Tidy data

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Introduction

- a lot of data we work with is *tabular*
- can be represented in a table with *rows* and *columns*
- maybe particular important for reporting data from repeated trials, experiments, conditions (neuroscience)
- links to *statistical reports* and *visualisations* we often want/need

Examples:

You probably have your own, but eg:

- rating in a questionnaire [per item, participant]
- reaction times [per trial, subject, condition]
- % fMRI signal change [per brain region across, subject, conditions]
- spike rate [per neuron, animal, task]

Just put them in a table, right!?

Figure 1: The ~~files~~ are in the ~~computer~~?

Anna Karenina principle

> "Happy families are all alike; every unhappy family is unhappy in its own way." — Leo Tolstoy

> "Tidy datasets are all alike, but every messy dataset is messy in its own way." — Hadley Wickham

Example table A

number of TB cases in country, population

```
table1 %>% gt()
```

country	year	cases	population
Afghanistan	1999	745	19987071

country	year	cases	population
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898
China	1999	212258	1272915272
China	2000	213766	1280428583

Example table B

```
table2 %>% gt()
```

country	year	type	count
Afghanistan	1999	cases	745
Afghanistan	1999	population	19987071
Afghanistan	2000	cases	2666
Afghanistan	2000	population	20595360
Brazil	1999	cases	37737
Brazil	1999	population	172006362
Brazil	2000	cases	80488
Brazil	2000	population	174504898
China	1999	cases	212258
China	1999	population	1272915272
China	2000	cases	213766
China	2000	population	1280428583

Example table C

```
table3 %>% gt()
```

country	year	rate
Afghanistan	1999	745/19987071
Afghanistan	2000	2666/20595360

country	year	rate
Brazil	1999	37737/172006362
Brazil	2000	80488/174504898
China	1999	212258/1272915272
China	2000	213766/1280428583

“Tidy” means

H. Wickham and G. Grolemund [1]

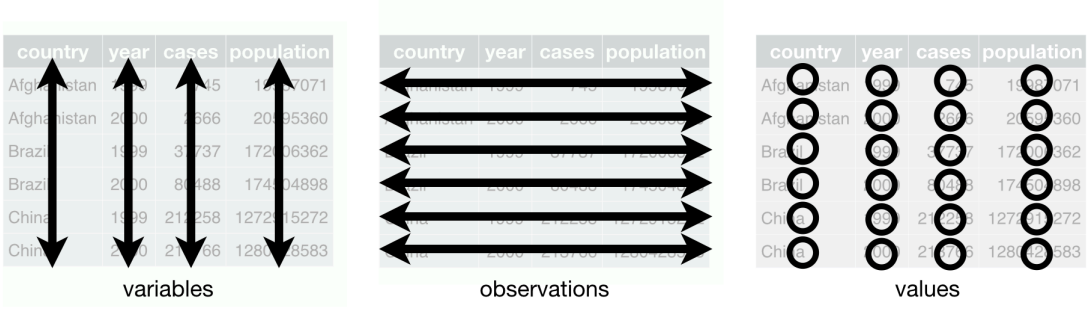


Figure 2: Tidy data illustration from R4DS

- each column represents a *variable*
- each row an *observation*
- each cell entry a *value* (number, text, …)

Benefits

- this layout leads to a series of elegant ways to manipulate table
- it’s a standard (so tool builders can make code to work with it)
- it plays nicely with storage (files) and visualisation (*grammar of graphics* ideas)

Manipulating tables: concepts

Some ideas that crop up in

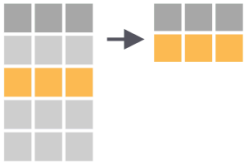
- `sql`
- **`dplyr` (a popular library in `r`),**
- `pandas` (in `python`)
- `QueryVerse.jl` (in `julia`)
- `tables` in `matlab`

Main ideas

A really good summary on this cheatsheet – using `r` syntax, but good for ideas!

- subsetting (rows, columns)
- mutating (calculating new values)
- aggregating (grouping, summarising)
- combining (including *relational* data, `join()`)

taking rows, `filter()`



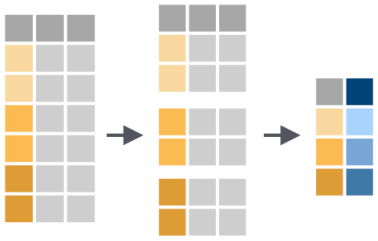
filter(.data, …, .preserve = FALSE**)** Extract rows that meet logical criteria.
filter(mtcars, mpg > 20)

taking columns, `select()`

select(.data, …**)** Extract columns as a table.
select(mtcars, mpg, wt)

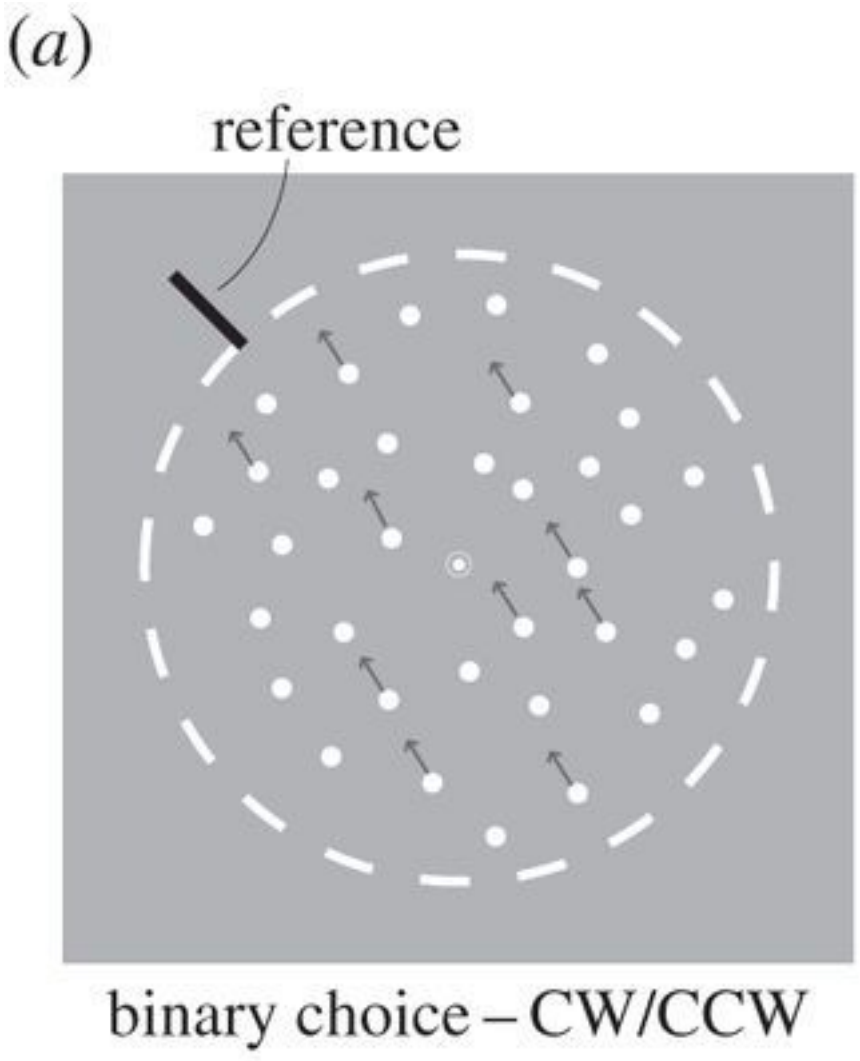
aggregate, `groupby(), summarize()`

Use **group_by(**.data, …, .add = FALSE, .drop = TRUE**)** to create a "grouped" copy of a table grouped by columns in ... dplyr functions will manipulate each "group" separately and combine the results.



```
mtcars  %>%
  group_by(cyl) %>%
  summarise(avg = mean(mpg))
```

By example (Psychophysics data)



As a table

```
d |> gt()
```

direction	p_cw	se	coherence	subject
−19.5	0.114	0.023	0.04	A
−15.5	0.173	0.030	0.04	A
−11.5	0.236	0.032	0.04	A
−7.5	0.276	0.033	0.04	A

direction	p_cw	se	coherence	subject
−3.5	0.390	0.036	0.04	A
0.5	0.430	0.037	0.04	A
4.5	0.516	0.037	0.04	A
8.5	0.599	0.035	0.04	A
12.5	0.719	0.033	0.04	A
16.5	0.748	0.031	0.04	A
20.5	0.780	0.031	0.04	A
−19.5	0.048	0.016	0.07	A
−15.5	0.089	0.021	0.07	A
−11.5	0.106	0.023	0.07	A
−7.5	0.152	0.026	0.07	A
−3.5	0.304	0.034	0.07	A
0.5	0.397	0.036	0.07	A
4.5	0.592	0.034	0.07	A
8.5	0.695	0.033	0.07	A
12.5	0.823	0.029	0.07	A
16.5	0.831	0.029	0.07	A
20.5	0.923	0.021	0.07	A
−19.5	0.010	0.007	0.13	A
−15.5	0.049	0.015	0.13	A
−11.5	0.098	0.022	0.13	A
−7.5	0.121	0.024	0.13	A
−3.5	0.218	0.030	0.13	A
0.5	0.424	0.038	0.13	A
4.5	0.611	0.038	0.13	A
8.5	0.715	0.035	0.13	A
12.5	0.820	0.028	0.13	A
16.5	0.924	0.020	0.13	A

direction	p_cw	se	coherence	subject
20.5	0.950	0.015	0.13	A
−19.5	0.005	0.005	0.25	A
−15.5	0.022	0.010	0.25	A
−11.5	0.047	0.015	0.25	A
−7.5	0.073	0.020	0.25	A
−3.5	0.140	0.026	0.25	A
0.5	0.375	0.034	0.25	A
4.5	0.593	0.037	0.25	A
8.5	0.825	0.029	0.25	A
12.5	0.904	0.021	0.25	A
16.5	0.945	0.017	0.25	A
20.5	0.972	0.012	0.25	A
−19.5	0.290	0.036	0.04	C
−15.5	0.345	0.037	0.04	C
−11.5	0.371	0.039	0.04	C
−7.5	0.393	0.040	0.04	C
−3.5	0.400	0.039	0.04	C
0.5	0.523	0.040	0.04	C
4.5	0.594	0.039	0.04	C
8.5	0.633	0.041	0.04	C
12.5	0.675	0.040	0.04	C
16.5	0.683	0.039	0.04	C
20.5	0.744	0.038	0.04	C
−19.5	0.172	0.032	0.07	C
−15.5	0.203	0.031	0.07	C
−11.5	0.236	0.035	0.07	C
−7.5	0.373	0.040	0.07	C
−3.5	0.417	0.041	0.07	C

direction	p_cw	se	coherence	subject
0.5	0.493	0.041	0.07	C
4.5	0.595	0.042	0.07	C
8.5	0.725	0.036	0.07	C
12.5	0.740	0.035	0.07	C
16.5	0.800	0.035	0.07	C
20.5	0.804	0.032	0.07	C
−19.5	0.092	0.025	0.13	C
−15.5	0.131	0.030	0.13	C
−11.5	0.234	0.035	0.13	C
−7.5	0.333	0.040	0.13	C
−3.5	0.385	0.043	0.13	C
0.5	0.531	0.042	0.13	C
4.5	0.672	0.039	0.13	C
8.5	0.745	0.036	0.13	C
12.5	0.796	0.034	0.13	C
16.5	0.777	0.032	0.13	C
20.5	0.908	0.023	0.13	C
−19.5	0.051	0.018	0.25	C
−15.5	0.082	0.024	0.25	C
−11.5	0.150	0.030	0.25	C
−7.5	0.261	0.035	0.25	C
−3.5	0.364	0.039	0.25	C
0.5	0.383	0.041	0.25	C
4.5	0.623	0.040	0.25	C
8.5	0.739	0.035	0.25	C
12.5	0.762	0.035	0.25	C
16.5	0.800	0.033	0.25	C
20.5	0.924	0.021	0.25	C

direction	p_cw	se	coherence	subject
−19.5	0.174	0.035	0.04	D
−15.5	0.231	0.038	0.04	D
−11.5	0.222	0.036	0.04	D
−7.5	0.284	0.040	0.04	D
−3.5	0.375	0.043	0.04	D
0.5	0.485	0.044	0.04	D
4.5	0.605	0.042	0.04	D
8.5	0.762	0.040	0.04	D
12.5	0.858	0.031	0.04	D
16.5	0.879	0.029	0.04	D
20.5	0.897	0.028	0.04	D
−19.5	0.064	0.022	0.07	D
−15.5	0.070	0.023	0.07	D
−11.5	0.138	0.030	0.07	D
−7.5	0.278	0.040	0.07	D
−3.5	0.360	0.044	0.07	D
0.5	0.504	0.045	0.07	D
4.5	0.639	0.043	0.07	D
8.5	0.776	0.036	0.07	D
12.5	0.832	0.033	0.07	D
16.5	0.944	0.021	0.07	D
20.5	0.959	0.018	0.07	D
−19.5	0.017	0.011	0.13	D
−15.5	0.065	0.022	0.13	D
−11.5	0.108	0.029	0.13	D
−7.5	0.252	0.039	0.13	D
−3.5	0.327	0.045	0.13	D
0.5	0.450	0.044	0.13	D

direction	p_cw	se	coherence	subject
4.5	0.696	0.044	0.13	D
8.5	0.855	0.031	0.13	D
12.5	0.933	0.021	0.13	D
16.5	0.969	0.016	0.13	D
20.5	0.992	0.008	0.13	D
−19.5	0.015	0.010	0.25	D
−15.5	0.030	0.016	0.25	D
−11.5	0.067	0.023	0.25	D
−7.5	0.105	0.028	0.25	D
−3.5	0.271	0.038	0.25	D
0.5	0.440	0.046	0.25	D
4.5	0.818	0.034	0.25	D
8.5	0.868	0.031	0.25	D
12.5	0.940	0.023	0.25	D
16.5	1.000	0.000	0.25	D
20.5	1.000	0.000	0.25	D
−19.5	0.169	0.030	0.04	E
−15.5	0.136	0.027	0.04	E
−11.5	0.214	0.033	0.04	E
−7.5	0.290	0.039	0.04	E
−3.5	0.413	0.044	0.04	E
0.5	0.474	0.043	0.04	E
4.5	0.586	0.044	0.04	E
8.5	0.681	0.039	0.04	E
12.5	0.682	0.037	0.04	E
16.5	0.791	0.036	0.04	E
20.5	0.831	0.033	0.04	E
−19.5	0.101	0.026	0.07	E

direction	p_cw	se	coherence	subject
−15.5	0.103	0.026	0.07	E
−11.5	0.129	0.030	0.07	E
−7.5	0.222	0.035	0.07	E
−3.5	0.307	0.040	0.07	E
0.5	0.469	0.042	0.07	E
4.5	0.634	0.038	0.07	E
8.5	0.755	0.034	0.07	E
12.5	0.748	0.038	0.07	E
16.5	0.865	0.028	0.07	E
20.5	0.910	0.023	0.07	E
−19.5	0.039	0.016	0.13	E
−15.5	0.036	0.016	0.13	E
−11.5	0.066	0.021	0.13	E
−7.5	0.131	0.029	0.13	E
−3.5	0.287	0.037	0.13	E
0.5	0.477	0.040	0.13	E
4.5	0.642	0.042	0.13	E
8.5	0.843	0.032	0.13	E
12.5	0.936	0.021	0.13	E
16.5	0.953	0.018	0.13	E
20.5	0.978	0.012	0.13	E
−19.5	0.000	0.000	0.25	E
−15.5	0.020	0.011	0.25	E
−11.5	0.035	0.015	0.25	E
−7.5	0.066	0.020	0.25	E
−3.5	0.217	0.033	0.25	E
0.5	0.407	0.042	0.25	E
4.5	0.752	0.035	0.25	E

direction	p_cw	se	coherence	subject
8.5	0.888	0.027	0.25	E
12.5	0.946	0.019	0.25	E
16.5	0.974	0.013	0.25	E
20.5	1.000	0.000	0.25	E
−19.5	0.446	0.043	0.04	F
−15.5	0.486	0.044	0.04	F
−11.5	0.577	0.042	0.04	F
−7.5	0.532	0.047	0.04	F
−3.5	0.559	0.045	0.04	F
0.5	0.593	0.045	0.04	F
4.5	0.595	0.041	0.04	F
8.5	0.565	0.045	0.04	F
12.5	0.612	0.041	0.04	F
16.5	0.615	0.042	0.04	F
20.5	0.684	0.038	0.04	F
−19.5	0.378	0.041	0.07	F
−15.5	0.518	0.042	0.07	F
−11.5	0.397	0.040	0.07	F
−7.5	0.470	0.044	0.07	F
−3.5	0.500	0.043	0.07	F
0.5	0.528	0.045	0.07	F
4.5	0.597	0.044	0.07	F
8.5	0.664	0.039	0.07	F
12.5	0.707	0.038	0.07	F
16.5	0.621	0.041	0.07	F
20.5	0.678	0.043	0.07	F
−19.5	0.272	0.039	0.13	F
−15.5	0.276	0.038	0.13	F

direction	p_cw	se	coherence	subject
–11.5	0.375	0.042	0.13	F
–7.5	0.489	0.041	0.13	F
–3.5	0.446	0.043	0.13	F
0.5	0.577	0.042	0.13	F
4.5	0.602	0.043	0.13	F
8.5	0.611	0.042	0.13	F
12.5	0.727	0.040	0.13	F
16.5	0.746	0.039	0.13	F
20.5	0.805	0.034	0.13	F
–19.5	0.178	0.033	0.25	F
–15.5	0.203	0.036	0.25	F
–11.5	0.276	0.041	0.25	F
–7.5	0.281	0.037	0.25	F
–3.5	0.457	0.041	0.25	F
0.5	0.543	0.039	0.25	F
4.5	0.626	0.041	0.25	F
8.5	0.738	0.039	0.25	F
12.5	0.779	0.038	0.25	F
16.5	0.857	0.030	0.25	F
20.5	0.852	0.031	0.25	F

`group_by` and `summarize`

- pick one coherence level
- group by direction
- summarise across all observers

````
```{r}
d |> filter(coherence == 0.25) |>
     group_by(direction) |>
     summarise(mean_p_cw = mean(p_cw)) |>
     gt()
```
````

result

```
d |> filter(coherence == 0.25) |>
     group_by(direction) |>
     summarise(mean_p_cw = mean(p_cw)) |>
     gt()
```

direction	mean_p_cw
−19.5	0.0498
−15.5	0.0714
−11.5	0.1150
−7.5	0.1572
−3.5	0.2898
0.5	0.4296
4.5	0.6824
8.5	0.8116
12.5	0.8662
16.5	0.9152
20.5	0.9496

plotting can follow same ideas

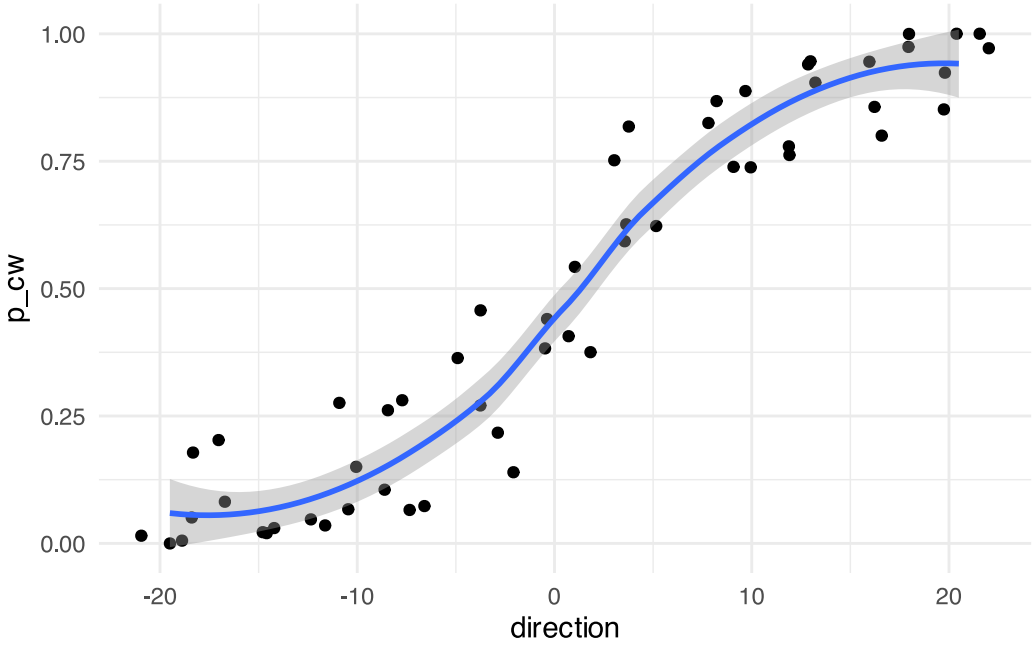
- *declarative* style (`ggplot`) versus
- *imperative* style (`matlab`, `matplotlib`, ...)[1]

plot example

5,6 lines of code to get this

```
d |> filter(coherence == 0.25) |>
     ggplot(aes(x = direction, y = p_cw)) +
      geom_jitter() +
      geom_smooth() +
      theme_minimal()
```

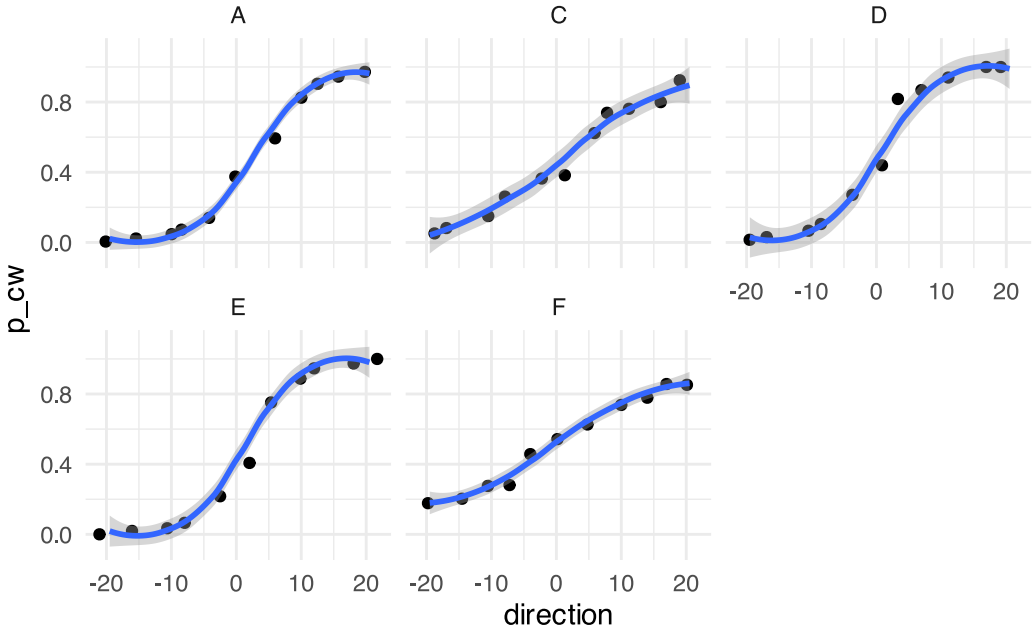
[1] what I used to use before I hit on / read the `tidyverse` stuff.



one additional line...

````
```{r}
      ...
      facet_wrap(~subject) +
      ...
```
````

```
d |> filter(coherence == 0.25) |>
     ggplot(aes(x = direction, y = p_cw)) +
      geom_jitter() +
      geom_smooth() +
      facet_wrap(~subject) +
      theme_minimal()
```



Discussion

- data files (`csv`, `parquet`, `feather` ??)
- what do people do (hand-wrap their own? other libraries)
- how uses an actual **database**?
- should we teach this at UG/PG level more??

References

Bibliography

[1] H. Wickham and G. Grolemund, “R for Data Science (2e).” Accessed: Feb. 22, 2023. [Online]. Available: https://r4ds.hadley.nz/