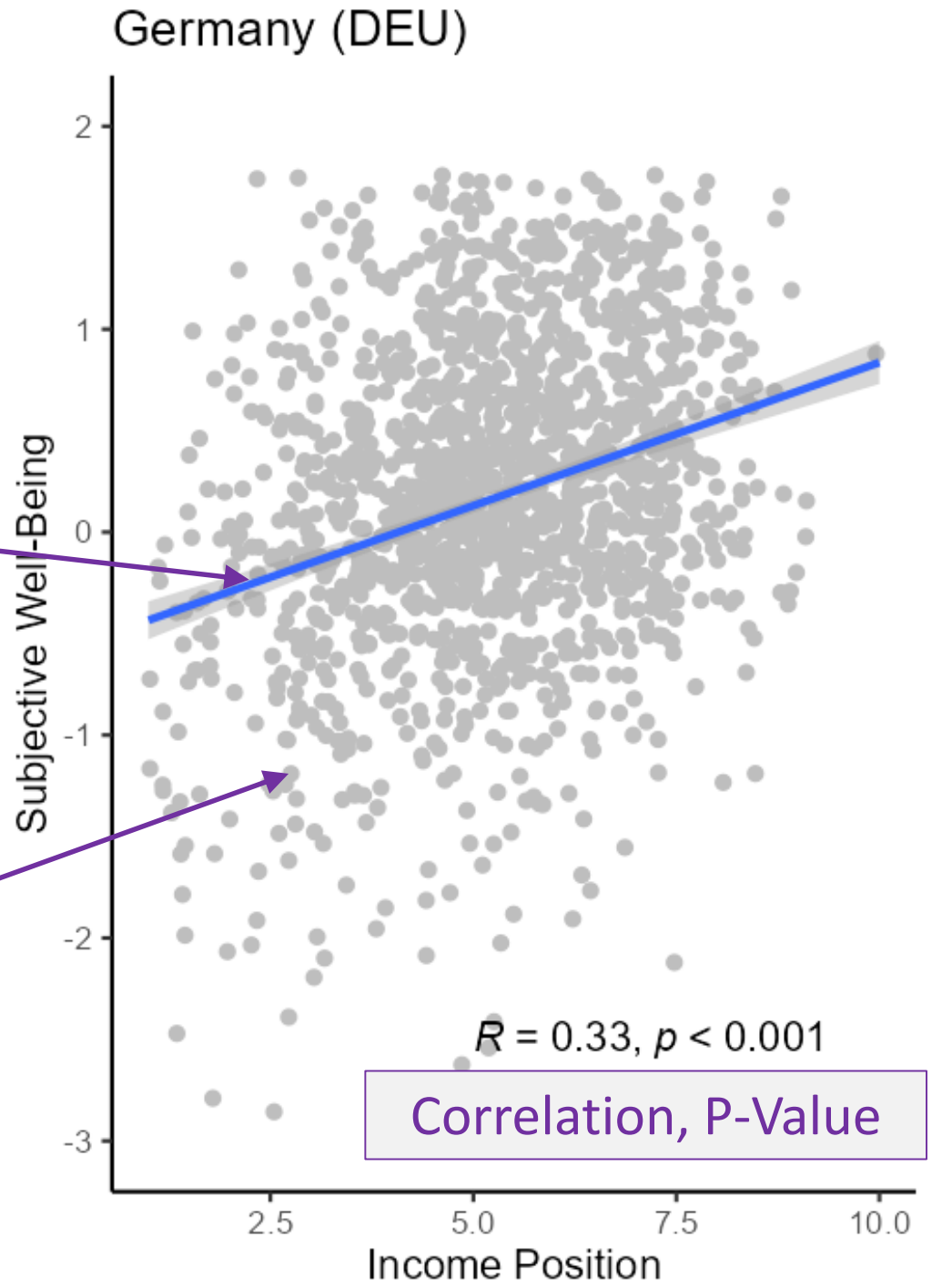
Example 2. NHST – Linear Association

Line of best fit
(minimizes sum of squared error)

Individual survey respondent (data point)



Correlation, P-Value

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Example 2. NHST – Linear Association, adjusted

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- Sometimes we want to adjust for other variables that might explain a linear association.
- With the *income-happiness association* for example, maybe people who are higher educated are happier, or people who have stronger religious beliefs.
- Other variables may explain a linear association better, or in part

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Example 2. NHST – Linear Association, adjusted

- Education* and well-being linear association.

*Note that ISCED is not intended as a linear measure, but we will use it that way for now just for the purposes of example (and we removed 9 for 'other').

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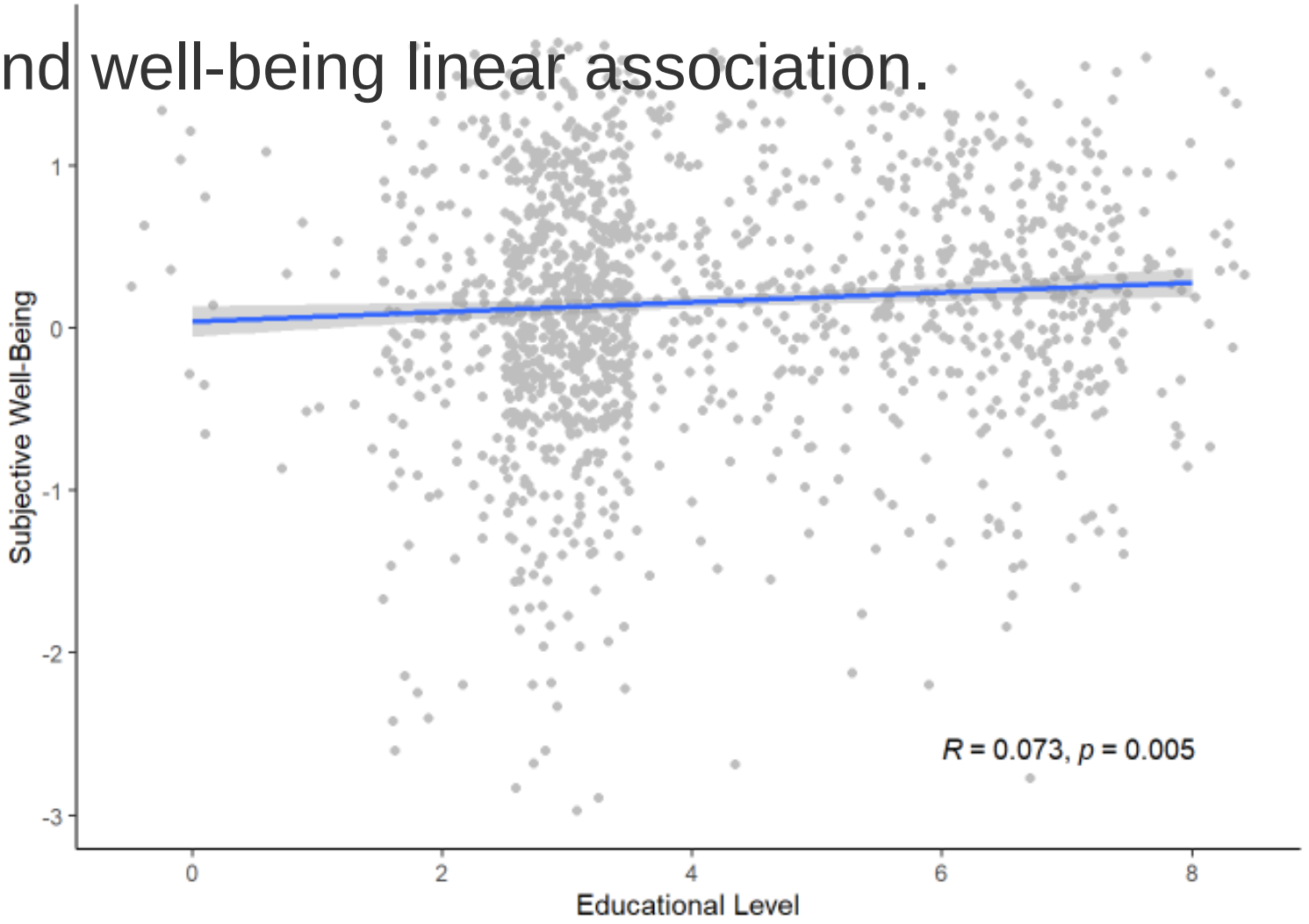
Example 2. NHST – Linear Association, adjusted

- Education* and well-being linear association.



*Note that ISCED is not intended as a linear measure, but we will use it that way for now just for the purposes of example (and we removed 9 for 'other').

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Example 3. NHST – Linear Association, adjusted

- One option is a **partial correlation**
- This procedure:
  - Compute residuals for x (dependent) ~ z (independent) model
  - Compute residuals for y (dependent) ~ z (independent) model
  - Compute correlation between the residuals

- In other words:

  A partial correlation is what remains of a linear association after removing the portion of that association that can be explained by a third variable

Does Education affect the *income-happiness* association in Germany?

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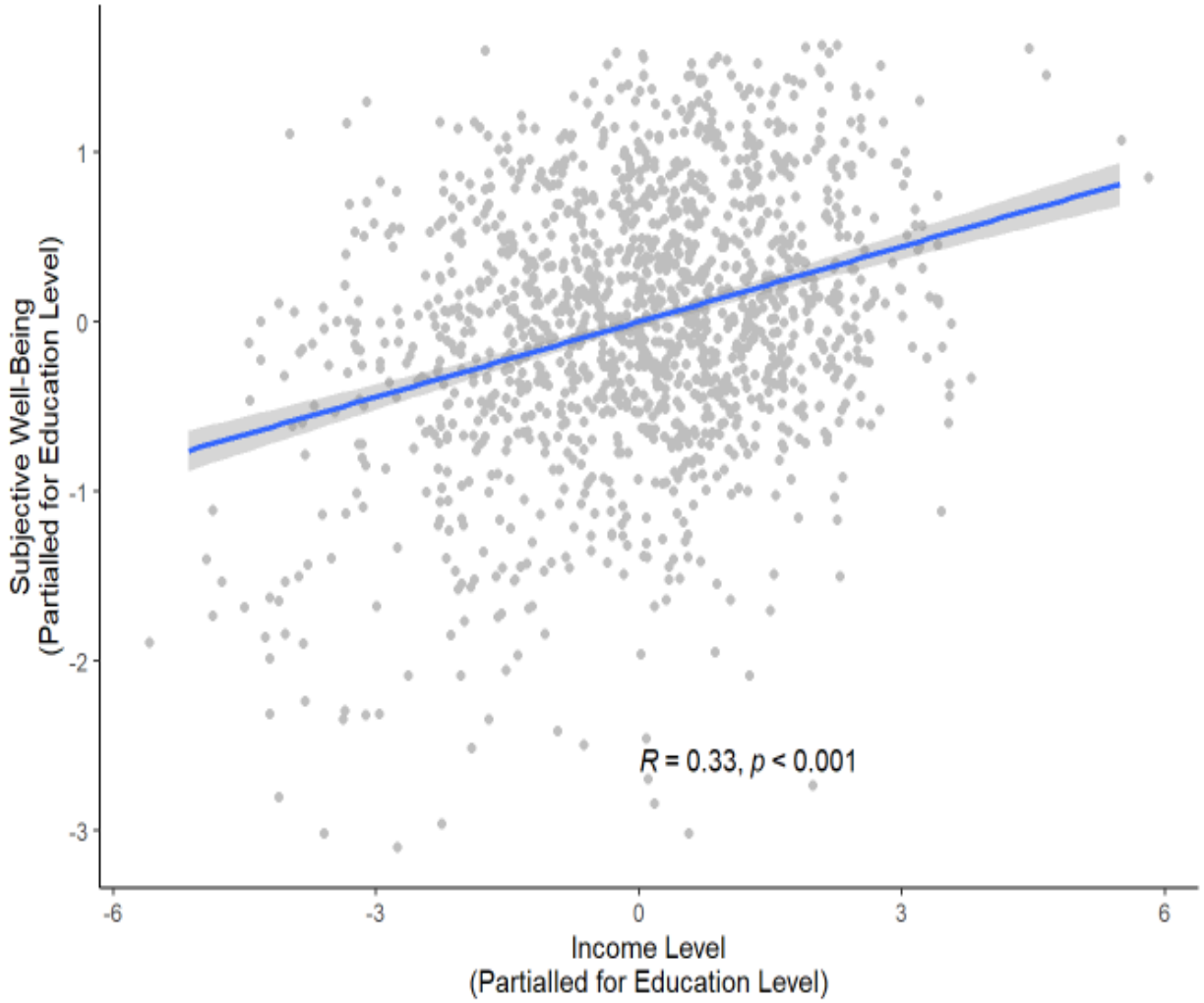
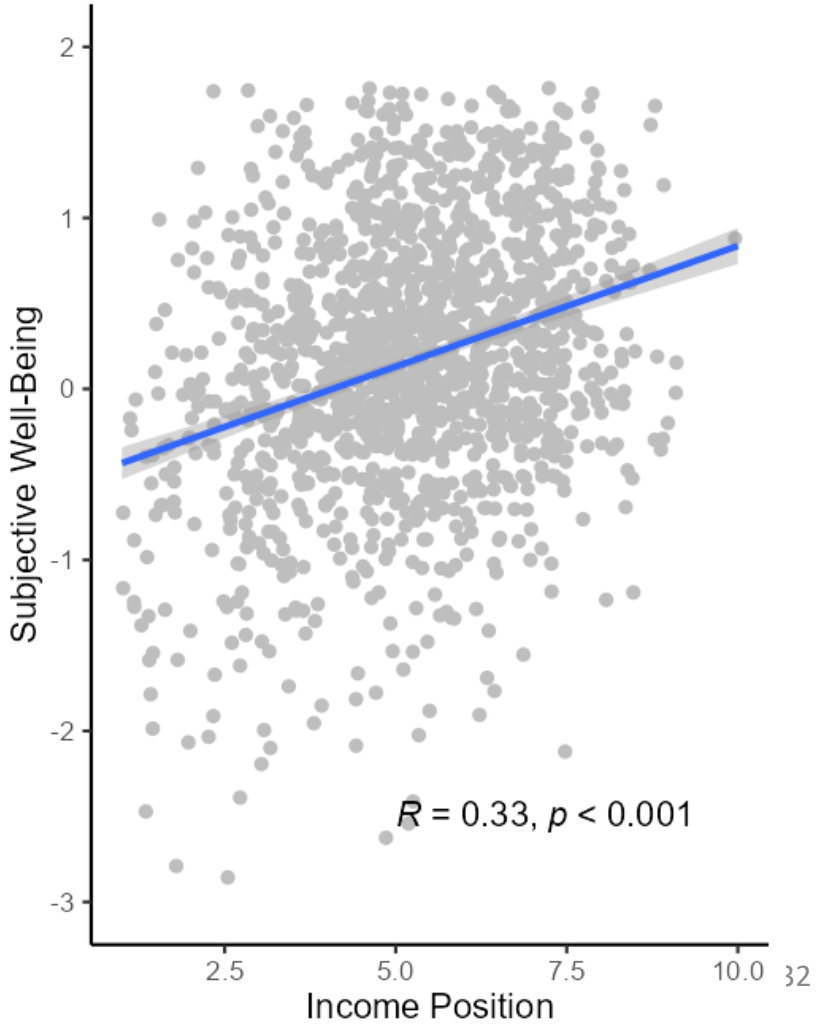
Adjusted Linear Association



Unadjusted Linear Association



Importance of God and Happiness?

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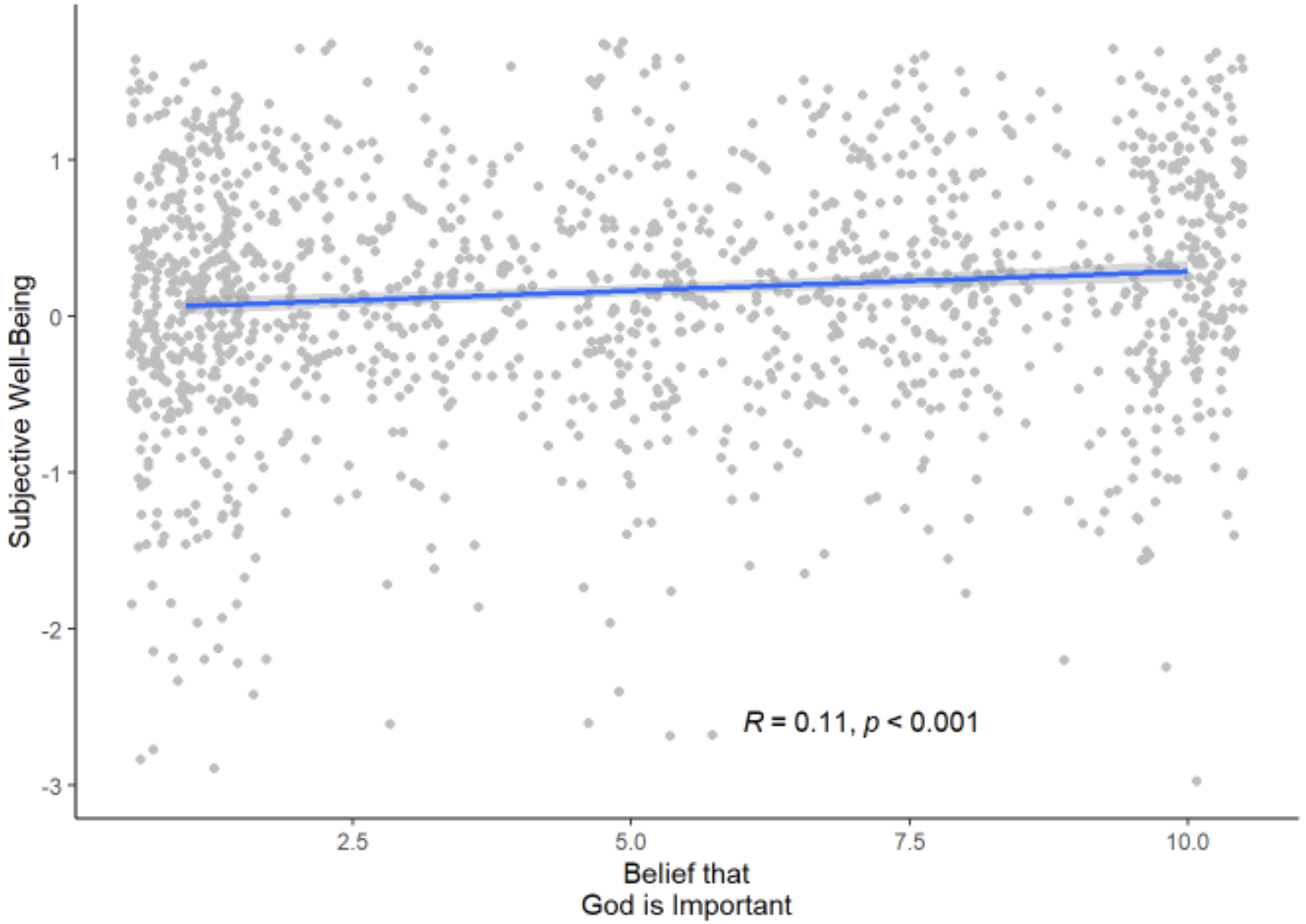

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Example 3. NHST – Linear Association, adjusted

- One option is a **partial correlation**
- Another option is a **linear regression**
  - Advantage is that it can adjust for many variables
  - Computer does the work
  - Statistical software provides results/p-values

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Example 3. NHST – Linear Association, adjusted

- Germany – 3 regressions

	Model 1	Model 2	Model 3
Income	0.14 ***	0.15 ***	0.15 ***
	(0.01)	(0.01)	(0.01)
Education		-0.02	-0.02
		(0.01)	(0.01)
God Importance			0.03 ***
			(0.01)
N	1445	1445	1445
R2	0.11	0.11	0.13

*** p < 0.001; ** p < 0.01; * p < 0.05.

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Example 3. NHST – Linear Association, adjusted

- Compare:

Ethiopia

	Model 1	Model 2	Model 3
Income	0.05 ***	0.05 ***	0.05 ***
	(0.01)	(0.01)	(0.01)
Education		-0.02	-0.02
		(0.01)	(0.01)
God Importance			0.01
			(0.03)
N	1222	1222	1222
R2	0.01	0.02	0.02

*** p < 0.001; ** p < 0.01; * p < 0.05.

Vietnam

	Model 1	Model 2	Model 3
Income	0.06 ***	0.07 ***	0.07 ***
	(0.01)	(0.01)	(0.01)
Education		-0.06 ***	-0.06 ***
		(0.01)	(0.01)
God Importance			0.01
			(0.01)
N	1200	1200	1200
R2	0.02	0.04	0.04

*** p < 0.001; ** p < 0.01; * p < 0.05.

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