Week 2: Data wrangling

ANTH 674: Research Design & Analysis in Anthropology

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Office Hours: Thursdays, 1:00–4:00pm in GSB 312

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Statistics vignette

- Let's play a game…

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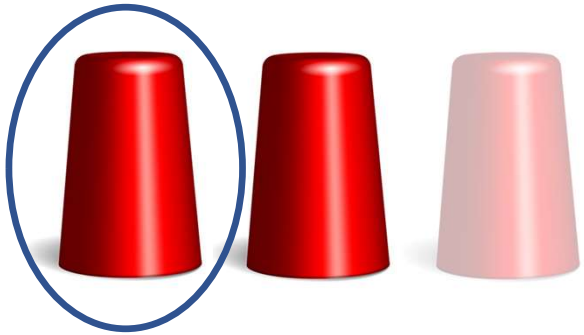
Statistics vignette

- Let's play a game…



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Statistics vignette

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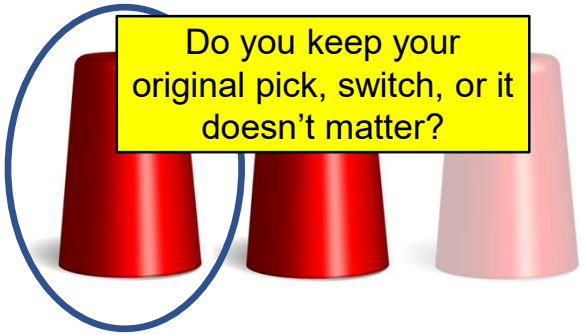

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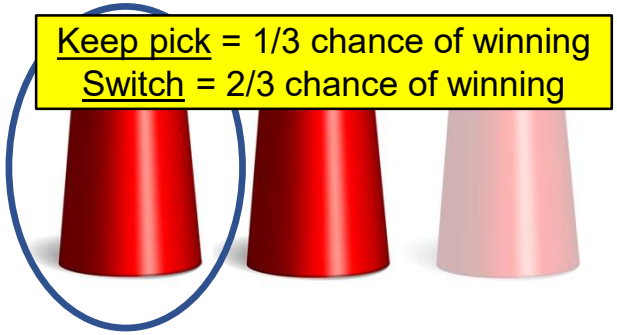
Statistics vignette

- Let's play a game…



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The Monty Hall problem

Suppose you're on a game show, and you're given the choice of three doors: Behind one door is a car; behind the others, goats. You pick a door, say No. 1, and the host, who knows what's behind the doors, opens another door, say No. 3, which has a goat. He then says to you, "Do you want to pick door No. 2?" Is it to your advantage to switch your choice?
—Craig F. Whitaker, Columbia, Md.

Ask Marilyn™
BY MARILYN VOS SAVANT

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Lecture outline

1. Data wrangling
   - What is it, and why is it important?
2. General rules for data organization in spreadsheets
   - Emphasize the intimate connection with R
3. Data structures

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Data wrangling

What is it, and why is it important?

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What is data wrangling?

- Cleaning and organizing raw data to suit your research questions and analyses
- Important because data are rarely in a form ready to be analyzed *according to your goals*
- Incredibly marketable skill! Some data scientists only wrangle data

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The data pipeline

Collect raw data

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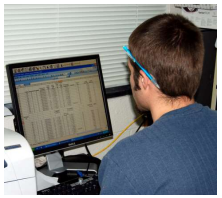
The data pipeline

Collect raw data → Enter data into computer spreadsheet



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	original.order	Transect	Occ	Relative age	Dental age	Species	Bone	Side	WS	Teeth	New Ind	Damage	Count	Articulated	Burial
2	1	T16-03	1	Adult	No Value	Zebra	Innominate	L	3		1	3,		No Value	No Value
3	2	T16-03	1	Adult	No Value	Zebra	Humerus	R	3		0	0		No Value	No Value
4	3	T16-03	1	Adult	No Value	Zebra	Tibia	L	3		0	0		No Value	No Value
5	4	T16-03	1	Adult	No Value	Zebra	Femur	R	3		0	1,		No Value	No Value
6	5	T16-03	2	Juvenile		2 Zebra	Cranium	L+R	3	dpM2-M1	1	4,		No Value	No Value
7	6	T16-03	2	Juvenile		2 Zebra	Innominate	R	3		0	1,		No Value	No Value
8	7	T16-03	2	Juvenile		2 Zebra	Cervical	NA	3		0			No Value	No Value
9	8	T16-03	2	Juvenile		2 Zebra	Femur	L	3		0			No Value	No Value
10	9	T16-03	2	Juvenile		2 Zebra	Axis	NA	3		0			No Value	No Value
11	10	T16-03	2	Juvenile		2 Zebra	Atlas	NA	3		0			No Value	No Value
12	11	T16-03	2	Juvenile		2 Zebra	Cervical	NA	3		0			No Value	No Value
13	12	T16-03	2	Juvenile		2 Zebra	Thoracic	NA	3		0			No Value	No Value
14	13	T16-03	2	Juvenile		2 Zebra	Thoracic	NA	3		0			No Value	>50%
15	14	T16-03	2	Juvenile		2 Zebra	Rib	Indt	3		0		3	No Value	No Value
16	15	T16-03	2	Juvenile		2 Zebra	Humerus	L	3		0			No Value	No Value

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The data pipeline

Collect raw data → Enter data into computer spreadsheet

- Also enter **metadata** – "data about data"
- For example:
  - Name of data collector
  - GPS coordinates
  - When data was collected
  - Funding support
  - Methods used to collect data
  - Units of measurement
  - Description of abbreviations
  - What the variables are

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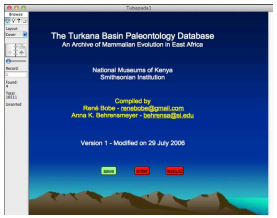
The data pipeline

Collect raw data → Enter data into computer spreadsheet



Published datasets/ databases

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Where issues arise

Collect raw data → Enter data into computer spreadsheet

- Missing data
- Erroneous measurements (e.g., broken or miscalibrated instruments)

Published datasets/ databases

Subject number	Human height (inches)
1	64
2	70
3	
4	58
5	110
6	124
7	118

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Where issues arise

Collect raw data → Enter data into computer spreadsheet

- Missing data
- Transcription errors
- Inconsistent data formats
- Combine data in one cell

Published datasets/ databases

Subject number	Human height (inches)	Sex	Date of birth
1	64	M	1970-02-24
22	70	m	1992-09-12
3		F	1977-07-11
4	58	F	1965-03-20
5	6	Fem	1982-05-25
6	73	M	06-10-1987
7; 8	68; 62	M; M	2000-12-13

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Where issues arise

Collect raw data → Enter data into computer spreadsheet

- Missing data
- Transcription errors
- Inconsistent data formats
- Combine data in one cell

In 13 audits of real-world spreadsheets, an average of 88% contain errors (Panko 2008)

Published datasets/ databases

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1	64	M	1970-02-24
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6	73	M	06-10-1987
7; 8	68; 62	M; M	2000-12-13

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Where issues arise

Collect raw data → Enter data into computer spreadsheet

- Ideally 100% clean, but often not
- Missing data
- Inconsistent data formats
- Extra variables
- Extra data

Published datasets/ databases

```
> head(iris)
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
1          5.1         3.5          1.4         0.2  setosa
2          4.9         3.0          1.4         0.2  setosa
3          4.7         3.2          1.3         0.2  setosa
4          4.6         3.1          1.5         0.2  setosa
5          5.0         3.6          1.4         0.2  setosa
6          5.4         3.9          1.7         0.4  setosa
```

- What if I'm interested only in petal lengths of individuals from *Iris virginica* species?

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How to wrangle?

- Once research question & general analytical methodology is defined, it's clear how data should be collected and organized
- **ALWAYS** keep the raw "dirty" data file! Save cleaned data to new file
- **ALWAYS** back up your data (e.g., external hard drive, the cloud)!

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Important not only for analyses

- Need to (should) publish raw data these days
  - Data collection supported by public funds *legally must* be published (granting agency technically owns the data)
  - Increases collegiality and rate of scientific progress (e.g., large-scale analyses)
  - Transparency & replicability of analyses
  - Clean data → increase your citation count!
- Be courteous & publish data in clean, analyzable format!

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R makes wrangling (relatively) easy!

- Don't need to fix *every single* data entry by hand
- Leaves a record of what you did (your R script)

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Questions?

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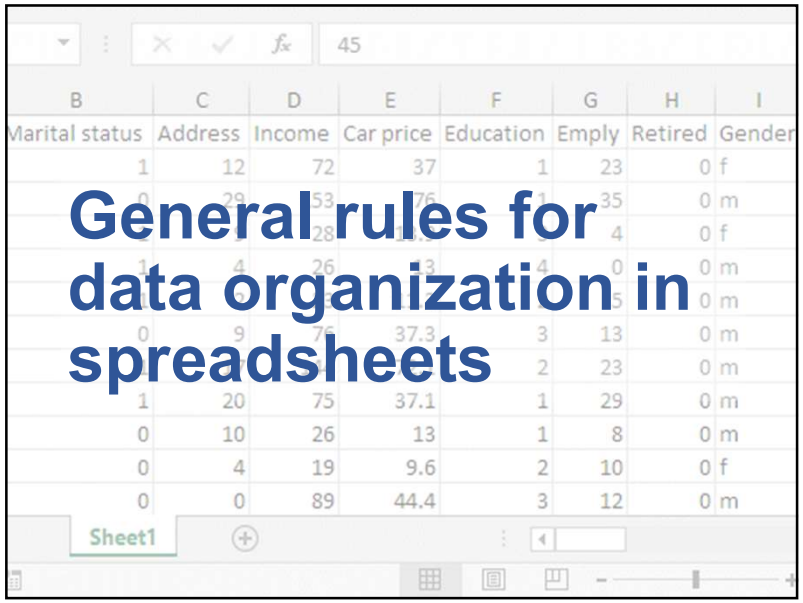

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What is a spreadsheet?

- An electronic page in which each row represents a single observation (i.e., unit of study), and each column represents a variable

Variables

	A	B	C	D
1	**ID Number**	**First**	**Last**	**Email**
2	5	Bob	Tester	Bob@gmail.com
3	3	Jane	Smith	Jane@gmail.com
4	8	Lazada	Inc	Lazada@gmail.com
5	103	Stuff	&nonsense	Stuff@gmail.com

Observations

Cell

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What is a spreadsheet?

- An electronic page in which each row represents a single observation (i.e., unit of study), and each column represents a variable
- Used for entering, storing, analyzing (not anymore), and visualizing data (not anymore)
  - Analyzing & visualizing data in R ensures original dataset remains unchanged
- Most commonly used program is Microsoft Excel (it's what I use)
- For R, use comma-separated values (.csv) files (not proprietary & works in Excel)

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CSV format

Plain text format

```
id,sex,glucose,insulin,triglyc
101,Male,134.1,0.60,273.4
102,Female,120.0,1.18,243.6
103,Male,124.8,1.23,297.6
104,Male,83.1,1.16,142.4
105,Male,105.2,0.73,215.7
```

- What it looks like in Excel

- Only **one** Excel sheet can be saved to **one** CSV file!

	A	B	C	D	E
1	id	sex	glucose	insulin	triglyc
2	101	Male	134.1	0.60	273.4
3	102	Female	120.0	1.18	243.6
4	103	Male	124.8	1.23	297.6
5	104	Male	83.1	1.16	142.4
6	105	Male	105.2	0.73	215.7

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Rules for data organization

- In general, how R handles names, numbers, etc. is how data should be structured
- In fact, cleaning a dataset in R for analyses → dataset is publishable!
- Becoming proficient in R makes you better at organizing data!

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Rules for data organization

1. Make sure your names are always ***consistent***
   1. R will treat "M", "`male`", and "`Male`" as completely different. Stick to one!
   2. Likewise, be careful of extra spaces! "`Male`" is treated differently than "`Male `"
   3. Be consistent with your formatting (e.g., don't use both `2020-08-29` and `08-29-2020`)

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Rules for data organization

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Rules for data organization

1. Make sure your names are always ***consistent***
2. Use NA to represent missing data
   1. Best to not leave spreadsheet cell blank (even though R will automatically replace it w/ NA)
   2. R is great at dealing with NAs, so don't use other symbols (e.g., ".", "-")
   3. Can add notes about missing data in another column

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Rules for data organization

1. Make sure your names are always ***consistent***
2. Use NA to represent missing data
3. Avoid spaces. Use underscores ("snake case"), periods, or camel case instead
   - `human_height`, `human.height`, `humanHeight`

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Rules for data organization

1. Make sure your names are always ***consistent***
2. Use NA to represent missing data
3. Avoid spaces. Use underscores ("snake case"), periods, or camel case instead
4. Avoid special characters (e.g., $, @, %, !, #, &, *)
5. Use short, informative variable names (e.g., `HumanHeight_in`)

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Why are these bad names?

good name	good alternative	avoid
`Max_temp_C`	`MaxTemp`	`Maximum Temp (°C)`
`Precipitation_mm`	`Precipitation`	`precmm`
`Mean_year_growth`	`MeanYearGrowth`	`Mean growth/year`
`sex`	`sex`	`M/F`
`weight`	`weight`	`w.`
`cell_type`	`CellType`	`Cell type`
`Observation_01`	`first_observation`	`1st Obs.`

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Rules for data organization

6. Put only one piece of data in each cell
   1. E.g., don't input:
      `1. 11,40` for lat/long
      `2. 75kg` for mass
      `3. ~10?` (uncertain measurement)
   2. When in doubt, put data in separate columns

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Rules for data organization

6. Put only one piece of data in each cell
7. Do not use font color or highlighting
   1. R cannot interpret font colors/highlighting
   2. Won't be saved in a CSV file anyway

	A	B	C
1	id	date	glucose
2	101	2015–06–14	149.3
3	102	2015–06–14	95.3
4	103	2015–06–18	97.5
5	104	2015–06–18	1.1
6	105	2015–06–18	108.0
7	106	2015–06–20	149.0
8	107	2015–06–20	169.4

	A	B	C	D
1	id	date	glucose	outlier
2	101	2015–06–14	149.3	FALSE
3	102	2015–06–14	95.3	FALSE
4	103	2015–06–18	97.5	FALSE
5	104	2015–06–18	1.1	TRUE
6	105	2015–06–18	108.0	FALSE
7	106	2015–06–20	149.0	FALSE
8	107	2015–06–20	169.4	FALSE

Broman & Woo 2018

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Questions?

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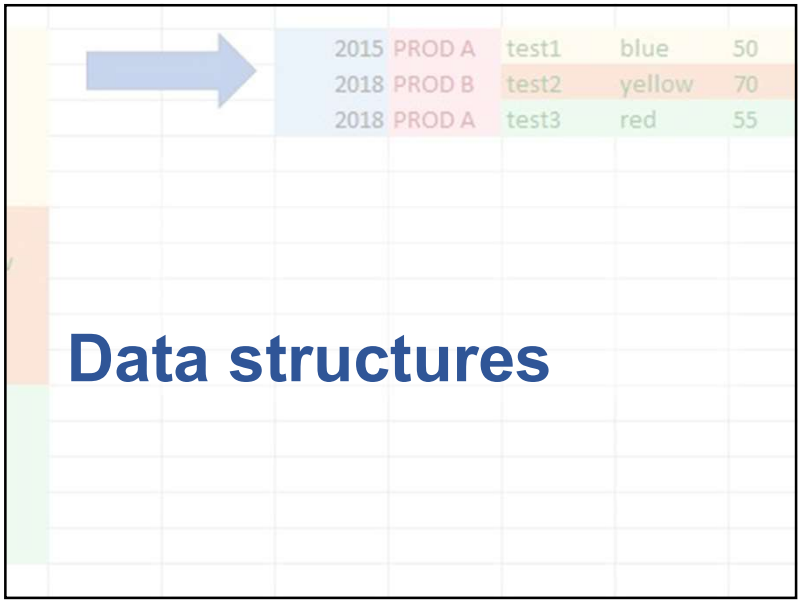

Data structures

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Data structure

- ***Always*** rectangular!

	A	B	C	D	E
1	id	sex	glucose	insulin	triglyc
2	101	Male	134.1	0.60	273.4
3	102	Female	120.0	1.18	243.6
4	103	Male	124.8	1.23	297.6
5	104	Male	83.1	1.16	142.4
6	105	Male	105.2	0.73	215.7

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Data structure

- ***Always*** rectangular!
- What **NOT** to do:

	A	B	C	D	E	F	G	H	I
1		1 min				5 min			
2	strain	normal		mutant		normal		mutant	
3	A	147	139	166	179	334	354	451	474
4	B	246	240	178	172	514	611	412	447

- Will give R fits & difficult to work with!

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What to do instead

	A	B	C	D	E	F	G	H	I
1		1 min				5 min			
2	strain	normal		mutant		normal		mutant	
3	A	147	139	166	179	334	354	451	474
4	B	246	240	178	172	514	611	412	447

Each row = unique combination of variables

First row **ONLY** for variable names

	A	B	C	D	E
1	strain	genotype	min	replicate	response
2	A	normal	1	1	147
3	A	normal	1	2	139
4	B	normal	1	1	246
5	B	normal	1	2	240
6	A	mutant	1	1	166
7	A	mutant	1	2	179
8	B	mutant	1	1	178
9	B	mutant	1	2	172
10	A	normal	5	1	334
11	A	normal	5	2	354

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Relating different spreadsheets

- To keep spreadsheets rectangular, may need to keep different rectangles in different files
- Relate rectangles to each other using consistent variable names
  - e.g., don't use `HumanHeight` in one and `Human_Height` in another

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Relating different spreadsheets

	A	B	C	D	E	F	G	H	I	J
1	Species	Apak	Aralee_Issie	Aramis	Asa_Issie	Asa_Koma	Asbole	Bed_I	Bed_III	Bed_IV
2	Aepyceros_afarensis	0	1	0	0	0	0	0	0	0
3	Aepyceros_aff_dietrchi	0	0	0	0	0	0	0	0	0
4	Aepyceros_aff_premelampus	0	0	0	0	0	0	0	0	0
5	Aepyceros_cf_afarensis	0	0	0	0	0	0	0	0	0
6	Aepyceros_cf_melampus	0	0	0	0	0	0	0	0	0
7	Aepyceros_cf_premelampus	0	0	0	0	0	0	0	0	0
8	Aepyceros_datoadeni	0	0	0	0	0	0	0	0	0
9	Aepyceros_dietrchi	0	0	0	0	0	0	0	0	0
10	Aepyceros_melampus	0	0	0	0	0	0	1	0	0

	A	B	C	D	E	F	G	H	I	J
1	Country	Basin	Site	Lat	Long	Formation_Sequence	Min. Age	Max. Age	Mean Age	Duration
2	Kenya	Turkana	Apak	2.9	36.05	Nachukui Formation	4.2	5	4.6	0.8
3	Ethiopia	Awash	Aralee_Issie			Woranso-Mille	3.57	3.76	3.67	0.19
4	Ethiopia	Awash	Aramis	10.3	40.3	Sagantole Formation	4.4	4.4	4.4	0
5	Ethiopia	Awash	Asa_Issie			Sagantole Formation			4.12	0
6	Ethiopia	Awash	Asa_Koma	10.3	40.26	Adu-Asa Formation	5.54	5.77	5.66	0.23
7	Ethiopia	Awash	Asbole	11.05	40.67	Busidima Formation	0.6	0.8	0.7	0.2
8	Tanzania	-	Bed_I	-2.98	35.3	Olduvai Gorge	1.8	2.038	1.919	0.238
9	Tanzania	-	Bed_III	-2.98	35.3	Olduvai Gorge	0.8	1.2	1	0.4
10	Tanzania	-	Bed_IV	-2.98	35.3	Olduvai Gorge	0.6	0.8	0.7	0.2

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Questions?

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Summary

- The importance of data wrangling
- Rules for data in spreadsheets
  - Keep names consistent
  - Use NA to represent missing data
  - Avoid spaces & special characters
  - Use short, informative names
  - One piece of data per cell
  - Don't use highlighting or font coloring
- Keep spreadsheets rectangular!
  - Use different spreadsheets if necessary
- When in doubt, refer to Broman & Woo, 2018
- If you follow these rules when entering data, the less wrangling you will need to do later

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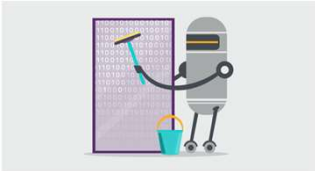
But how to clean data?

- Thus far, you learned what good data practices are
- But what to do if you are dealing with bad, dirty data (***very*** common)?
- This week's R tutorial will teach you how to fix these data issues using R



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