Day 2, Part 4: Exploratory Data Analysis & Data Visualization

Introduction to Python

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Exploratory data analysis

- "Exploratory data analysis can never be the whole story, but nothing else can serve as the foundation stone--as the first step." (Tukey, 1977)
- Exploratory data analysis (EDA) is the first and often most important step in research
- Study's feasibility, scope and framing would usually depend on its results
- Specific details of EDA depend upon the type and quality of data available

Measurement scales

TABLE 1

Scale	Basic Empirical Operations	Mathematical Group Structure	Permissible Statistics (invariantive)
NOMINAL	Determination of equality	*Permutation group* $x' = f(x)$ $f(x)$ means any one-to-one substitution	Number of cases Mode Contingency correlation
ORDINAL	Determination of greater or less	*Isotonic group* $x' = f(x)$ $f(x)$ means any monotonic increasing function	Median Percentiles
INTERVAL	Determination of equality of intervals or differences	*General linear group* $x' = ax + b$	Mean Standard deviation Rank-order correlation Product-moment correlation
RATIO	Determination of equality of ratios	*Similarity group* $x' = ax$	Coefficient of variation

Source: Stevens (1946)

Measurement scales in Pandas

- The 4 measurement scales defined by Stevens (1946) can be roughly represented in pandas as follows:
- *Interval* and *ratio* -> numeric
- *Nominal* and *ordinal* -> categorical

Loading the dataset

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In [1]:
```
import pandas as pd
```

Loading the dataset

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```

In [2]:
```
# This time let's skip the 2nd row, which contains questions
kaggle2021 = pd.read_csv('../data/kaggle_survey_2021_responses.csv', sk
kaggle2021.head(n = 1)
```

```
/tmp/ipykernel_282529/2302513793.py:2: DtypeWarning: Columns (19
5,201) have mixed types. Specify dtype option on import or set l
ow_memory=False.
  kaggle2021 = pd.read_csv('../data/kaggle_survey_2021_response
s.csv', skiprows = [1])
```

Out[2]:

	Time from Start to Finish (seconds)	Q1	Q2	Q3	Q4	Q5	Q6	Q7_Part_1	Q7_Part_2
0	910	50-54	Man	India	Bachelor's degree	Other	5-10 years	Python	R

1 rows × 369 columns

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0	910	50-54	Man	India	Bachelor's degree	Other	5-10 years	Python	R

1 rows × 369 columns

In [3]:
```
# We will load the questions as a separate dataset
kaggle2021_qs = pd.read_csv('../data/kaggle_survey_2021_responses.csv',
```

```
kaggle2021_qs
```

Out[3]:

	Time from Start to Finish (seconds)	Q1	Q2	Q3	Q4	Q5	Q6	Q7_Part_1
0	Duration (in seconds)	What is your age (# years)?	What is your gender? - Selected Choice	In which country do you currently reside?	What is the highest level of formal education ...	Select the title most similar to your current ...	For how many years have you been writing code ...	What programming languages do you use on a reg..

1 rows × 369 columns

Summarizing numeric variables

- DataFrame methods in pandas can automatically handle (exclude) missing data (`NaN`)

Summarizing numeric variables

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In [4]:
```
kaggle2021.describe() # DataFrame.describe() provides an range of summa
```

Out[4]:

	Time from Start to Finish (seconds)	Q7_Part_12	Q9_Part_12	Q10_Part_16	Q12_Part_5	Q14_
count	2.597300e+04	0.0	0.0	0.0	0.0	
mean	1.105466e+04	NaN	NaN	NaN	NaN	
std	1.014716e+05	NaN	NaN	NaN	NaN	
min	1.200000e+02	NaN	NaN	NaN	NaN	
25%	4.430000e+02	NaN	NaN	NaN	NaN	
50%	6.560000e+02	NaN	NaN	NaN	NaN	
75%	1.038000e+03	NaN	NaN	NaN	NaN	
max	2.488653e+06	NaN	NaN	NaN	NaN	

8 rows × 31 columns

Methods for summarizing numeric variables

Methods for summarizing numeric variables

In [5]:
```
kaggle2021.iloc[:,0].mean() # Rather than using describe(), we can appl
```

Out[5]:
```
11054.66492126439
```

Methods for summarizing numeric variables

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```
kaggle2021.iloc[:,0].mean() # Rather than using describe(), we can appl
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Out[5]:
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```

In [6]:
```
kaggle2021.iloc[:,0].median() # Median
```

Out[6]:
```
656.0
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In [6]:
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kaggle2021.iloc[:,0].median() # Median
```

Out[6]:
```
656.0
```

In [7]:
```
kaggle2021.iloc[:,0].std() # Standard deviation
```

Out[7]:
```
101471.6221245172
```

Methods for summarizing numeric variables

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```
kaggle2021.iloc[:,0].mean() # Rather than using describe(), we can appl
```

Out[5]:
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```

In [6]:
```
kaggle2021.iloc[:,0].median() # Median
```

Out[6]:
```
656.0
```

In [7]:
```
kaggle2021.iloc[:,0].std() # Standard deviation
```

Out[7]:
```
101471.6221245172
```

In [8]:
```
import statistics ## We don't have to rely only on methods provided by
statistics.stdev(kaggle2021.iloc[:,0])
```

Out[8]:
```
101471.6221245172
```

Summarizing categorical variables

Summarizing categorical variables

In [9]:
```
kaggle2021.describe(include = 'all') # Adding include = 'all' tells par
```

Out[9]:

	Time from Start to Finish (seconds)	Q1	Q2	Q3	Q4	Q5	Q6	Q7_Part_
count	2.597300e+04	25973	25973	25973	25973	25973	25973	2186
unique	NaN	11	5	66	7	15	7	
top	NaN	25-29	Man	India	Master's degree	Student	1-3 years	Pytho
freq	NaN	4931	20598	7434	10132	6804	7874	2186
mean	1.105466e+04	NaN	NaN	NaN	NaN	NaN	NaN	Na
std	1.014716e+05	NaN	NaN	NaN	NaN	NaN	NaN	Na
min	1.200000e+02	NaN	NaN	NaN	NaN	NaN	NaN	Na
25%	4.430000e+02	NaN	NaN	NaN	NaN	NaN	NaN	Na
50%	6.560000e+02	NaN	NaN	NaN	NaN	NaN	NaN	Na
75%	1.038000e+03	NaN	NaN	NaN	NaN	NaN	NaN	Na
max	2.488653e+06	NaN	NaN	NaN	NaN	NaN	NaN	Na

11 rows × 369 columns

Methods for summarizing categorical variables

Methods for summarizing categorical variables

In [10]:
```
kaggle2021.iloc[:,2].mode() # Mode, most frequent value
```

Out[10]:
```
0    Man
Name: Q2, dtype: object
```

Methods for summarizing categorical variables

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```
kaggle2021.iloc[:,2].mode() # Mode, most frequent value
```

Out[10]:
```
0    Man
Name: Q2, dtype: object
```

In [11]:
```
kaggle2021.iloc[:,2].value_counts() # Counts of unique values
```

Out[11]:
```
Q2
Man                          20598
Woman                         4890
Prefer not to say              355
Nonbinary                       88
Prefer to self-describe         42
Name: count, dtype: int64
```

Methods for summarizing categorical variables

In [10]:
```
kaggle2021.iloc[:,2].mode() # Mode, most frequent value
```

Out[10]:
```
0    Man
Name: Q2, dtype: object
```

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```
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```

Out[11]:
```
Q2
Man                          20598
Woman                         4890
Prefer not to say              355
Nonbinary                       88
Prefer to self-describe         42
Name: count, dtype: int64
```

In [12]:
```
kaggle2021.iloc[:,2].value_counts(normalize = True) # We can further nc
```

Out[12]:
```
Q2
Man                          0.793054
Woman                        0.188272
Prefer not to say            0.013668
Nonbinary                    0.003388
Prefer to self-describe      0.001617
Name: proportion, dtype: float64
```

Summary of descriptive statistics methods

Method	Numeric	Categorical	Description
`count`	yes	yes	Number of non-NA observations
`value_counts`	yes	yes	Number of unique observations by value
`describe`	yes	yes	Set of summary statistics for Series/DataFrame
`min`, `max`	yes	yes (caution)	Minimum and maximum values
`quantile`	yes	no	Sample quantile ranging from 0 to 1
`sum`	yes	yes (caution)	Sum of values
`prod`	yes	no	Product of values
`mean`	yes	no	Mean
`median`	yes	no	Median (50% quantile)
`var`	yes	no	Sample variance
`std`	yes	no	Sample standard deviation
`skew`	yes	no	Sample skewness (third moment)
`kurt`	yes	no	Sample kurtosis (fourth moment)

Crosstabulation

- When working with survey data it is often useful to perform simple crosstabulations
- Crosstabulation (or *crosstab* for short) is a computation of group frequencies
- It is usually used for working with categorical variables that have a limited number of categories
- In pandas `pd.crosstab()` method is a special case of `pd.pivot_table()`

Crosstabulation in pandas

Crosstabulation in pandas

In [13]:
```
# Calculate crosstabulation between 'Age group' (Q1) and 'Gender' (Q2)
pd.crosstab(kaggle2021['Q1'], kaggle2021['Q2'])
```

Out[13]:

Q2	Man	Nonbinary	Prefer not to say	Prefer to self-describe	Woman
Q1					
18-21	3696	16	60	12	1117
22-24	3643	13	66	9	963
25-29	3859	12	61	5	994
30-34	2765	17	34	7	618
35-39	1993	7	42	7	455
40-44	1537	4	31	1	317
45-49	1171	4	24	1	175
50-54	811	3	14	0	136
55-59	509	4	7	0	72
60-69	504	4	10	0	35
70+	110	4	6	0	8

Margins in crosstab

Margins in crosstab

In [14]:
```
# It is often useful to see the proportions/percentages rather than raw
pd.crosstab(kaggle2021['Q1'], kaggle2021['Q2'], normalize = 'columns')
```

Out[14]:

Q2	Man	Nonbinary	Prefer not to say	Prefer to self-describe	Woman
Q1					
18-21	0.179435	0.181818	0.169014	0.285714	0.228425
22-24	0.176862	0.147727	0.185915	0.214286	0.196933
25-29	0.187348	0.136364	0.171831	0.119048	0.203272
30-34	0.134236	0.193182	0.095775	0.166667	0.126380
35-39	0.096757	0.079545	0.118310	0.166667	0.093047
40-44	0.074619	0.045455	0.087324	0.023810	0.064826
45-49	0.056850	0.045455	0.067606	0.023810	0.035787

Crosstabulation in pandas with `pivot_table`

Q2	Man	Nonbinary	Prefer not to say	Prefer to self-describe	Woman
Q1					
50-54	0.029373	0.045455	0.019437	0.000000	0.027812
			0.019718	0.000000	0.014724
60-69	0.024468	0.045455	0.028169	0.000000	0.007157
70+	0.005340	0.045455	0.016901	0.000000	0.001636

Crosstabulation in pandas with `pivot_table`

In [15]:
```
# For `values` variable we use `Q3`, but any other would work equally w
pd.pivot_table(kaggle2021, index = 'Q1', columns = 'Q2', values = 'Q3',
```

Out[15]:

Q2	Man	Nonbinary	Prefer not to say	Prefer to self-describe	Woman
Q1					
18-21	3696	16	60	12	1117
22-24	3643	13	66	9	963
25-29	3859	12	61	5	994
30-34	2765	17	34	7	618
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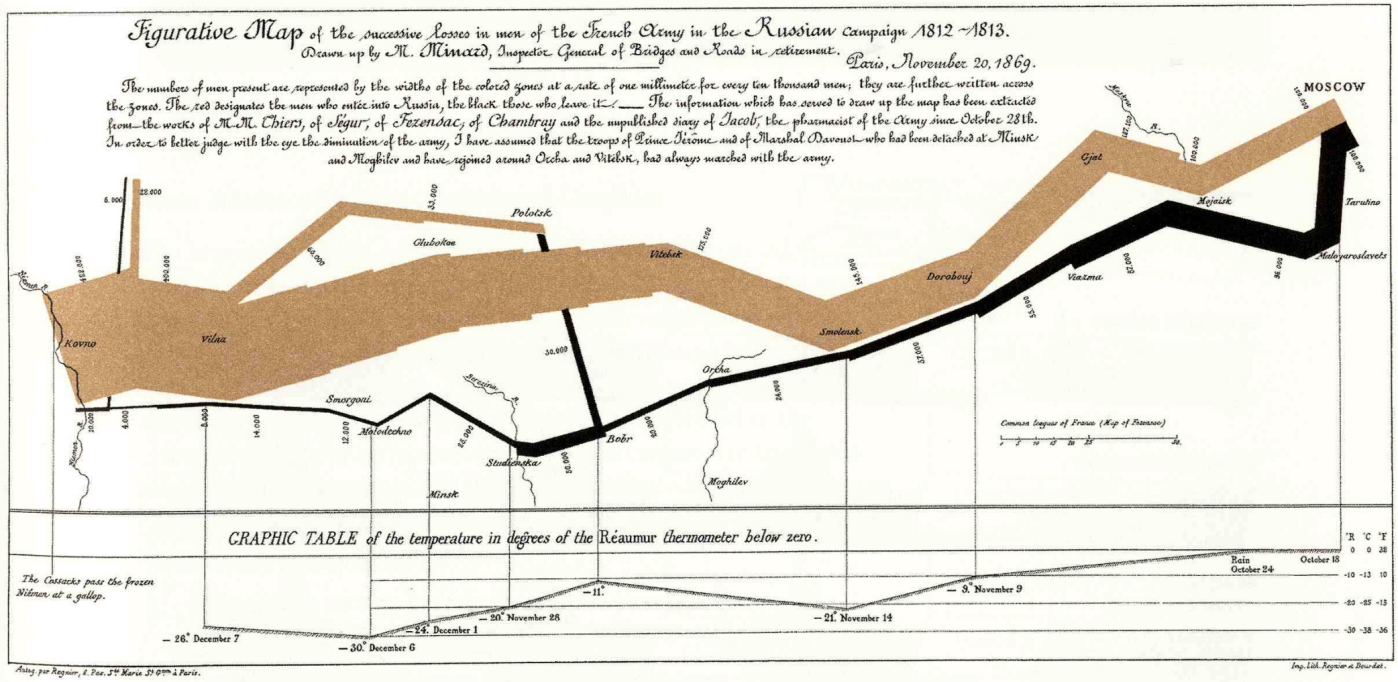
60-69	504	4	10	0	35
70+	110	4	6	0	8

Data visualization



Source: Tufte (2001), based on Marey (1885)

Data visualization in Python

- As with dealing with data, Python has no in-built, 'base' plotting functionality
- `matplotlib` has become the one of standard solutions
- It is often used in combination with `pandas`
- Other popular alternative include `seaborn` and `plotnine`
- Also `pandas` itself has some limited plotting facilities

`plotnine` - `ggplot` for Python

- `plotnine` implements Grammar of Graphics data visualisation scheme (Wilkinson, 2005)
- It mimics the syntax of a well-known R library `ggplot2` syntax (Wickham, 2010)
- In doing so, it makes the code (almost) seamlessly portable between the two languages

Grammar of graphics

- Grammar of Graphics is a powerful conceptualization of plotting
- Graphs are broken into multiple layers
- Layers can be recycled across multiple plots

Structure of ggplot calls in `plotnine`

- Creation of ggplot objects in `plotline` has the following structure:

```
ggplot(data = <DATA>) +\
    <GEOM_FUNCTION>(mapping = aes(<MAPPINGS>))
```

- If the *mappings* are re-used across geometric objects (e.g. scatterplot and line):

```
ggplot(data = <DATA>, mapping = aes(<MAPPINGS>)) +\
    <GEOM_FUNCTION>() +\
    <GEOM_FUNCTION>()
```

Creating a ggplot in `plotnine`

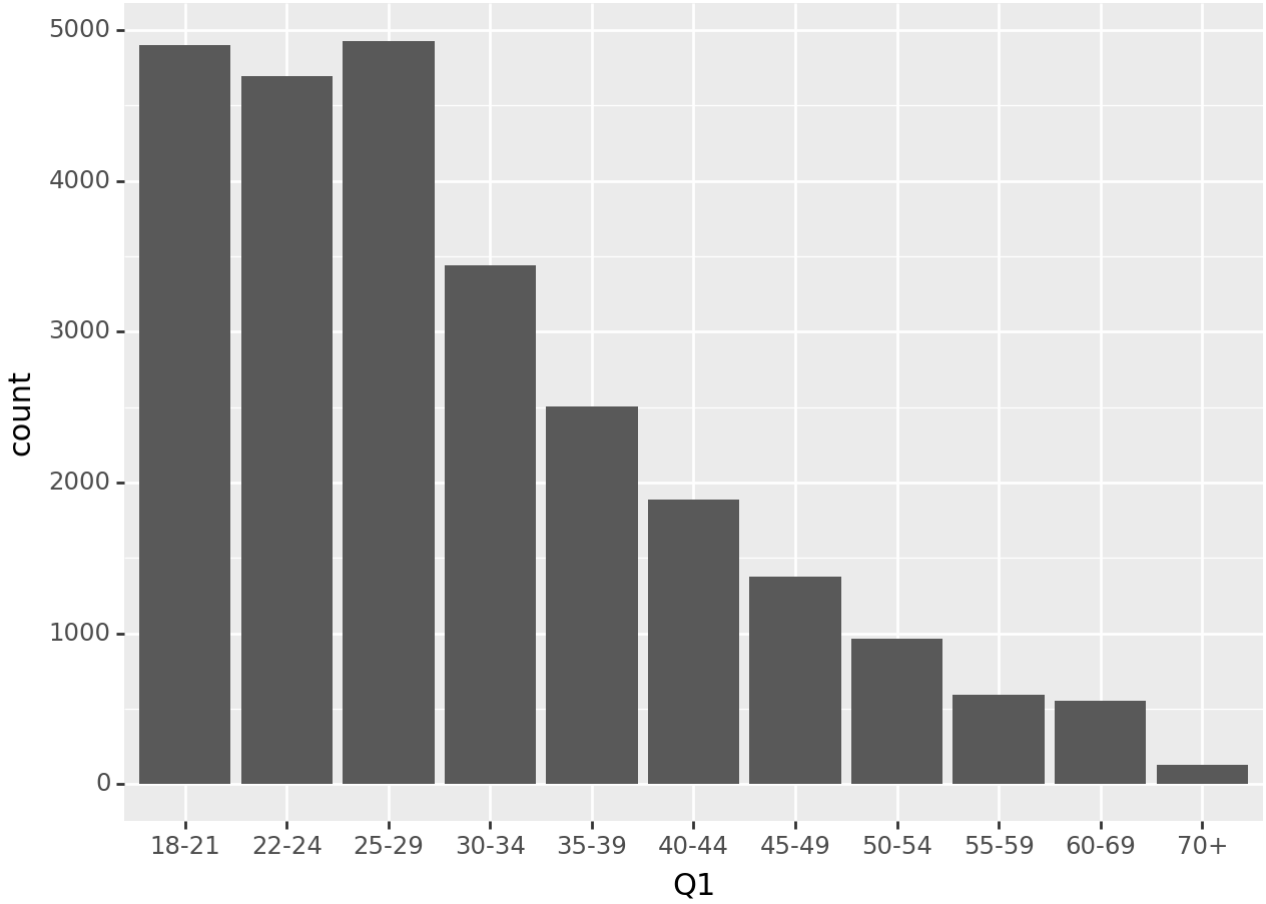
Creating a ggplot in `plotnine`

In [16]:
```
from plotnine import *
```

Creating a ggplot in `plotnine`

In [16]:
```
from plotnine import *
```

In [17]:
```
q1_plot = ggplot(data = kaggle2021) + geom_bar(aes(x = 'Q1')) # Basic 
q1_plot
```



Out[17]: <Figure Size: (640 x 480)>

Compare to base `pandas`

Compare to base `pandas`

In [18]:
```
# First we need to group dataset by 'Age group' (Q1) and summarize it w
kaggle2021_q1_grouped = kaggle2021.groupby(['Q1']).size()
kaggle2021_q1_grouped.head(n = 3)
```

Out[18]:
```
Q1
18-21    4901
22-24    4694
25-29    4931
dtype: int64
```

Compare to base `pandas`

In [18]:
```
# First we need to group dataset by 'Age group' (Q1) and summarize it w
kaggle2021_q1_grouped = kaggle2021.groupby(['Q1']).size()
kaggle2021_q1_grouped.head(n = 3)
```

Out[18]:
```
Q1
18-21    4901
22-24    4694
25-29    4931
dtype: int64
```

In [19]:
```
kaggle2021_q1_grouped.plot(kind = 'bar')
```

Out[19]:
```
<Axes: xlabel='Q1'>
```

Compare to `matplotlib`

Compare to `matplotlib`

In [20]:
```
import matplotlib.pyplot as plt
```

Compare to `matplotlib`

In [20]:
```
import matplotlib.pyplot as plt
```

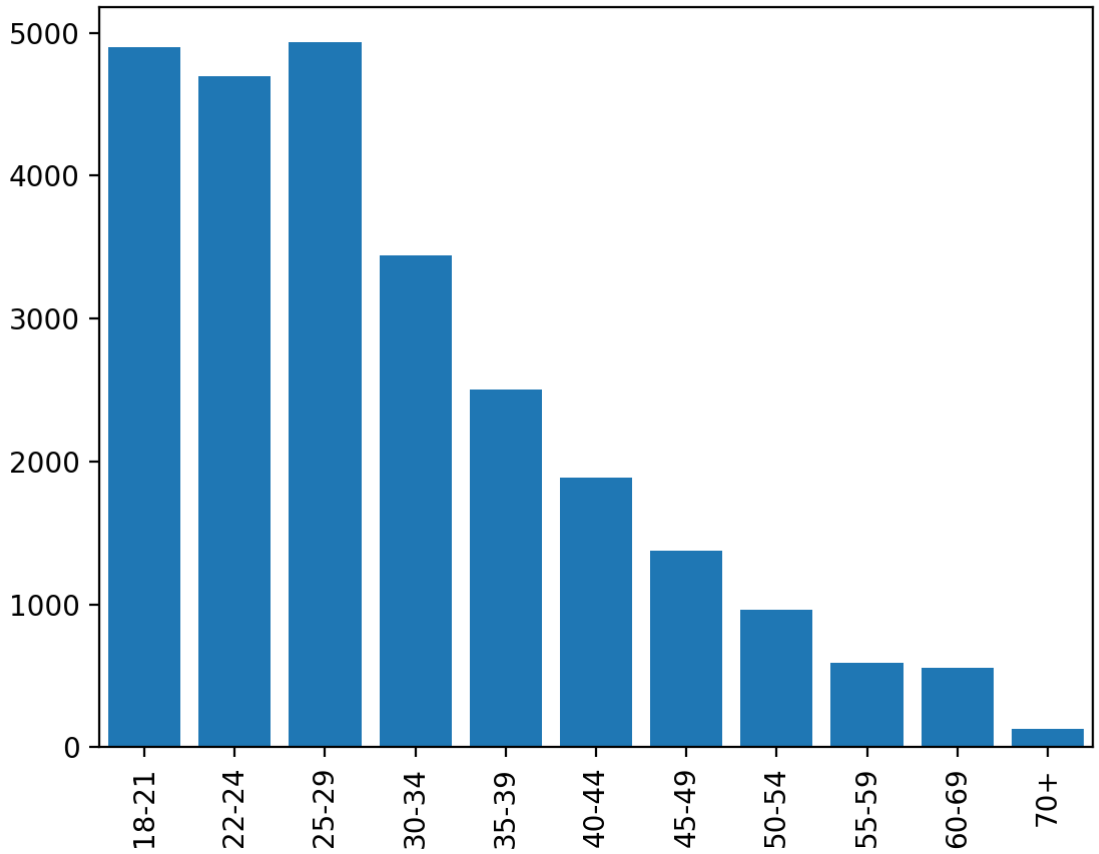
In [21]:
```
# `matplotlib` is more low-level library
# plots would need more work to be 'prettified'
plt.bar(x = kaggle2021_q1_grouped.index, height = kaggle2021_q1_grouped
```

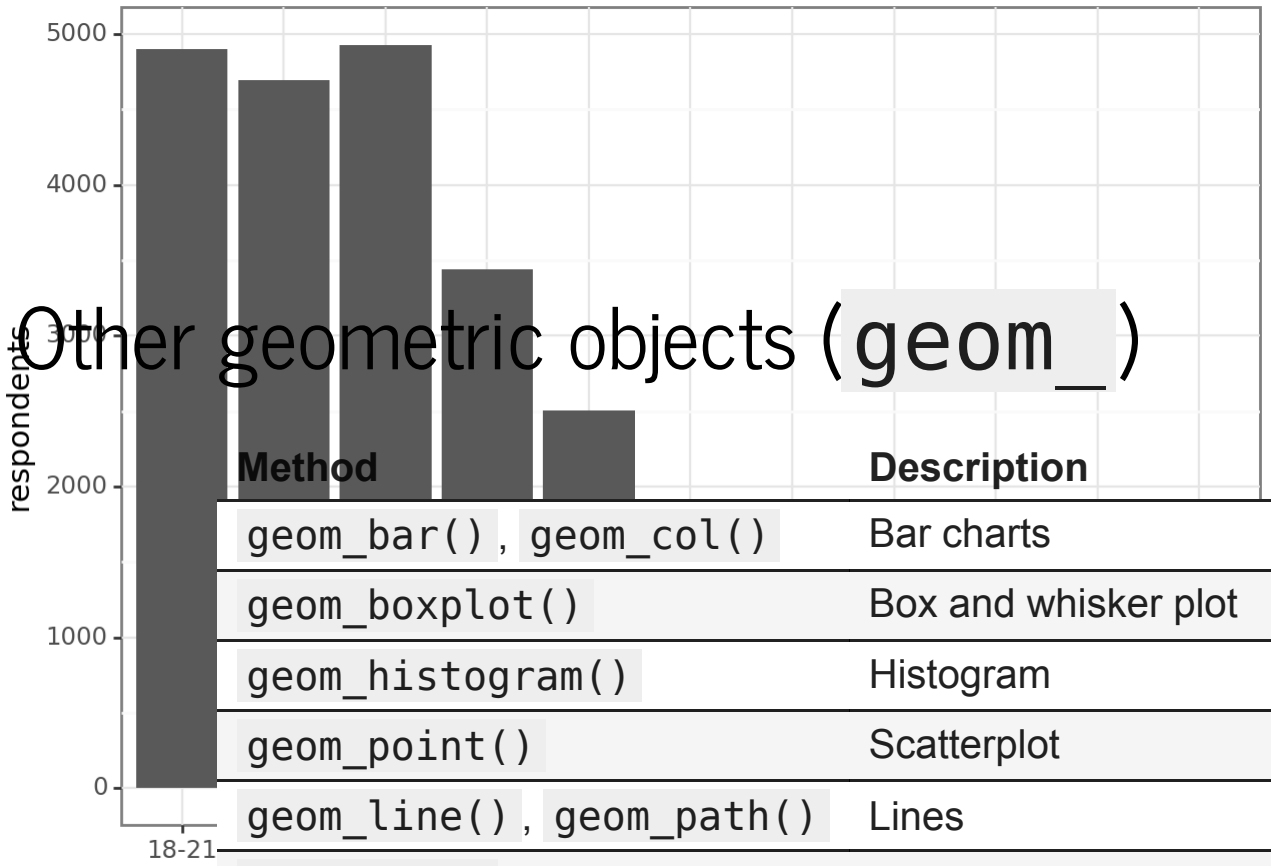
Out[21]:
```
<BarContainer object of 11 artists>
```

Prettifying ggplot in `plotnine`

Prettifying ggplot in `plotnine`

In [22]:
```
# Here we change default axes' labels and then apply B&W theme
q1_plot_pretty = q1_plot +\
    labs(x = 'Age group', y = 'respondents') +\
    theme_bw()
q1_plot_pretty
```


5000
4000
3000
2000
1000
0
18-21
22-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-69
70+



Other geometric objects (`geom_`)

Method	Description
`geom_bar()`, `geom_col()`	Bar charts
`geom_boxplot()`	Box and whisker plot
`geom_histogram()`	Histogram
`geom_point()`	Scatterplot
`geom_line()`, `geom_path()`	Lines
`geom_map()`	Geographic areas
`geom_smooth()`	Smoothed conditional means
`geom_violin()`	Violin plots

Out[22]: <Figure

Writing plots out in `plotnine`

- Output format is automatically determined from write-out file extension
- Commonly used formats are PDF, PNG and EPS

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In [23]:
```
q1_plot_pretty.save('../temp/q1_plot_pretty.pdf')
```

```
/opt/spyder/spyder-env/lib/python3.10/site-packages/plotnine/ggp
lot.py:587: PlotnineWarning: Saving 6.4 x 4.8 in image.
/opt/spyder/spyder-env/lib/python3.10/site-packages/plotnine/ggp
lot.py:588: PlotnineWarning: Filename: ../temp/q1_plot_pretty.pd
f
```

Additional visualization materials

Books:

- Hieran, Kiely. 2019. *Data Visualization: A Practical Introduction*. Princeton, NJ: Princeton University Press
- Tufte, Edward. 2001. *The Visual Display of Quantitative Information*. 2nd ed. Cheshire, CT: Graphics Press

Online:

- Plotnine: Grammar of Graphics for Python
- Plotnine Documentation
- Ggplot2 Documentation

Next

- Linear regression
- Communicating results