What are the chances?

INTRODUCTION TO STATISTICS

George Boorman
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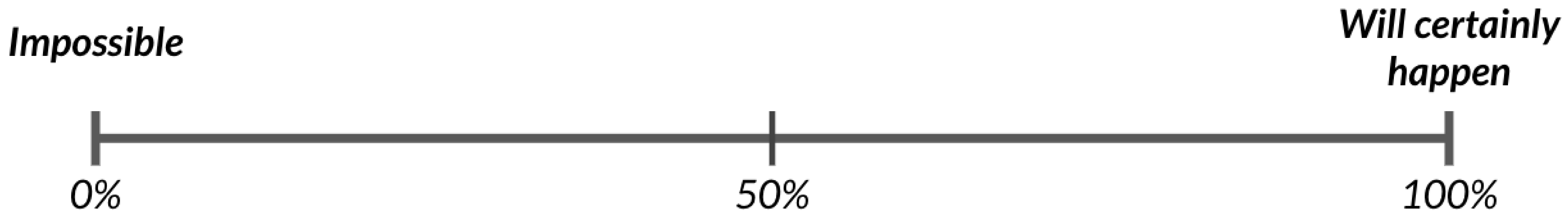
Measuring chance

What's the probability of an event?

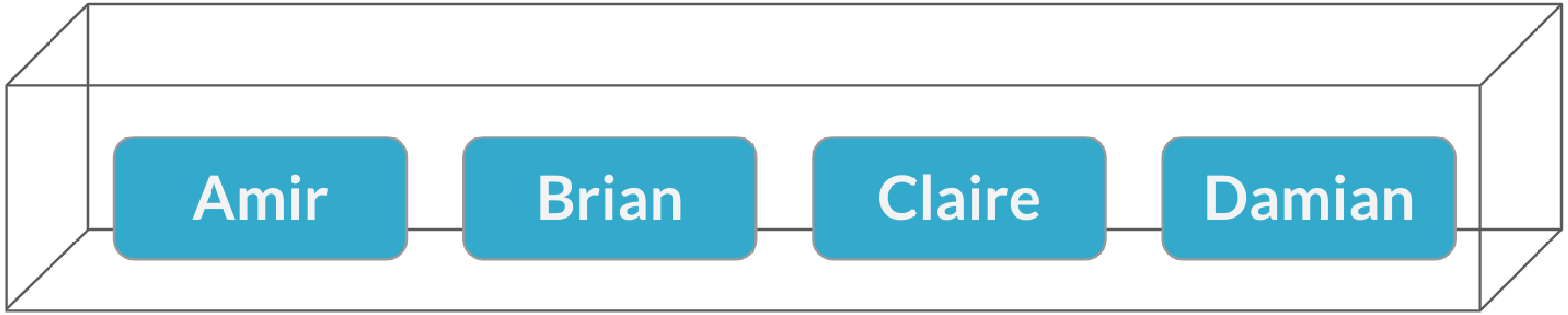
$$P(\text{event}) = \frac{\#\text{ ways event can happen}}{\text{total }\#\text{ of possible outcomes}}$$

Example: a coin flip

$$P(\text{heads}) = \frac{1\text{ way to get heads}}{2\text{ possible outcomes}} = \frac{1}{2} = 50\%$$

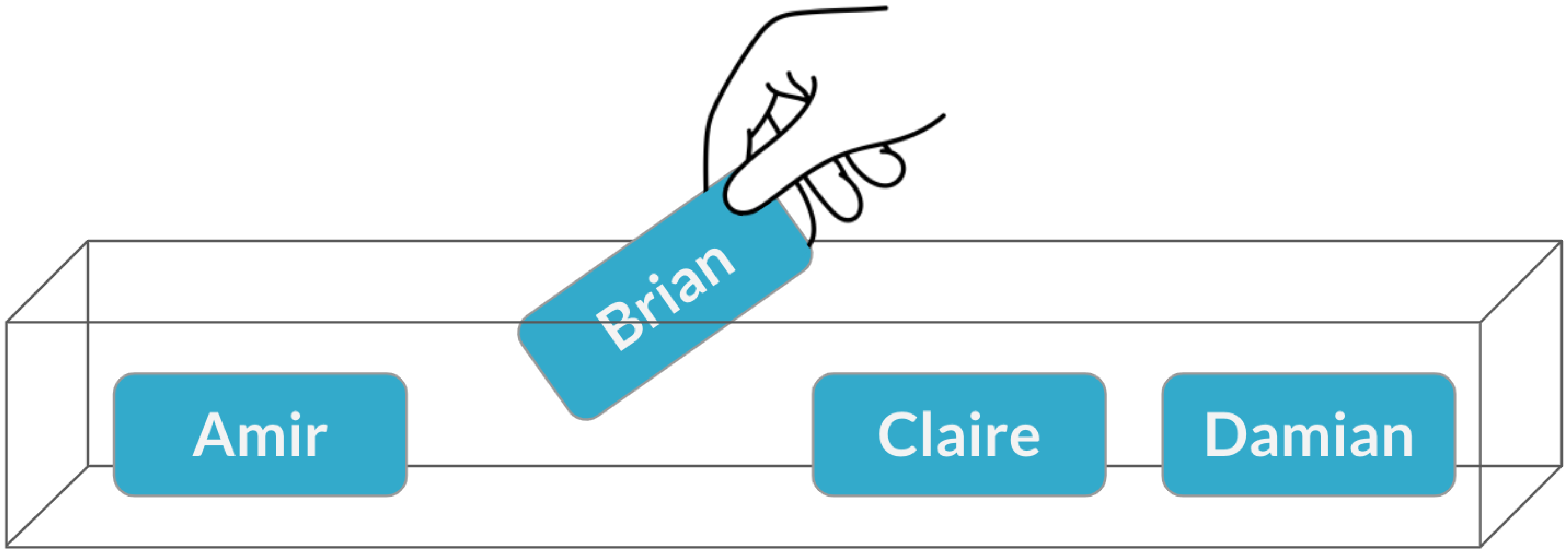


Assigning salespeople



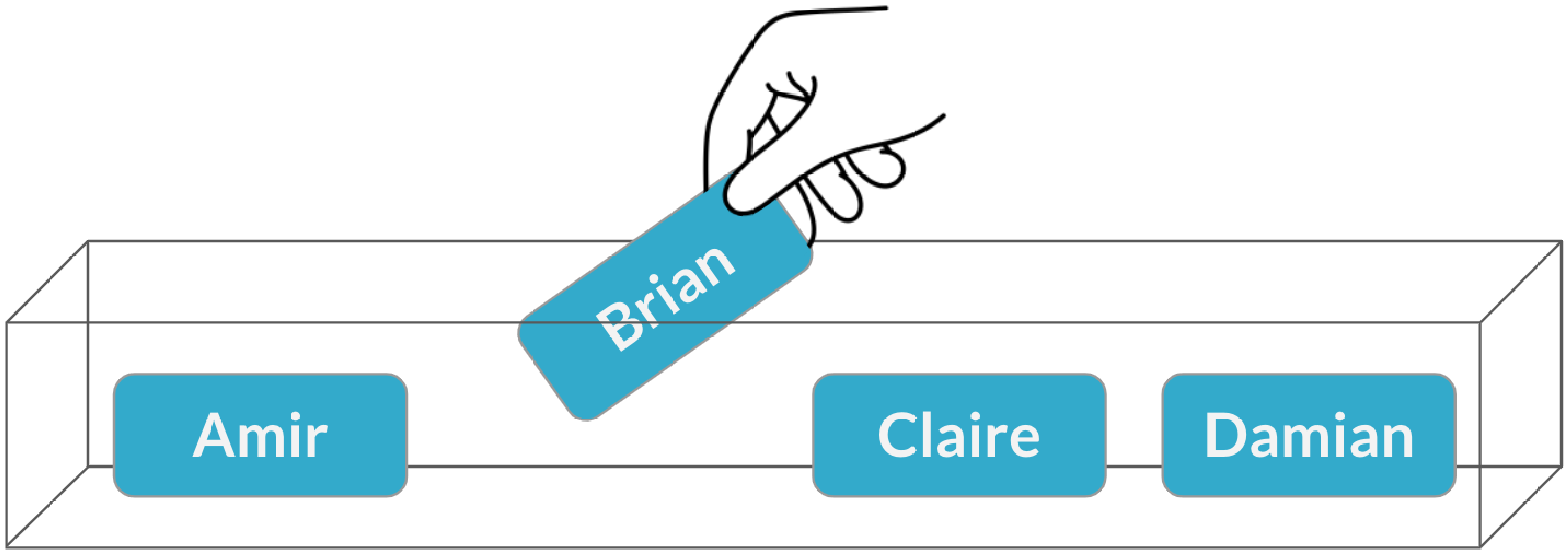
- **Sampling**

Assigning salespeople

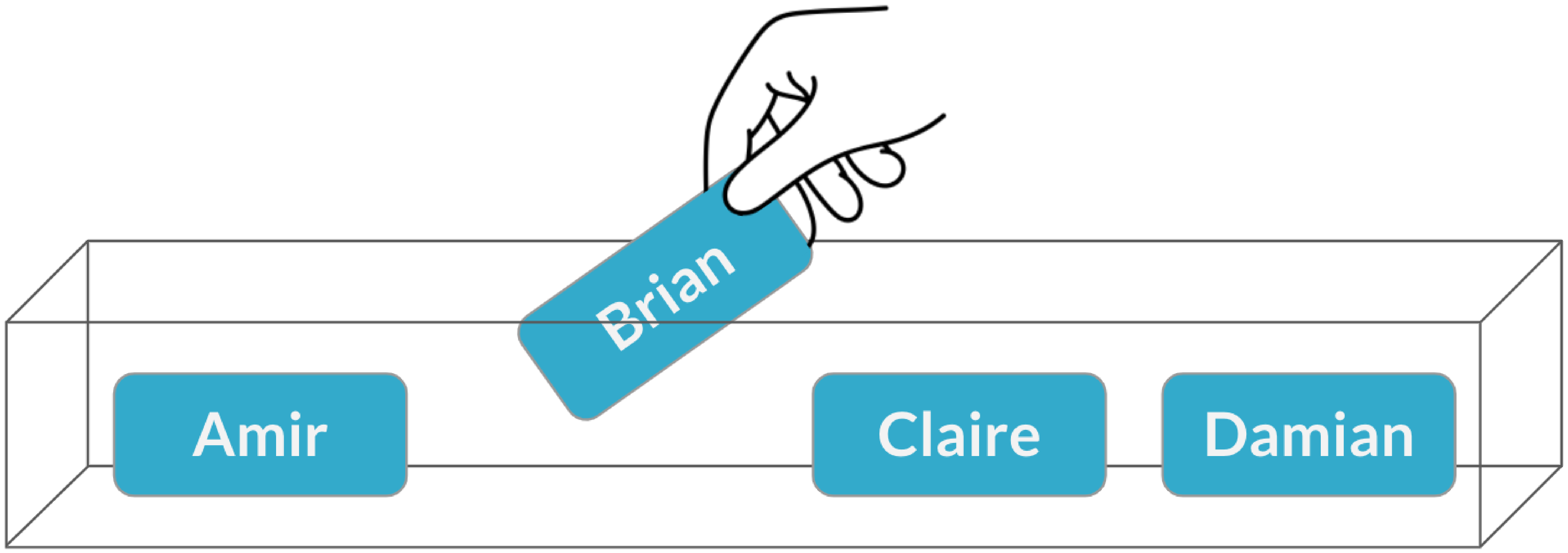


$$P(\text{Brian}) = \frac{1}{4} = 25\%$$

Morning meeting



Afternoon meeting



$$P(\text{Brian}) = \frac{1}{4} = 25\%$$

- **Sampling with replacement**

Independent probability

*Two events are **independent** if the probability of the second event **does not** change based on the outcome of the first event.*

Online retail sales

Order Number	Product Type	Net Quantity	Gross Sales	Discounts	Returns	Net Sales
200	Basket	13	3744.0	-316.80	0.00	3427.20
201	Basket	12	3825.0	-201.60	-288.0	3335.40
202	Basket	17	3035.0	-63.25	0.00	2971.75
203	Art & Sculpture	47	2696.8	-44.16	0.00	2652.64
204	Basket	17	2695.0	-52.50	-110.00	2532.50

[1] Image credit: https://unsplash.com/@rodriguezedm

Probability of an order for a jewelry product

Product Type	**Order Count**
Basket	551
Art & Sculpture	337
Jewelry	210
Kitchen	161
Home Decor	131
...	...
Total	**1767**

Probability of an order for a jewelry product

$$P(Jewelry) = \frac{Order\ Count(Jewelry)}{Sum(Total\ Order\ Count)}$$

$$P(Jewelry) = \frac{210}{1767}$$

$$P(Jewelry) = 11.88\%$$

Probabilities for all product types

Product Type	Order Count	Probability
Basket	551	31.18%
Art & Sculpture	337	19.07%
Jewelry	210	11.88%
Kitchen	161	9.11%
Home Decor	131	7.41%
...	...	...
Total	**1767**	**100%**

Let's practice!

INTRODUCTION TO STATISTICS

Conditional probability

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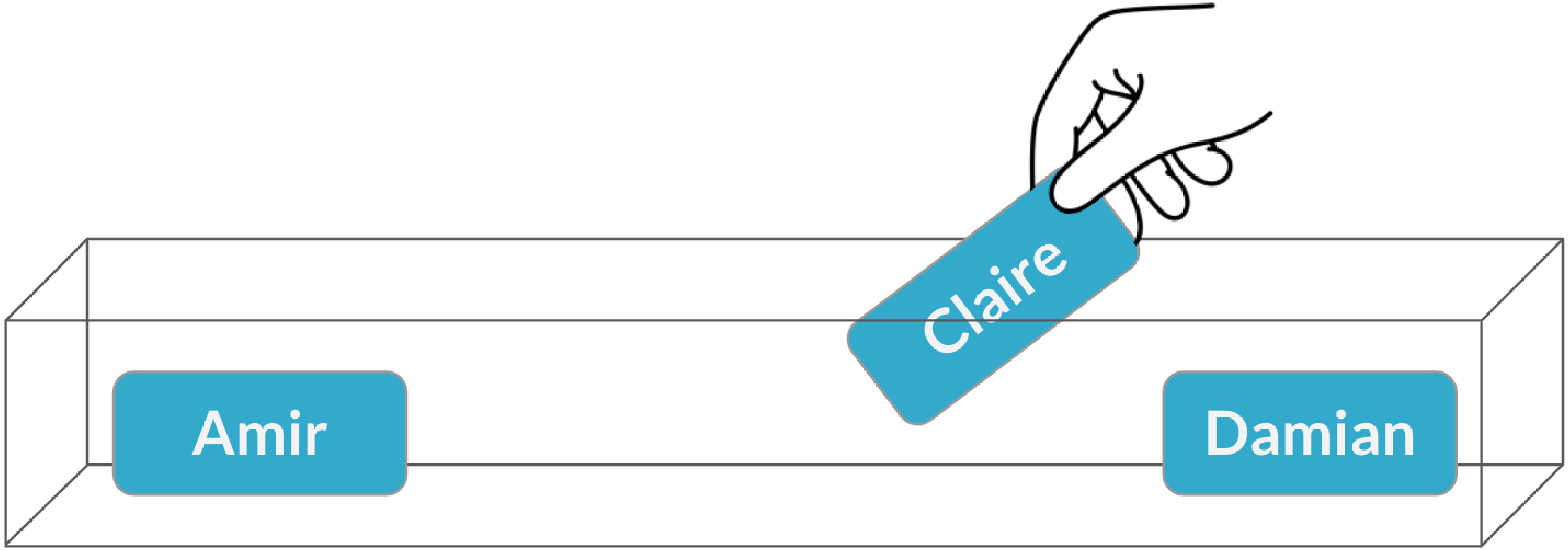
Multiple meetings

Sampling without replacement

Multiple meetings

Sampling without replacement



$$P(\text{Claire}) = \frac{1}{3} = 33\%$$

Dependent events

*Two events are **dependent** if the probability of the second event **is** affected by the outcome of the first event.*

Sampling without Replacement

First pick | *Second pick*

Amir

Brian

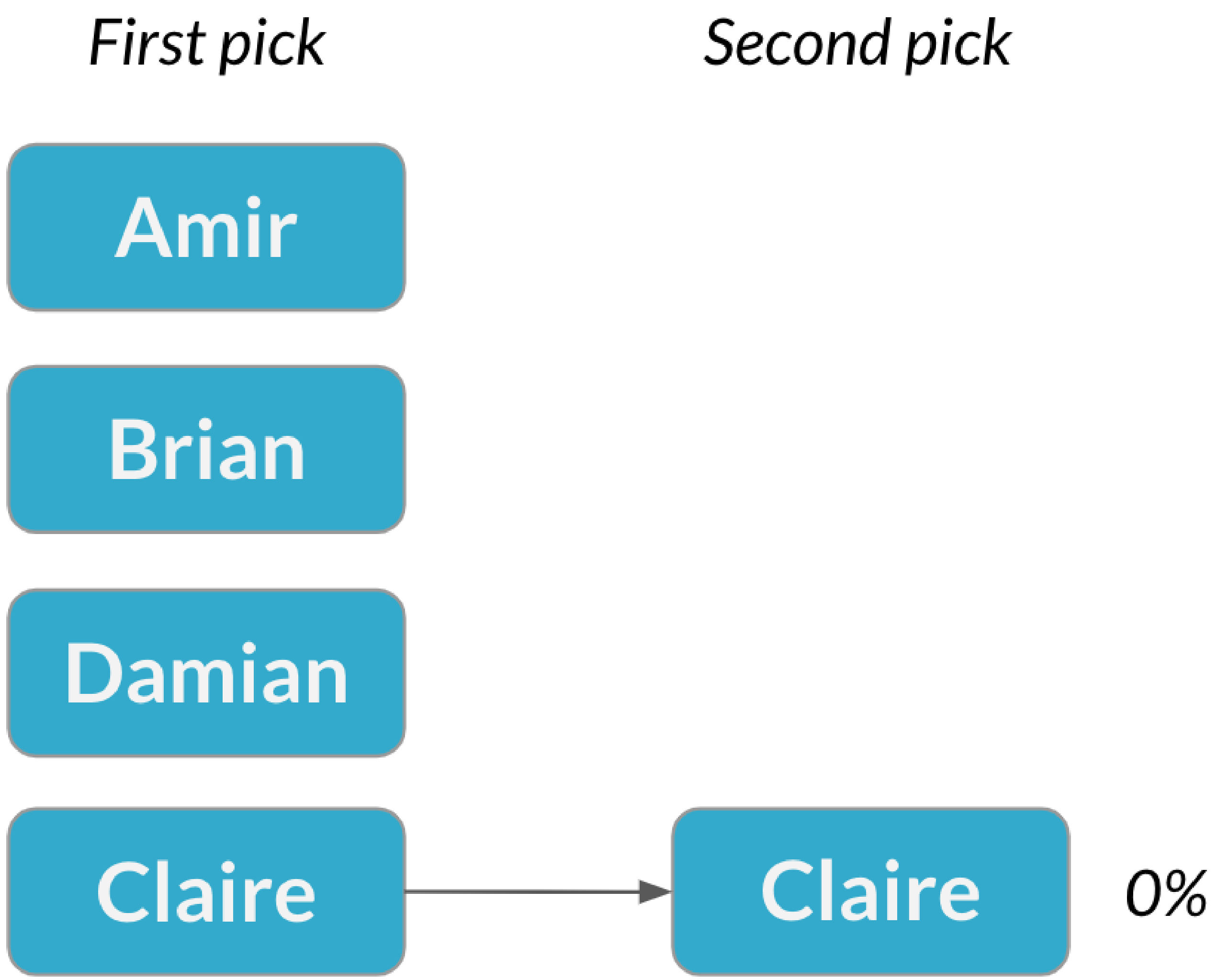
Damian

Claire

Dependent events

*Two events are **dependent** if the probability of the second event **is** affected by the outcome of the first event.*

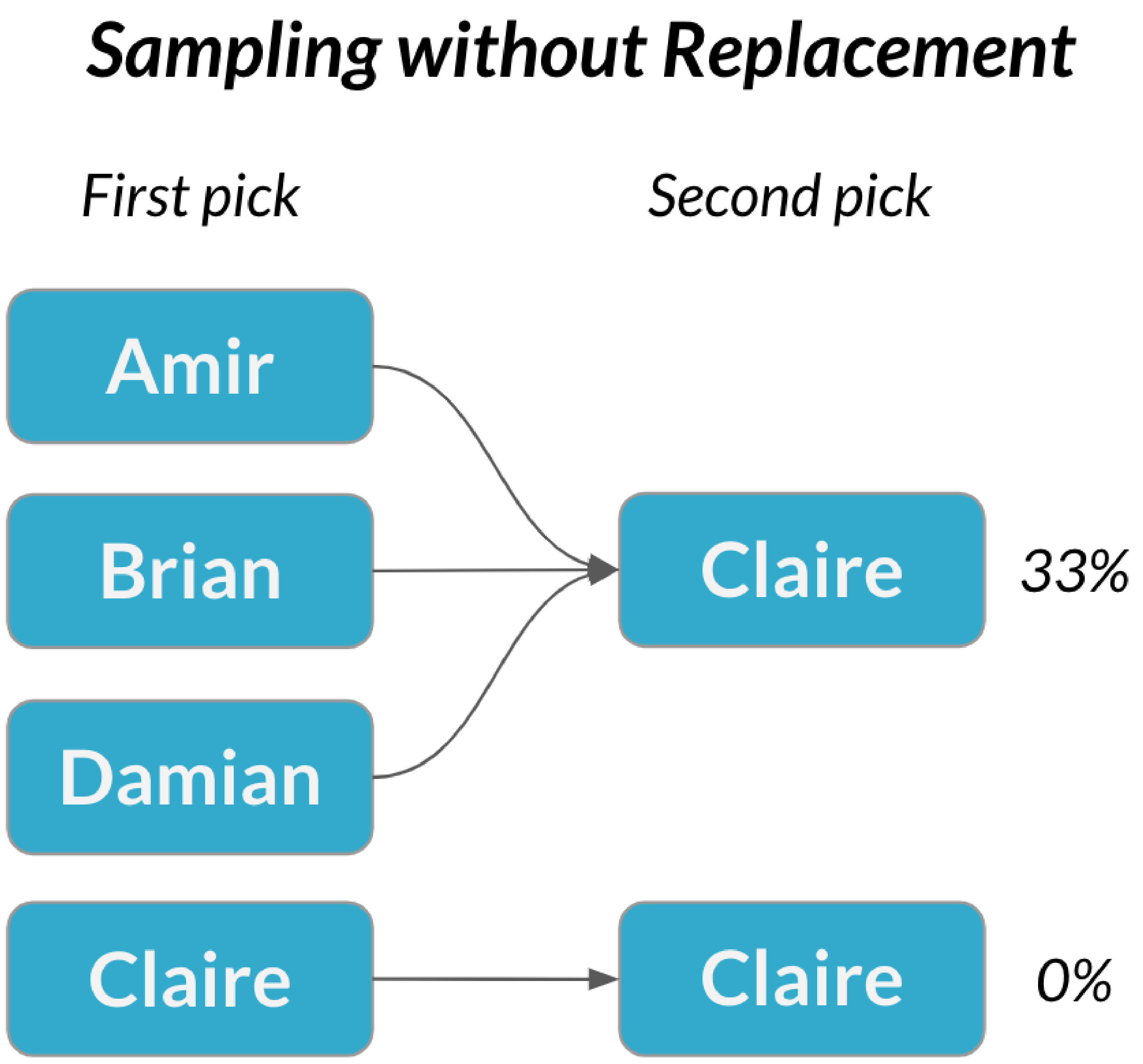
Sampling without Replacement



Dependent events

*Two events are **dependent** if the probability of the second event **is** affected by the outcome of the first event.*

Sampling without replacement = each pick is dependent



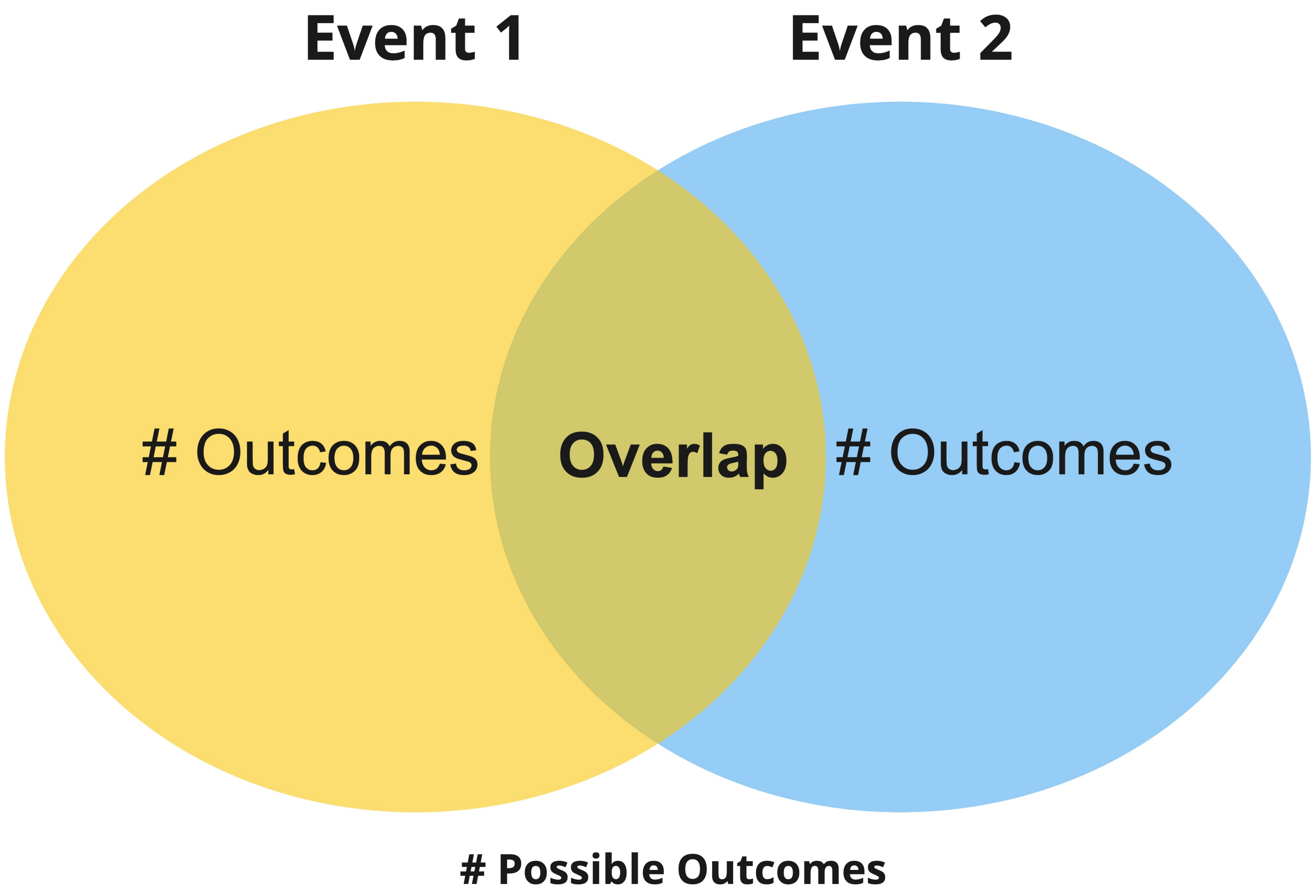
Conditional probability

- **Conditional probability** is used to calculate the probability of dependent events
  - The probability of one event is **conditional** on the outcome of another

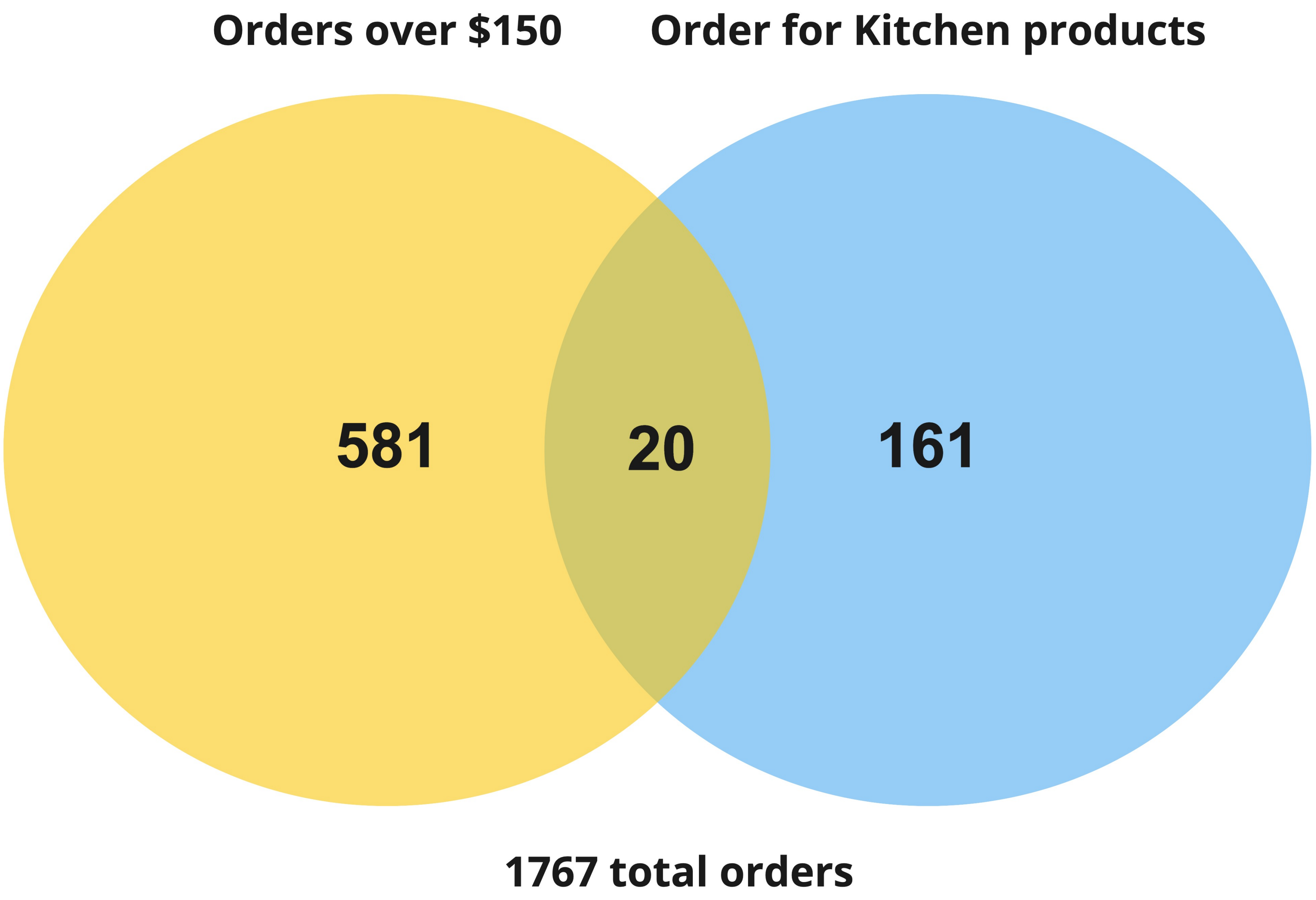
- Context, or **subject-matter expertise**, is critical!

[1] Image credit: https://unsplash.com/@pixeldan

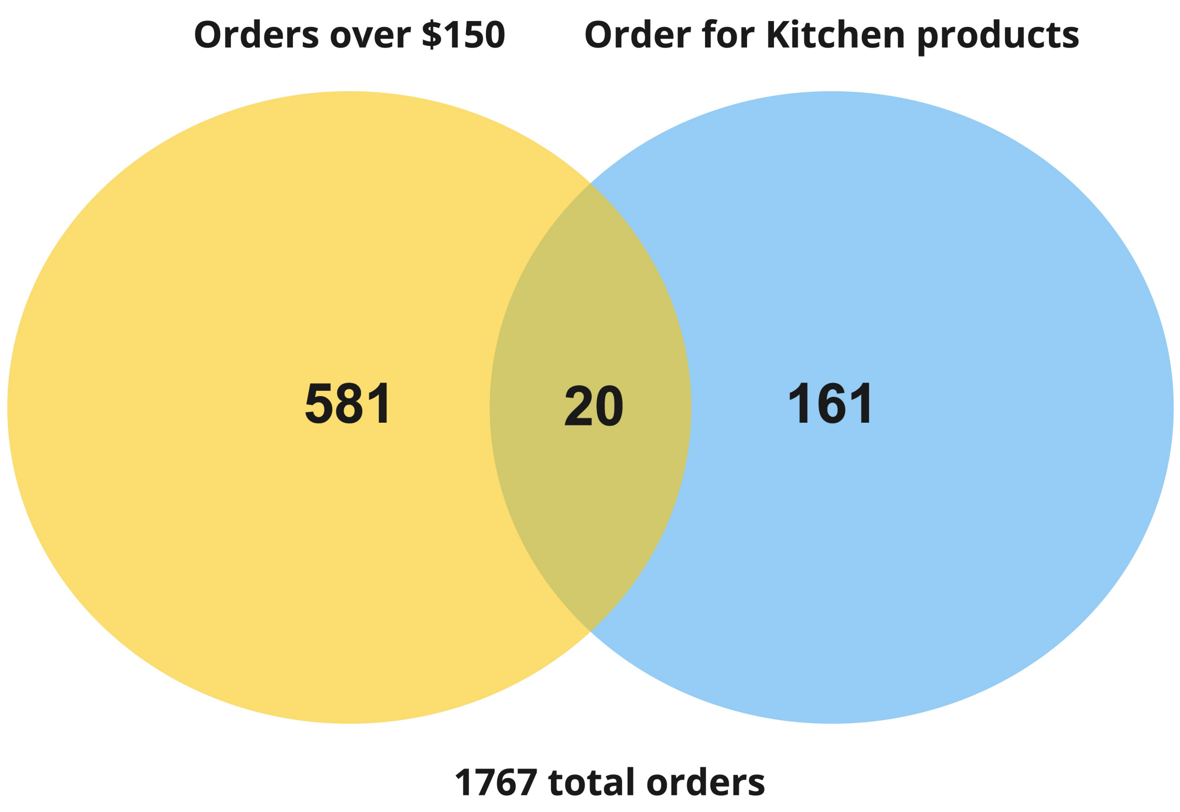
Venn diagrams

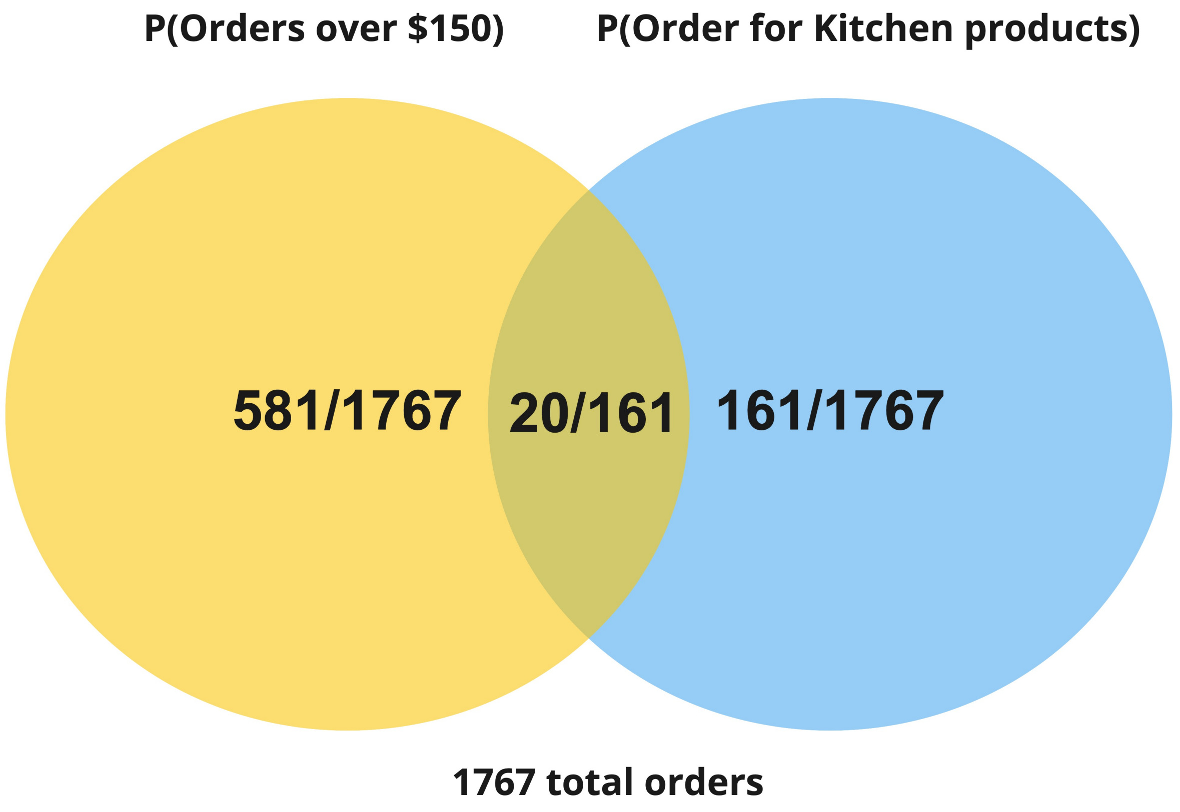


Kitchen sales over $150



Kitchen sales over $150

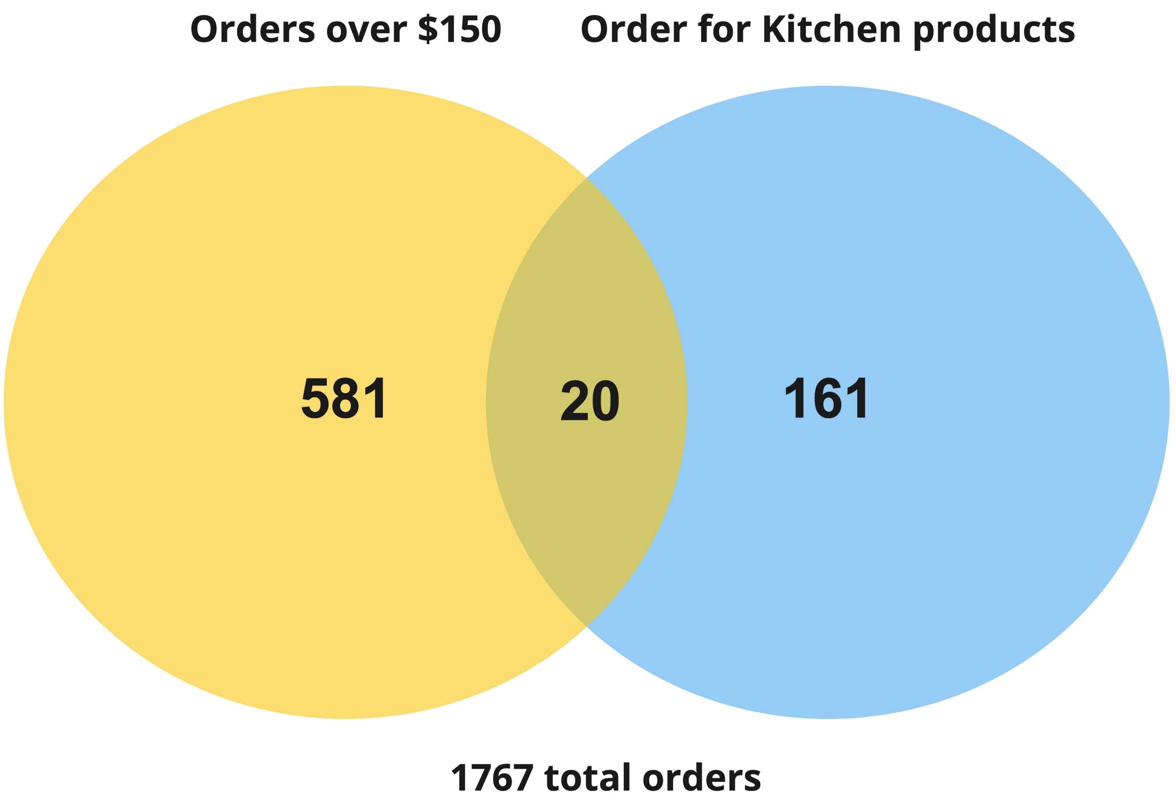


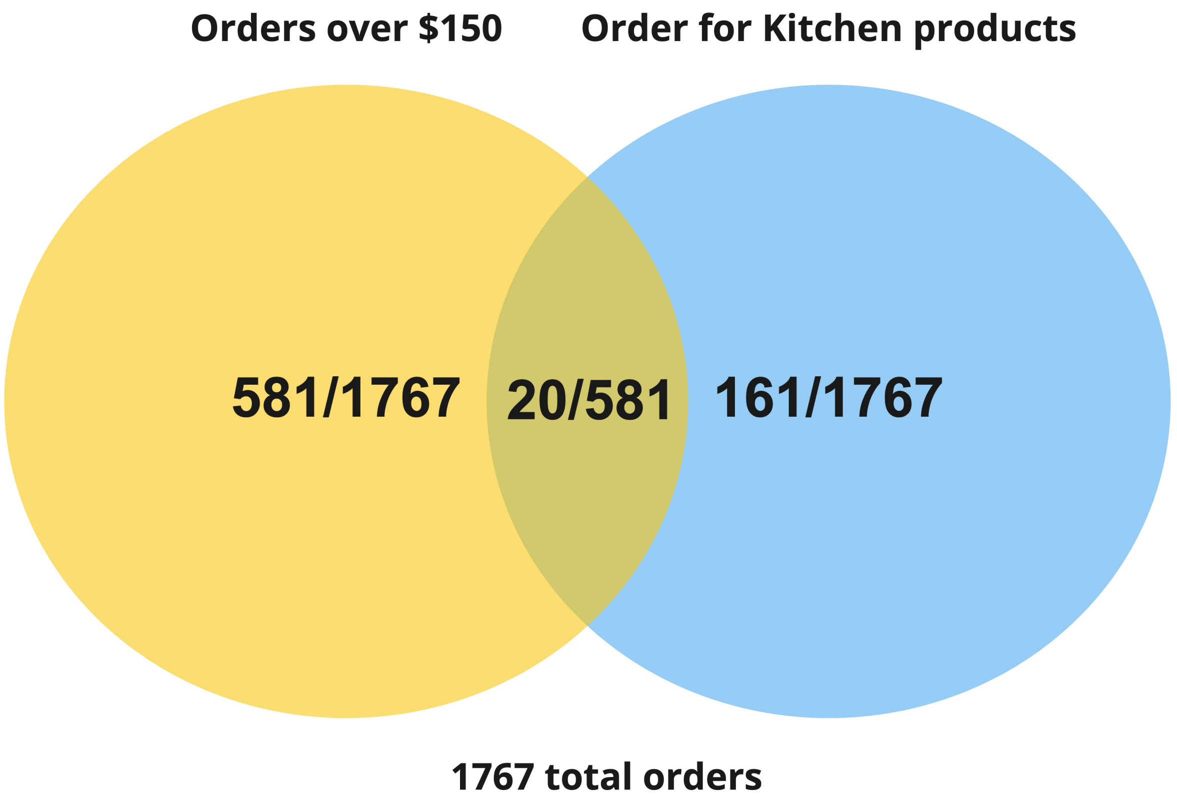


$$P(Order > 150|Kitchen) = \frac{\frac{20}{1767}}{\frac{161}{1767}}$$

$$P(Order > 150|Kitchen) = \frac{20}{161}$$

The order of events matters





$$P(Kitchen|Order > 150) = \frac{\frac{20}{1767}}{\frac{581}{1767}}$$

$$P(Kitchen|Order > 150) = \frac{20}{581}$$

Conditional probability formula

$$P(A|B) = \frac{P(A \; and \; B)}{P(B)}$$

- Probability of event A, given event B
- Probability of event A **and** event B
  - divided by the probability of event B

Let's practice!

INTRODUCTION TO STATISTICS

Discrete distributions

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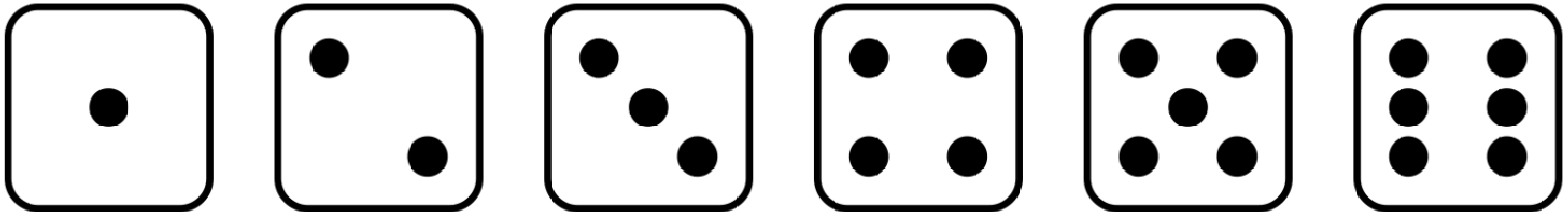
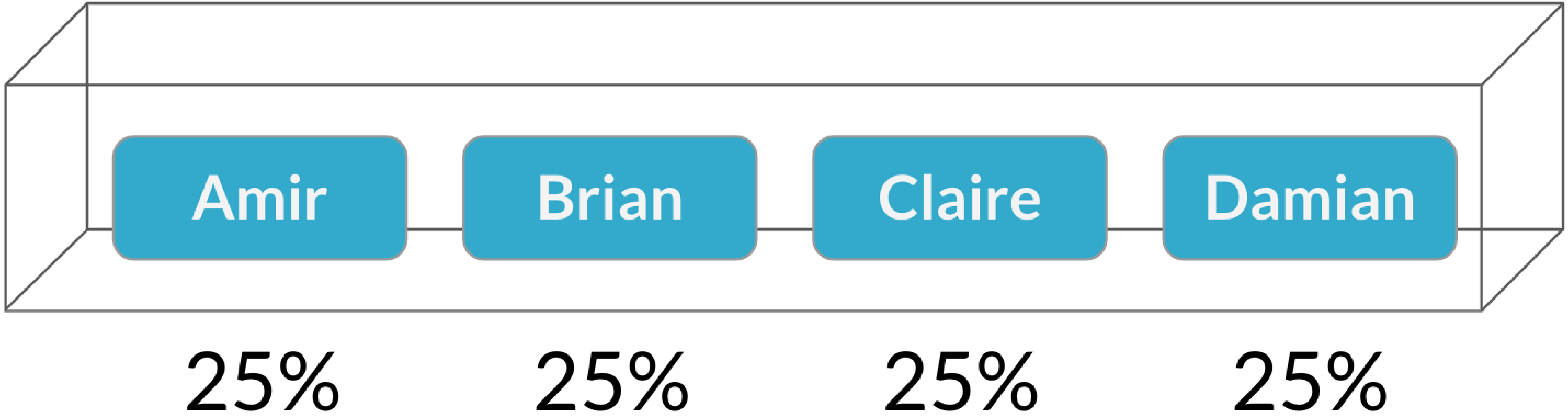
Rolling the dice



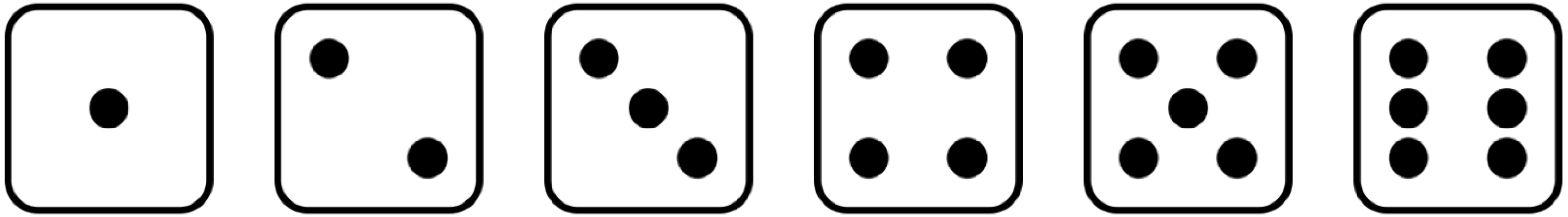
$\frac{1}{6}$ $\frac{1}{6}$ $\frac{1}{6}$ $\frac{1}{6}$ $\frac{1}{6}$ $\frac{1}{6}$

Choosing salespeople



Probability distribution

Describes the probability of each possible outcome in a scenario



1/6 1/6 1/6 1/6 1/6 1/6

Expected value: The ***mean*** of a probability distribution

Expected value of a fair die roll =

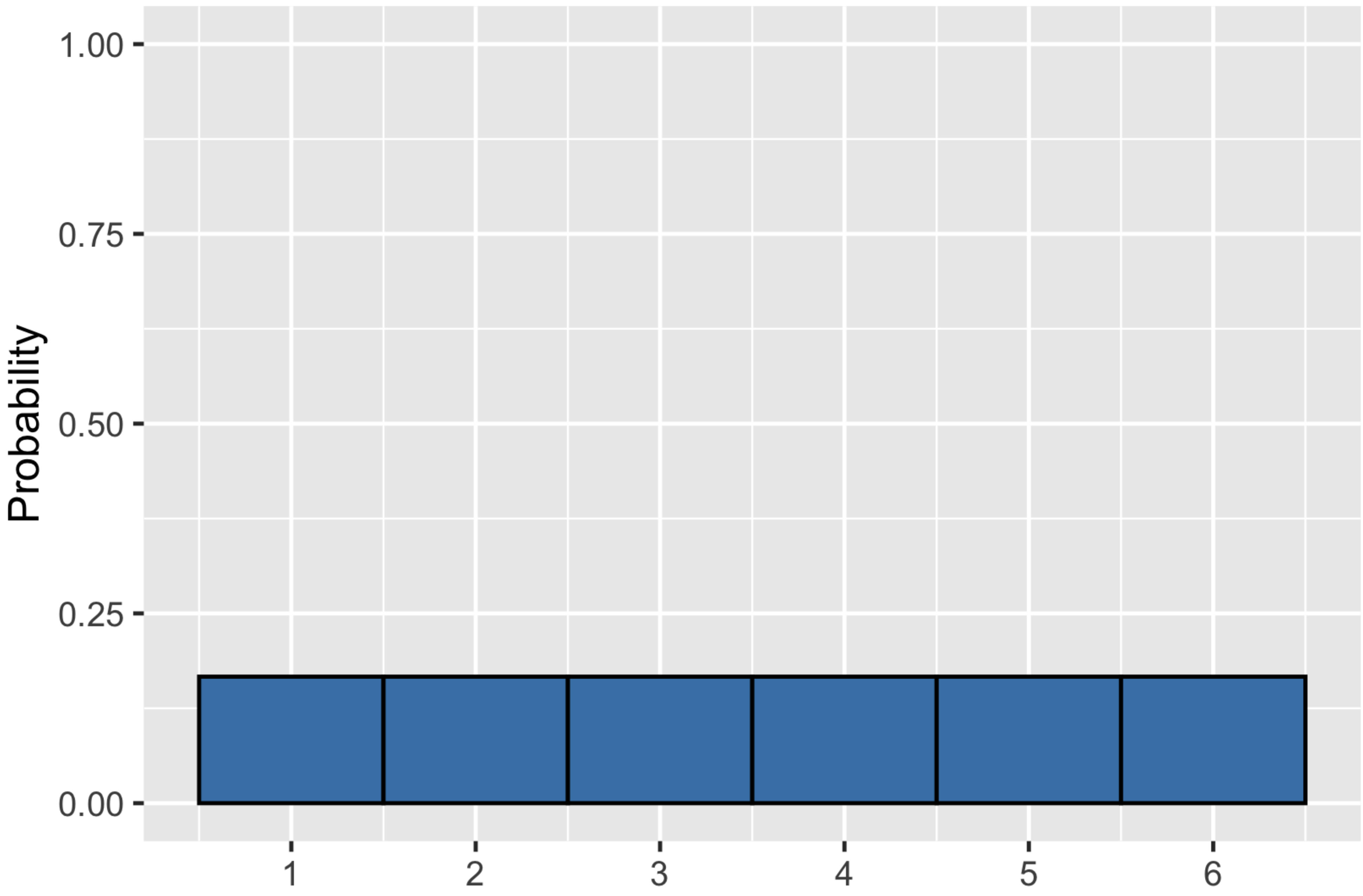
$$(1 \times \frac{1}{6}) + (2 \times \frac{1}{6}) + (3 \times \frac{1}{6}) + (4 \times \frac{1}{6}) + (5 \times \frac{1}{6}) + (6 \times \frac{1}{6}) = 3.5$$

Why are probability distributions important?

- Help us to quantify risk and inform decision making
- Used extensively in hypothesis testing
  - Probability that the results occurred by chance

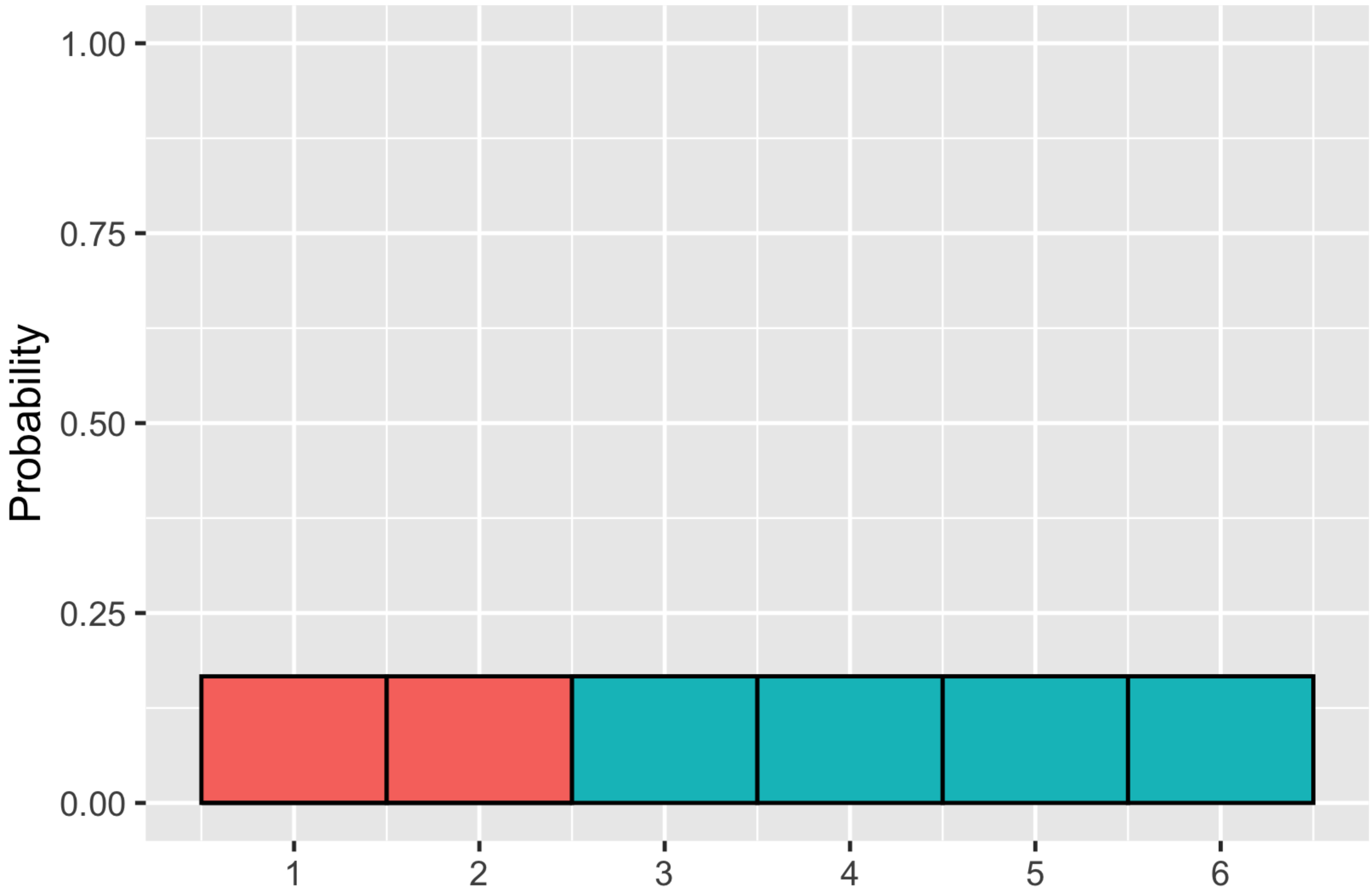
[1] Image credit: https://unsplash.com/@timmossholder

Visualizing a probability distribution



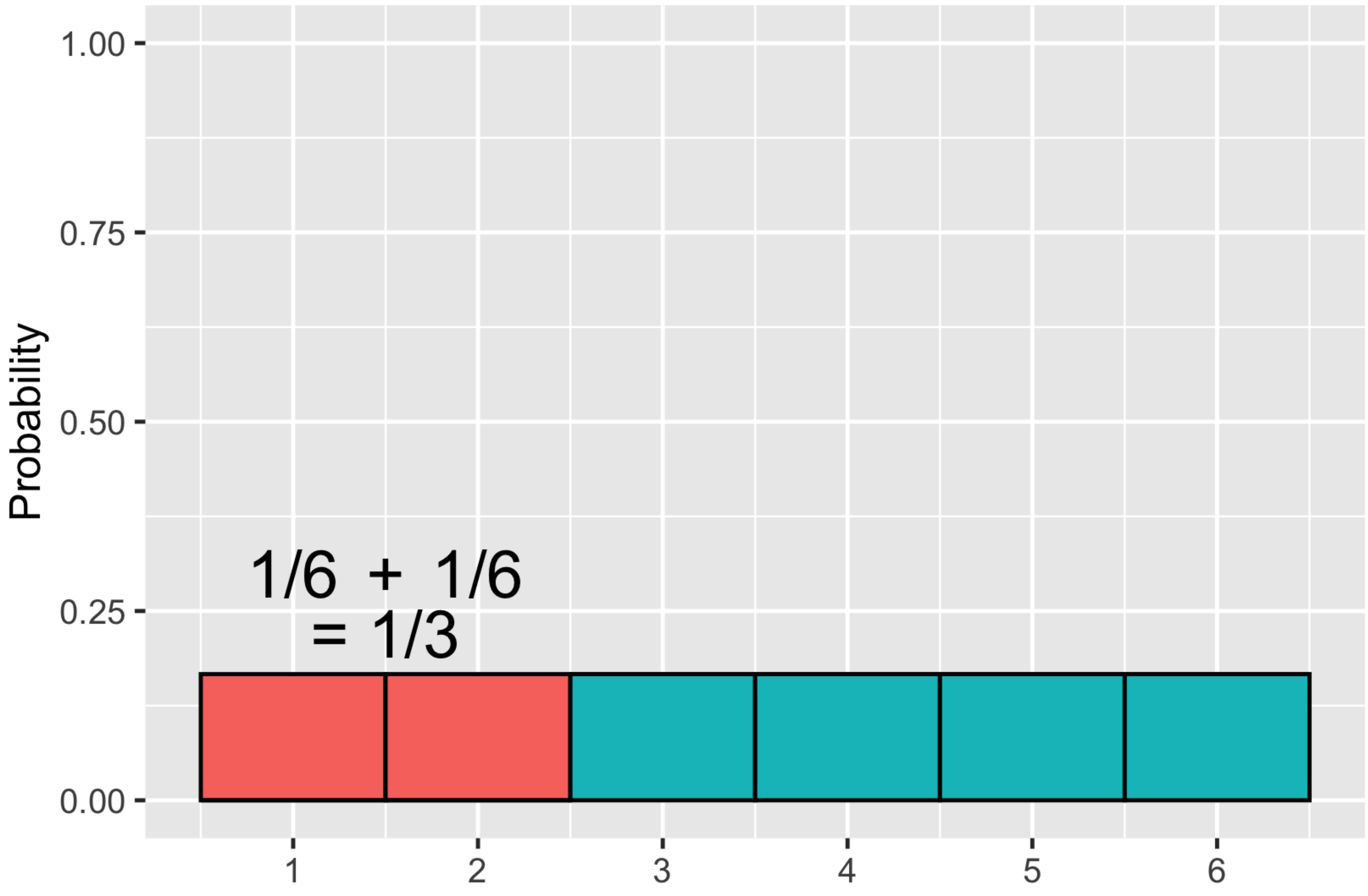
Probability = area

$$P(\text{die roll}) \leq 2 = ?$$

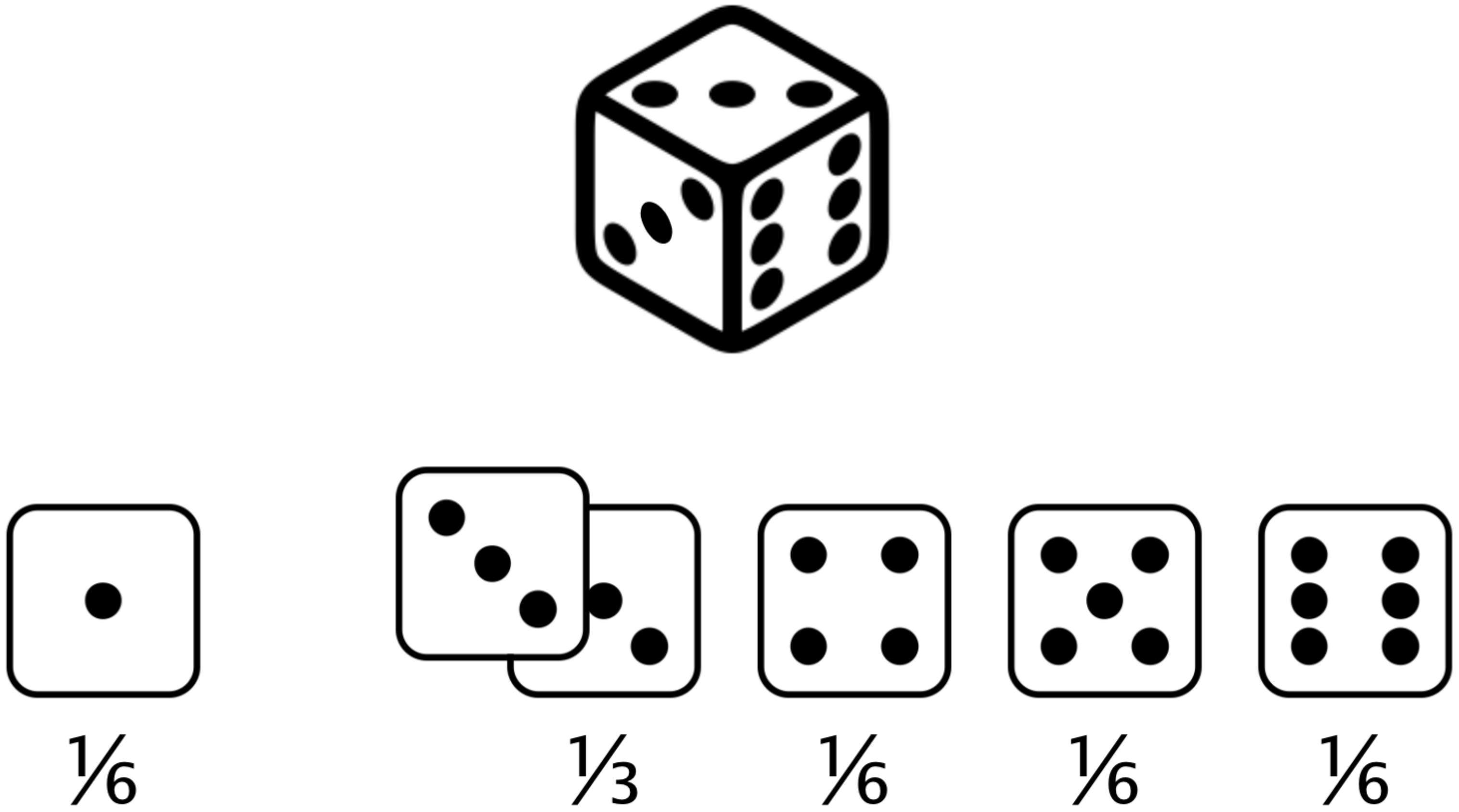


Probability = area

$$P(\text{die roll}) \leq 2 = 1/3$$



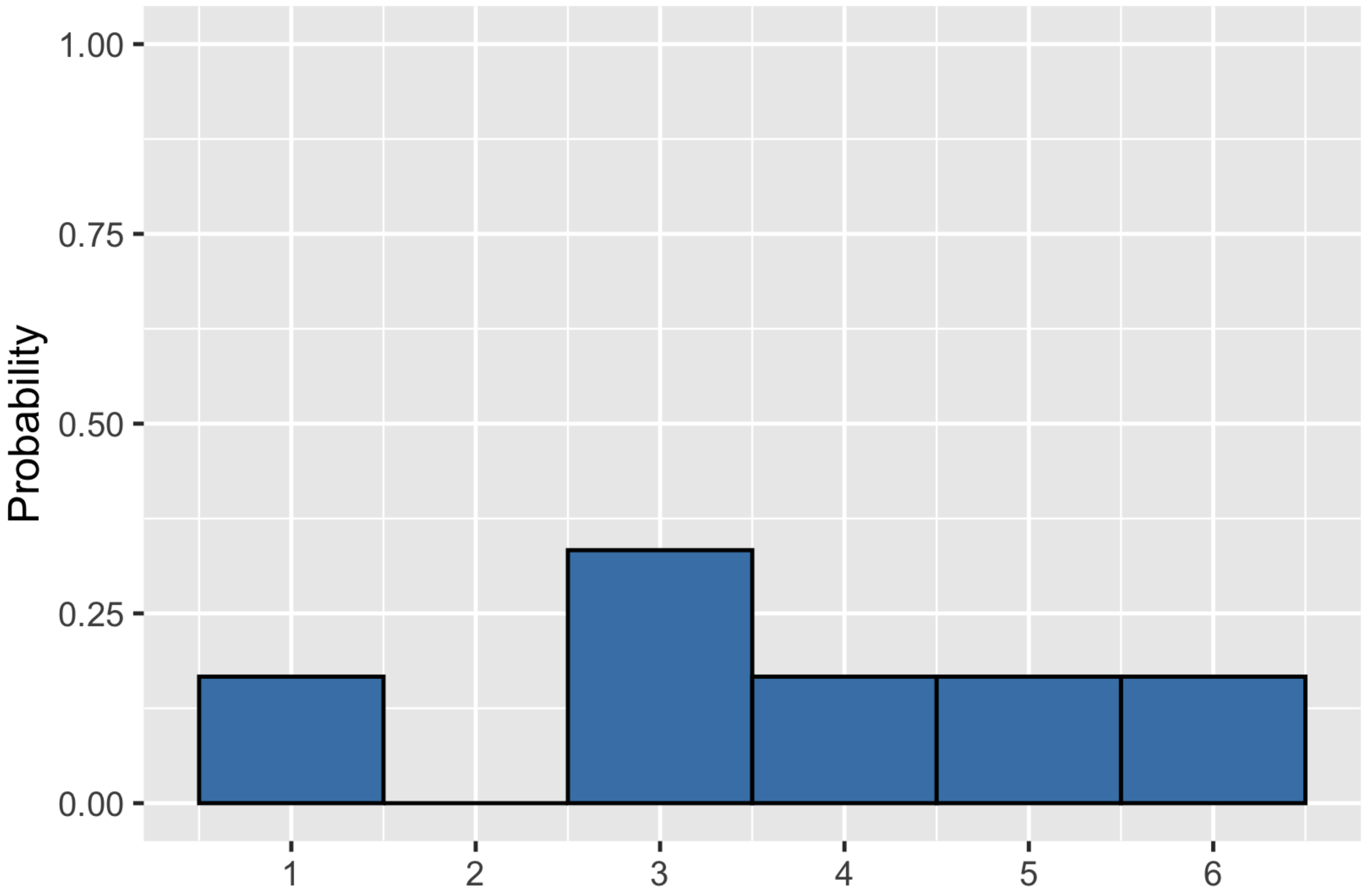
Uneven die



Expected value of uneven die roll =

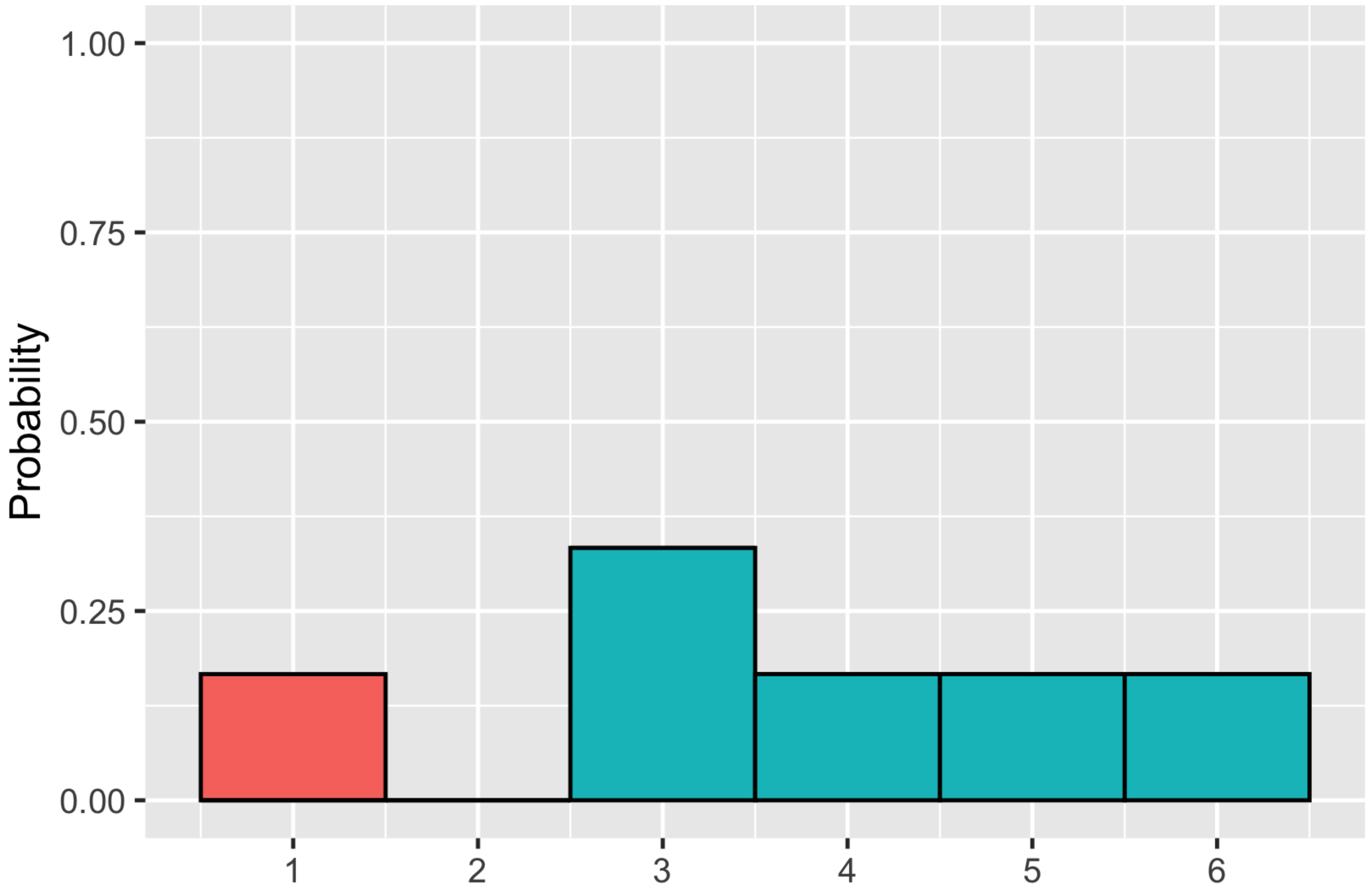
$$(1 \times \frac{1}{6}) + (2 \times 0) + (3 \times \frac{1}{3}) + (4 \times \frac{1}{6}) + (5 \times \frac{1}{6}) + (6 \times \frac{1}{6}) = 3.67$$

Visualizing uneven probabilities



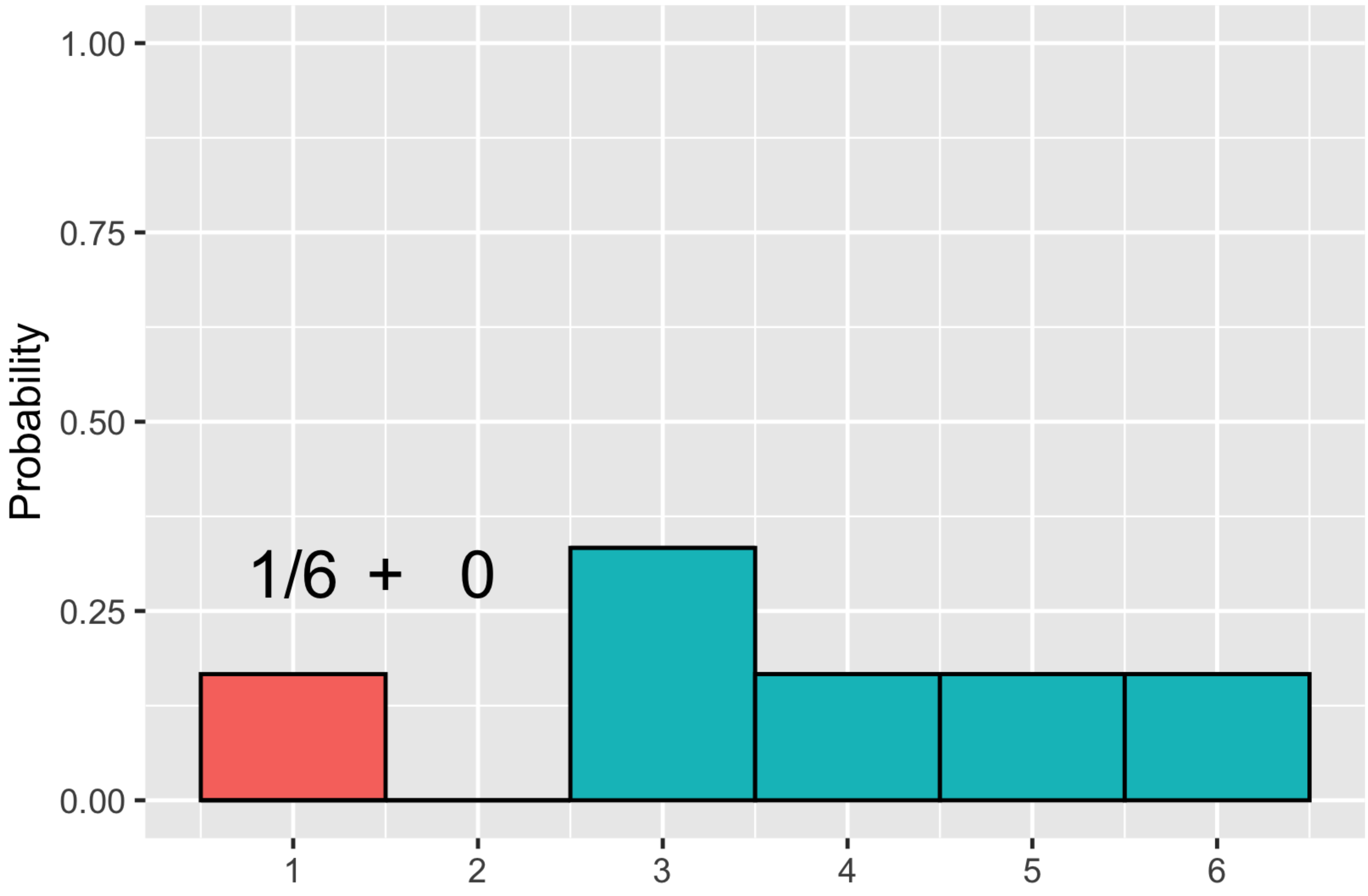
Adding areas

$$P(\text{uneven die roll}) \leq 2 = ?$$



Adding areas

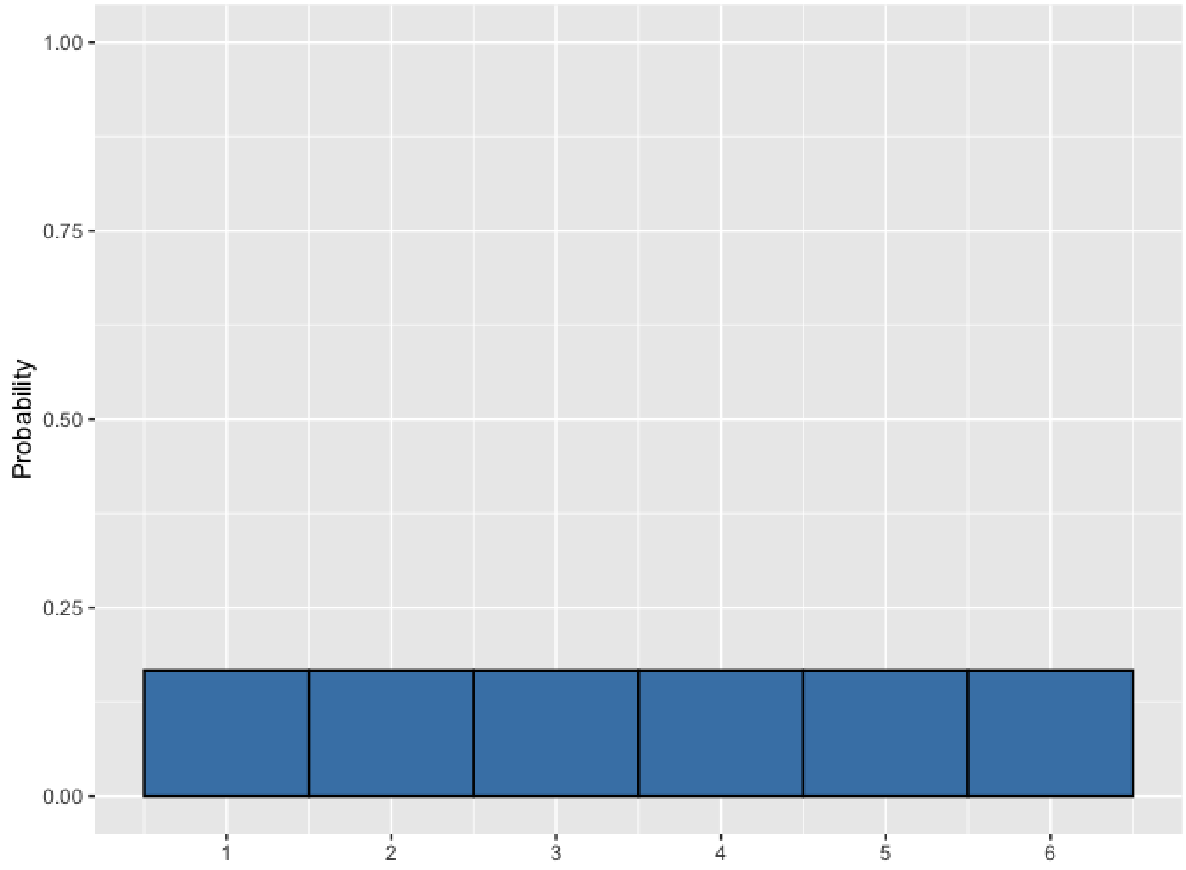
$$P(\text{uneven die roll}) \leq 2 = 1/6$$



Discrete probability distributions

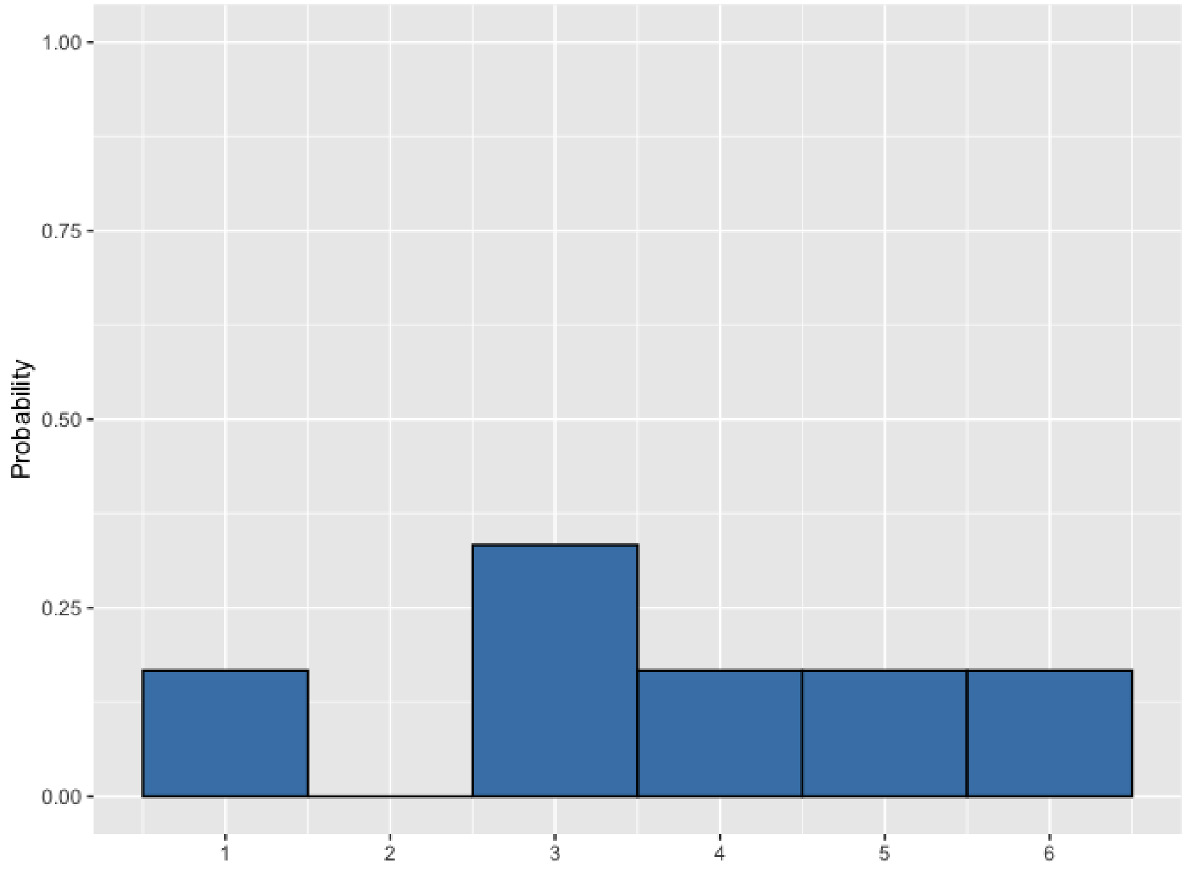
Describe probabilities for discrete outcomes

Fair die



Discrete uniform distribution

Uneven die



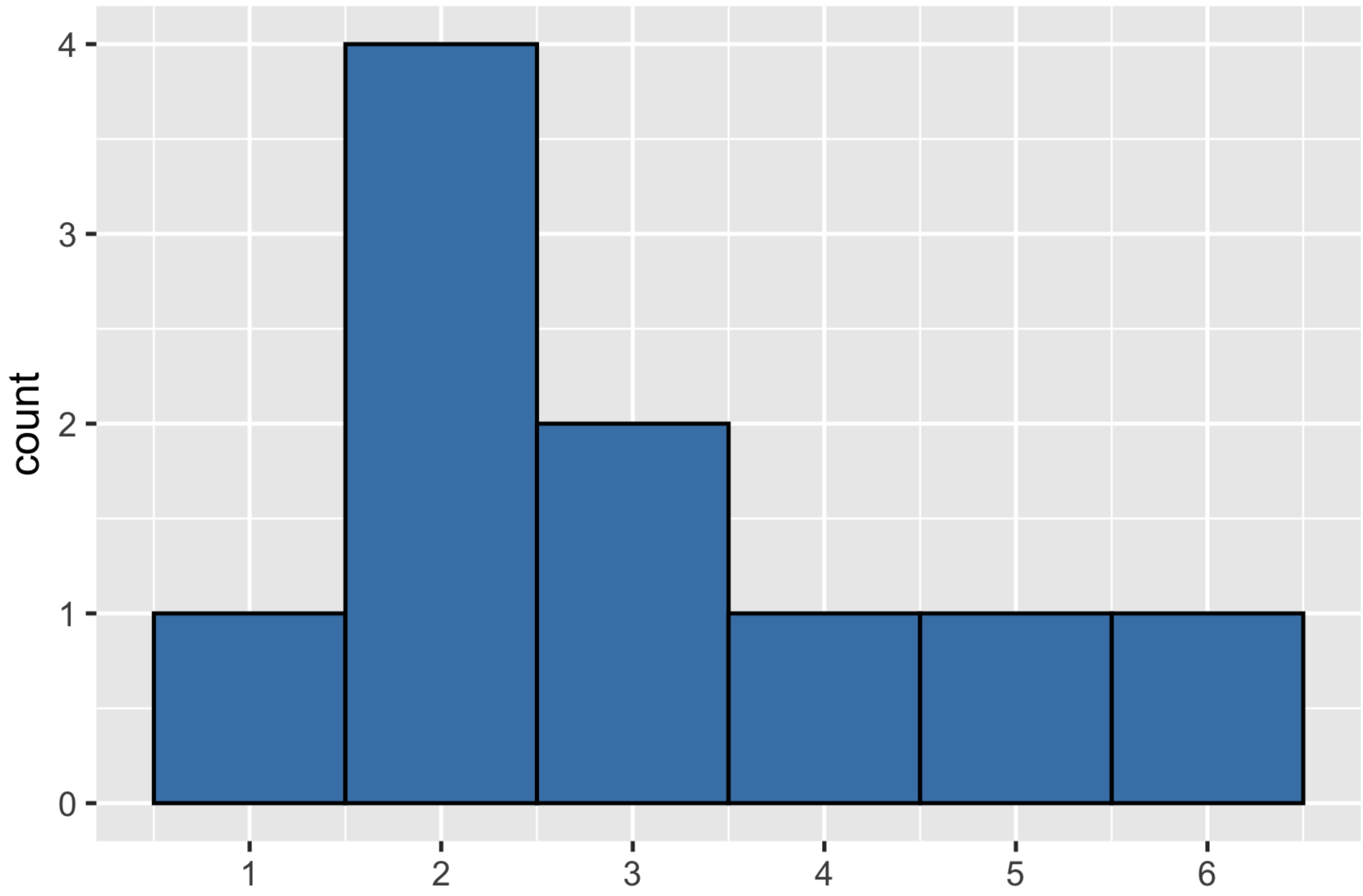
Sampling from a discrete distribution

Roll	Result
1	1
2	2
3	3
4	4
5	5
6	6

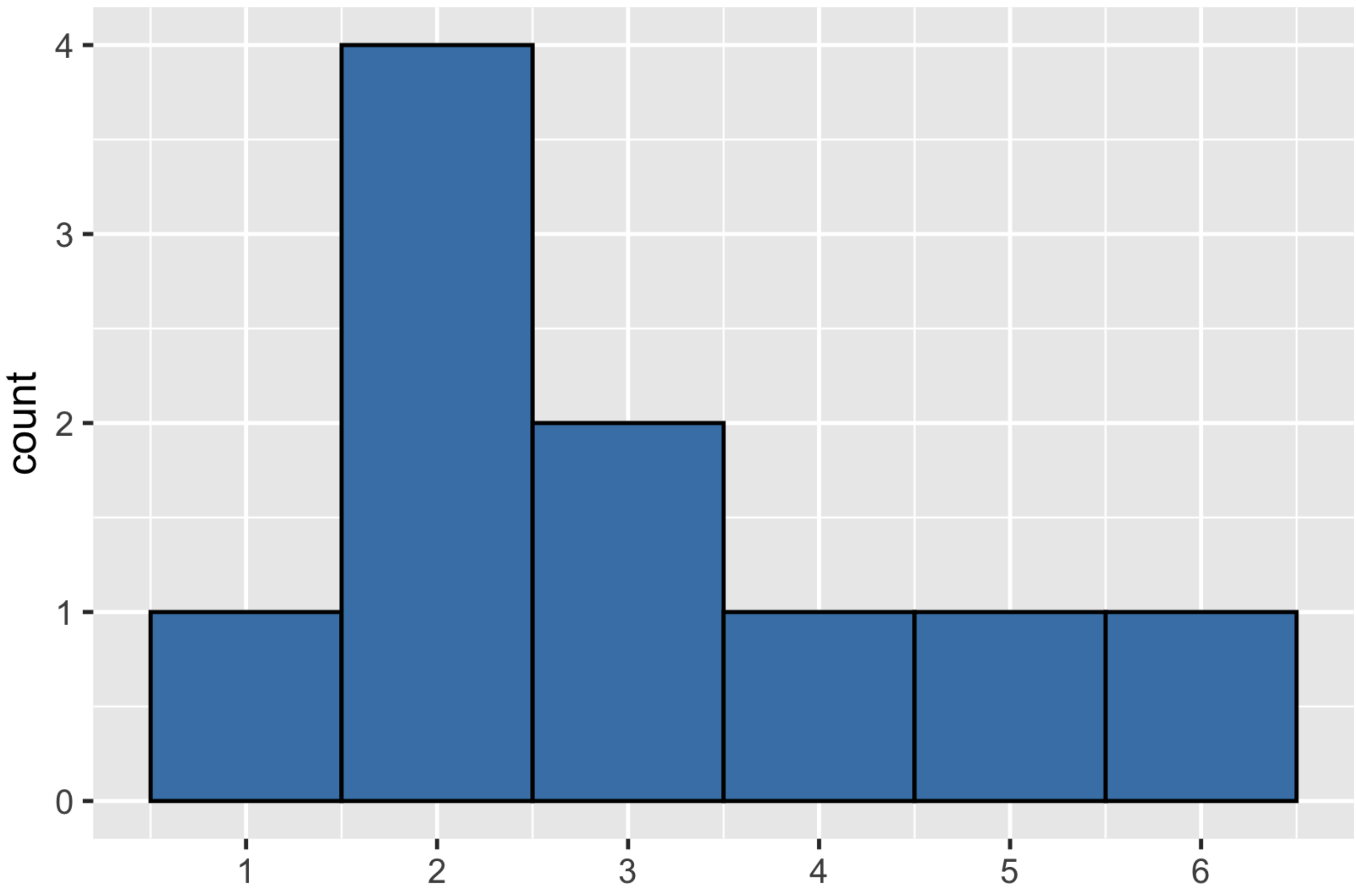
$Mean = 3.5$

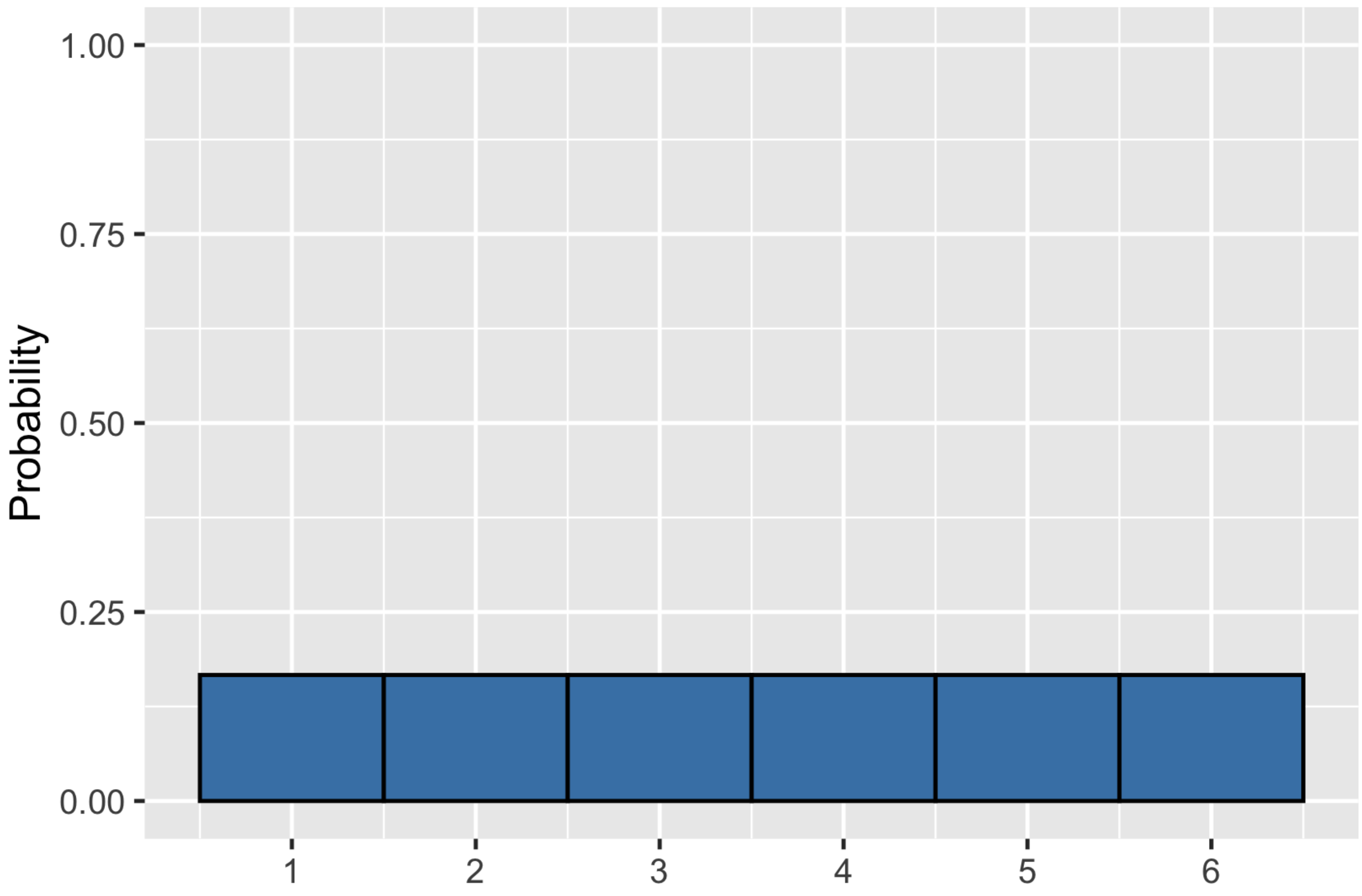
Roll	Result
1	3
2	1
3	2
4	4
5	6
6	3
7	2
8	2
9	2
10	5

Visualizing a sample



Sample distribution vs theoretical distribution



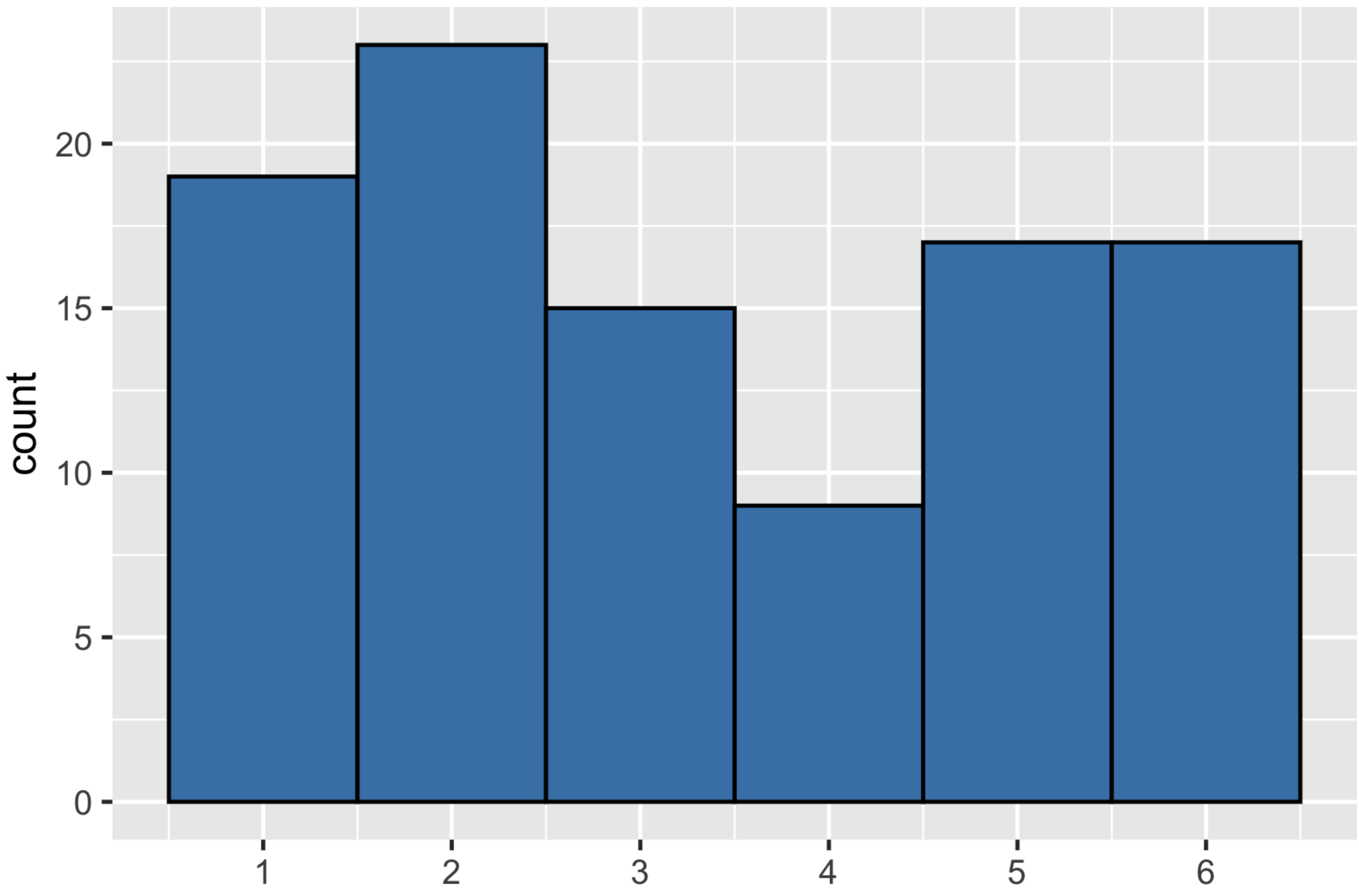


$$Mean = 3.0$$

$$Mean = 3.5$$

A bigger sample

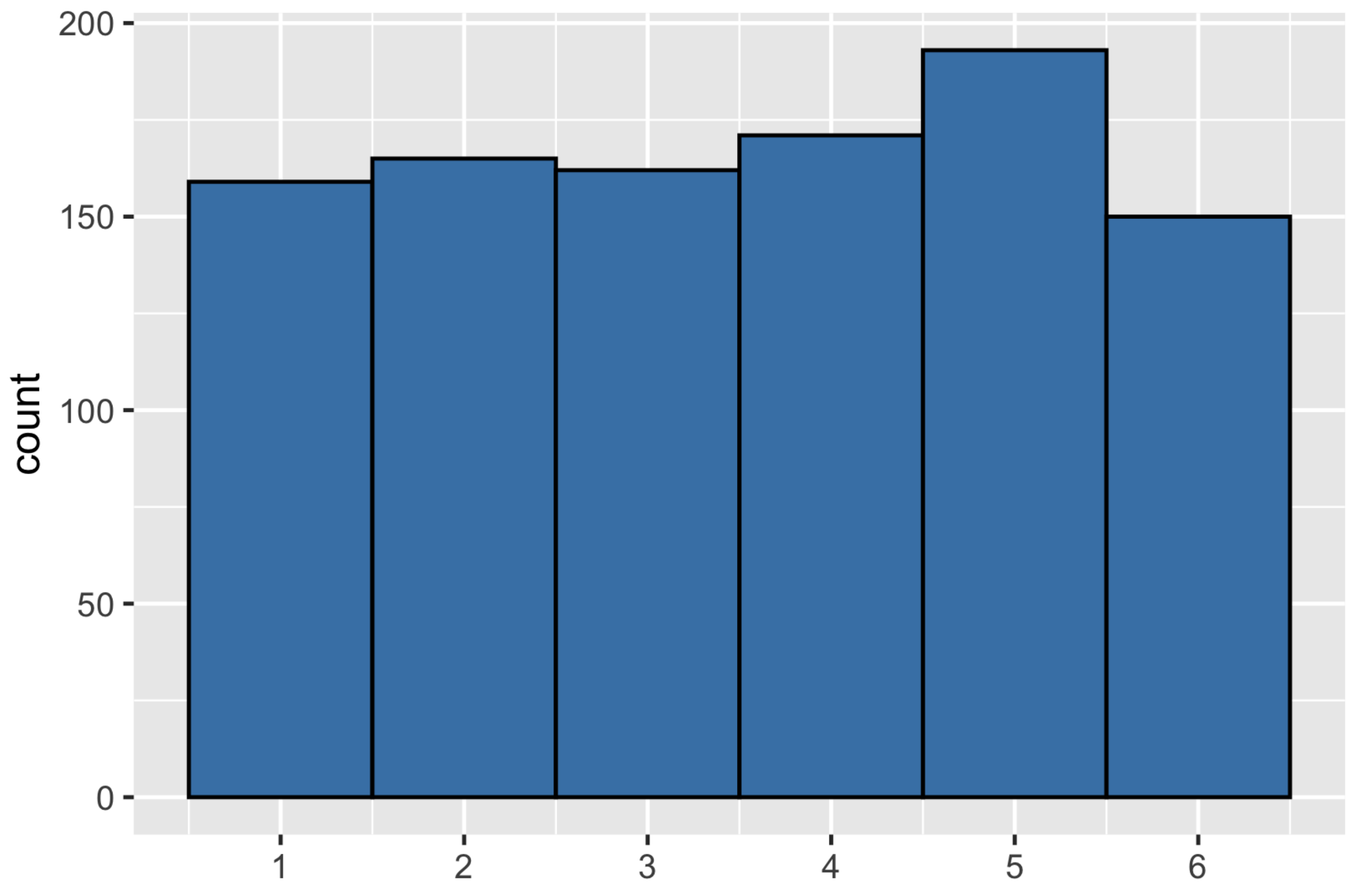
Sample of 100 rolls



$$Mean = 3.33$$

An even bigger sample

Sample of 1000 rolls



$$Mean = 3.52$$

Law of large numbers

As the size of your sample increases, the sample mean will approach the expected value.

Sample size	**Mean**
10	3.00
100	3.33
1000	3.52

Let's practice!

INTRODUCTION TO STATISTICS

Continuous distributions

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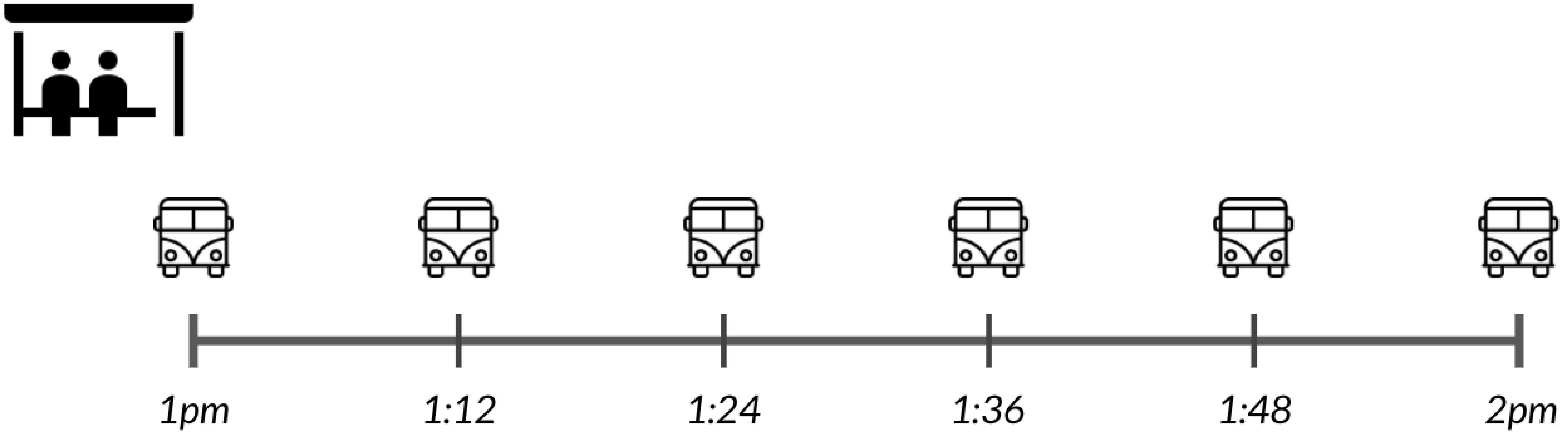
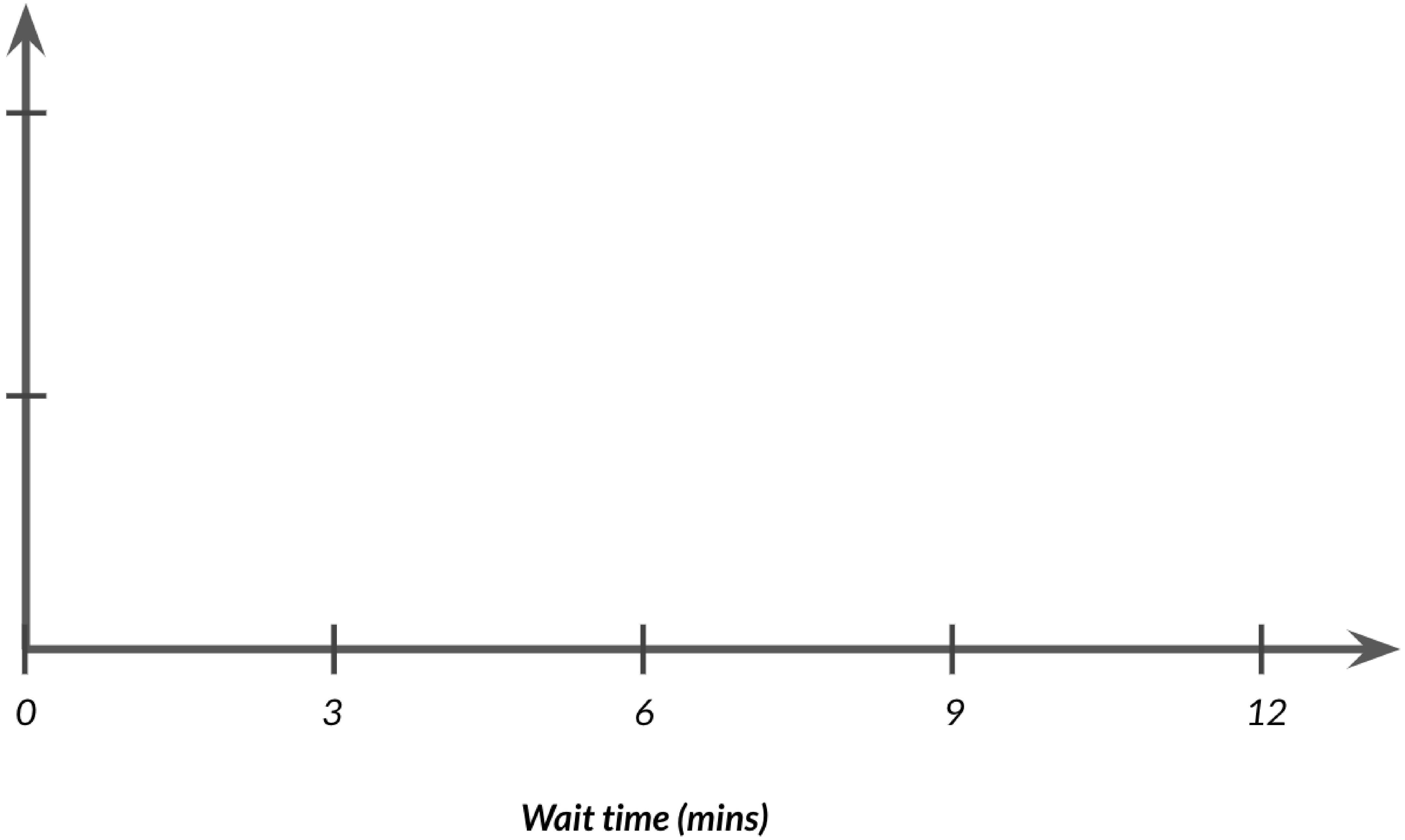
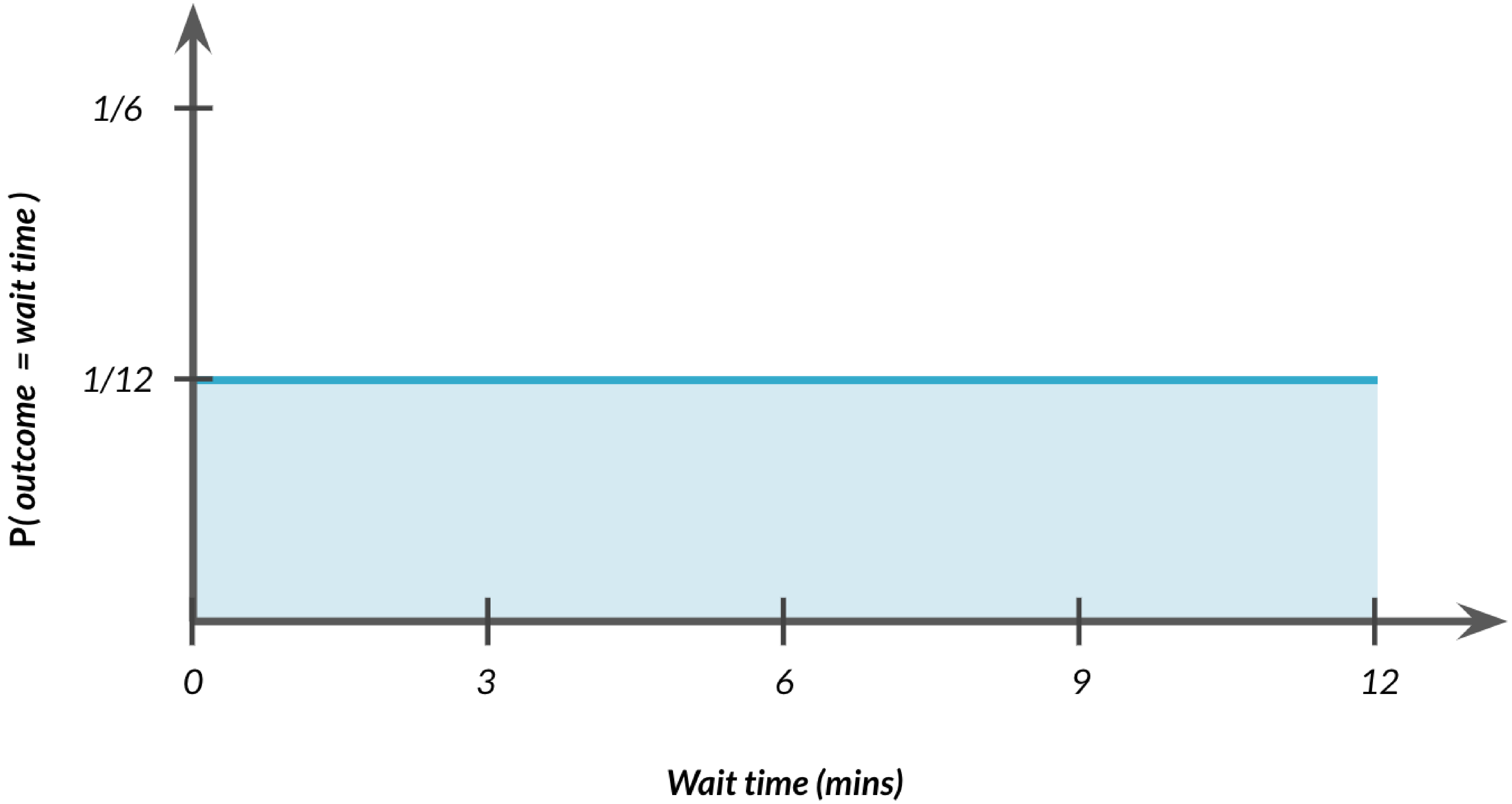
Waiting for the bus



Continuous uniform distribution

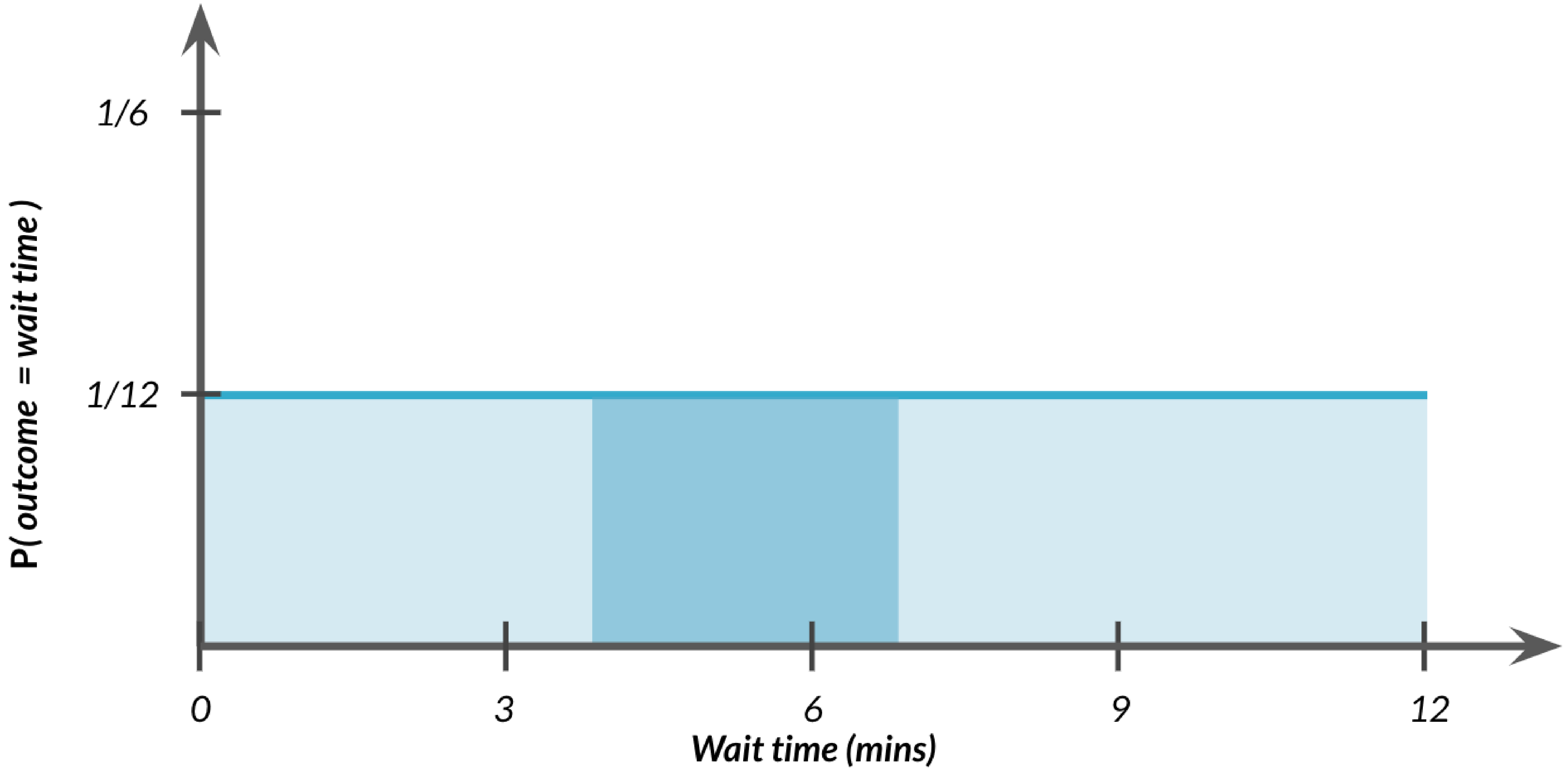


Continuous uniform distribution



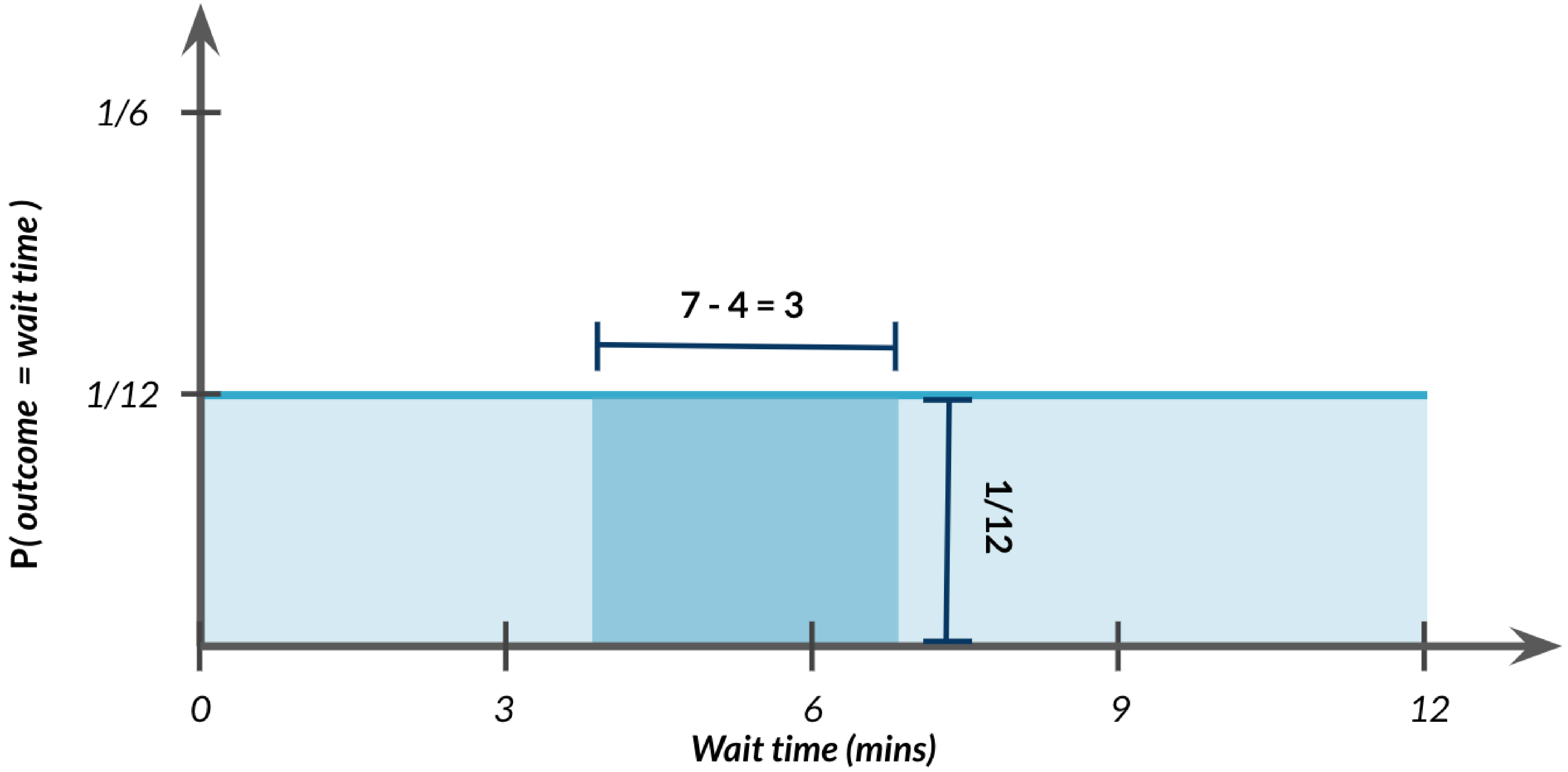
Probability still = area

$$P(4 \leq \text{wait time} \leq 7) = \ ?$$



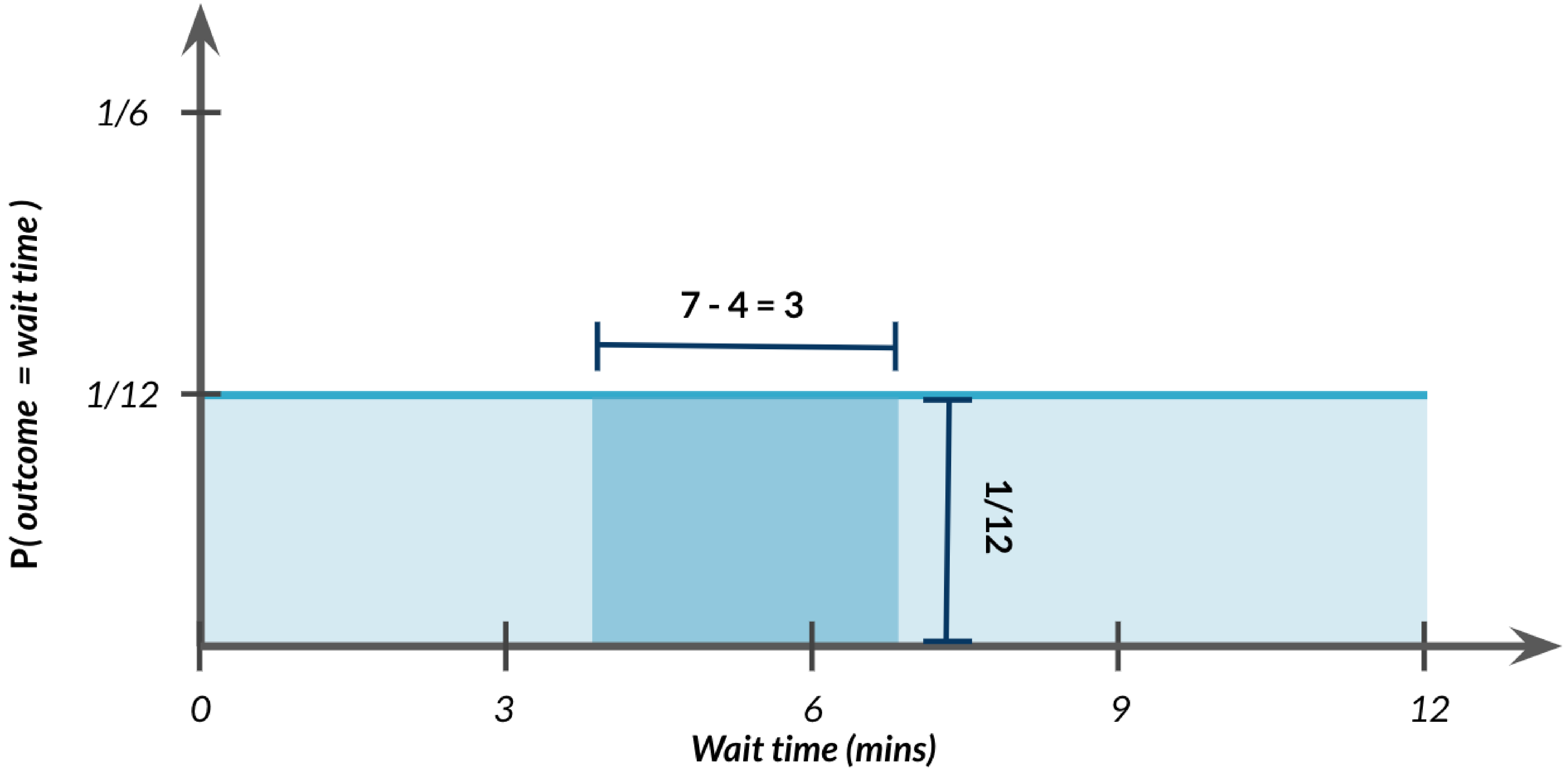
Probability still = area

$$P(4 \leq \text{wait time} \leq 7) = \ ?$$



Probability still = area

$$P(4 \leq \text{wait time} \leq 7) = 3 \times 1/12 = 3/12$$

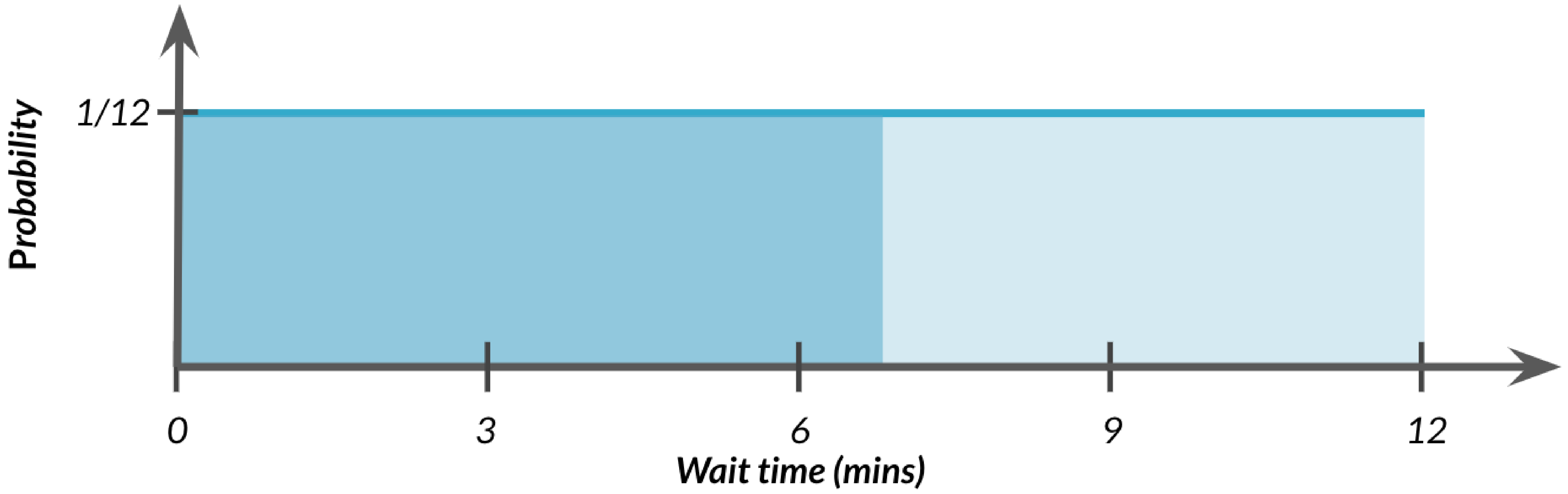


Waiting seven minutes or less

$$P(\text{wait time} \leq 7) = \ ?$$

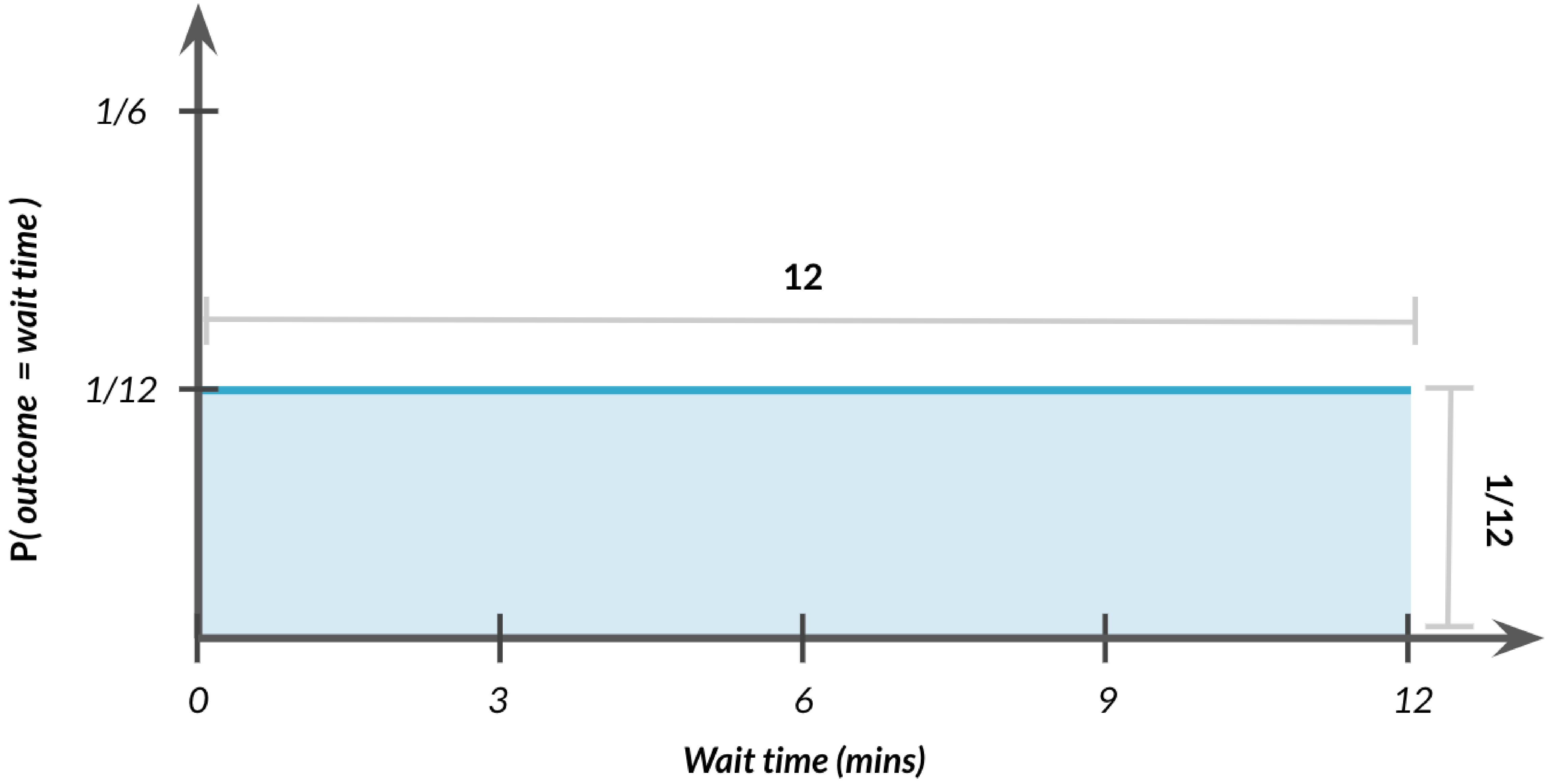
$$P(\text{wait time} \leq 7) = \frac{7-0}{12}$$

$$P(\text{wait time} \leq 7) = \frac{7}{12} = 58.33\%$$



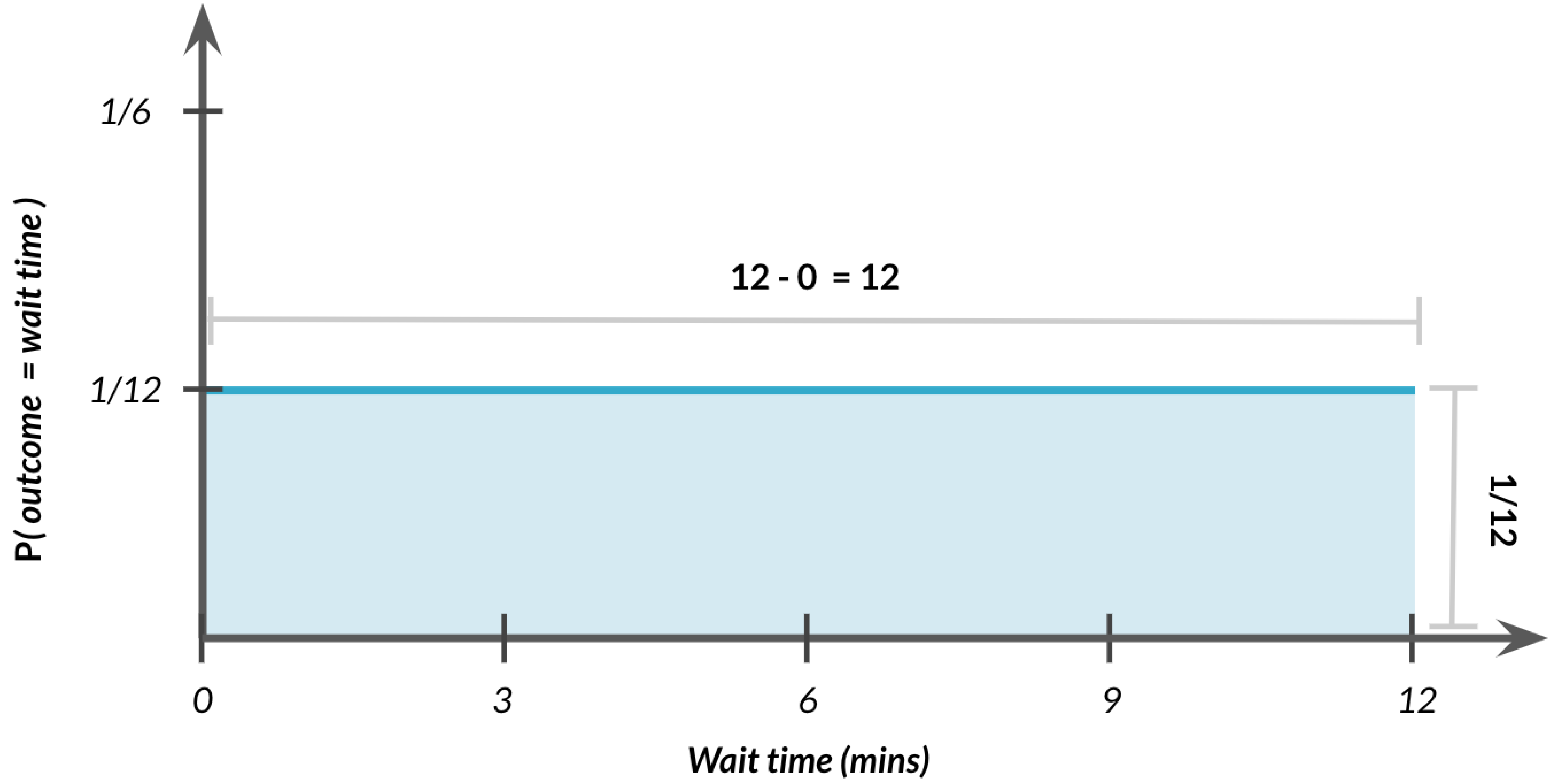
Total area = 1

$$P(0 \leq \text{wait time} \leq 12) = \ ?$$



Total area = 1

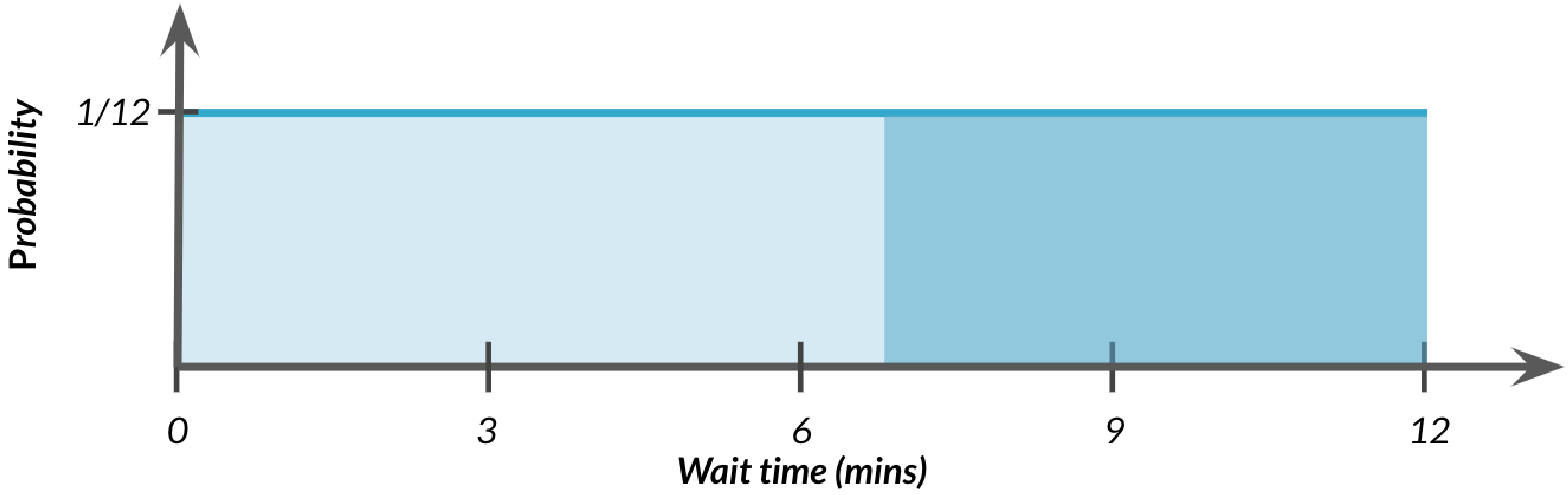
$$P(0 \leq \text{outcome} \leq 12) = 12 \times 1/12 = 1$$



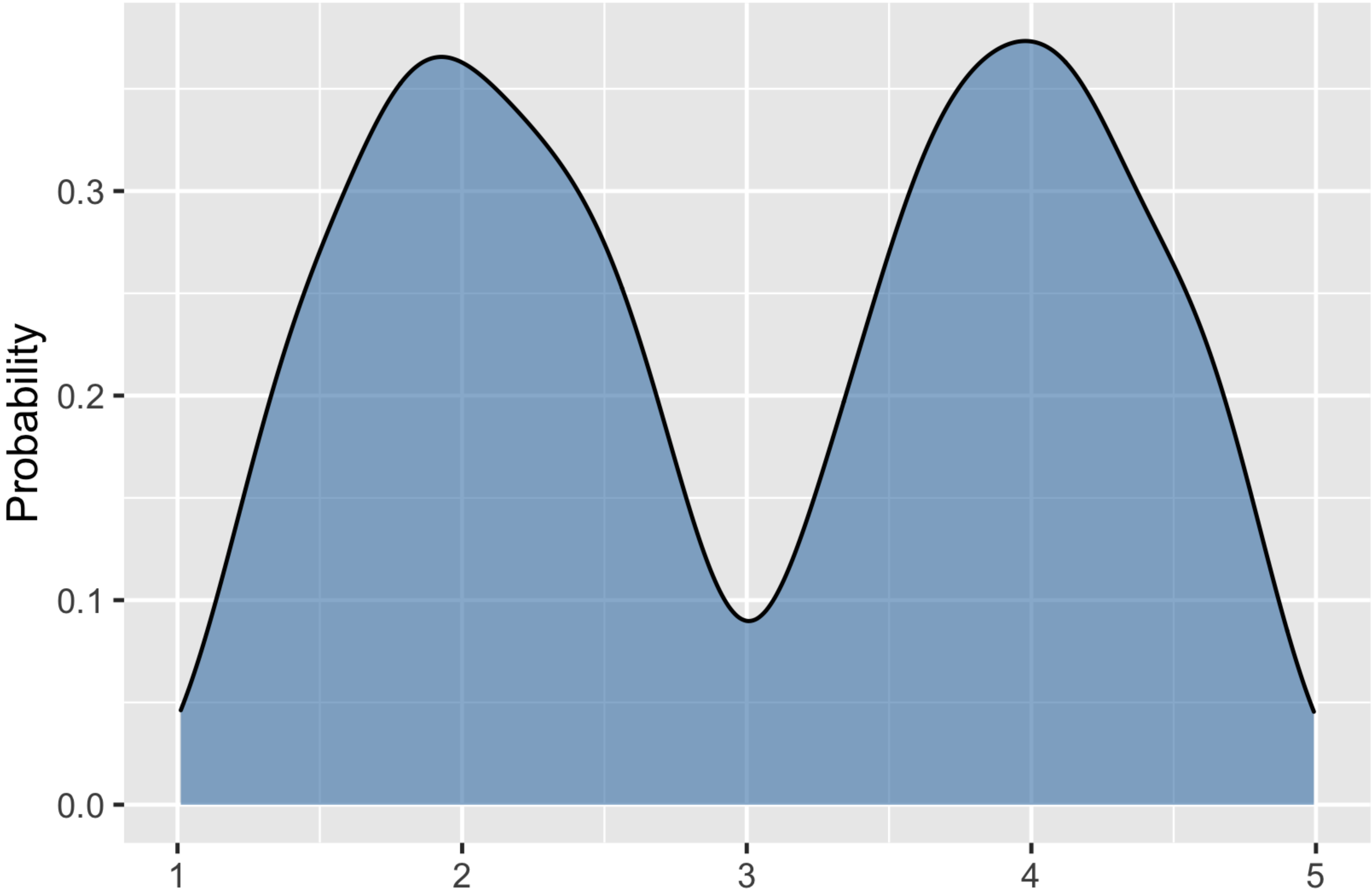
Probability of waiting more than seven minutes

$$P(\text{wait time} \geq 7) = 1 - \frac{7}{12}$$

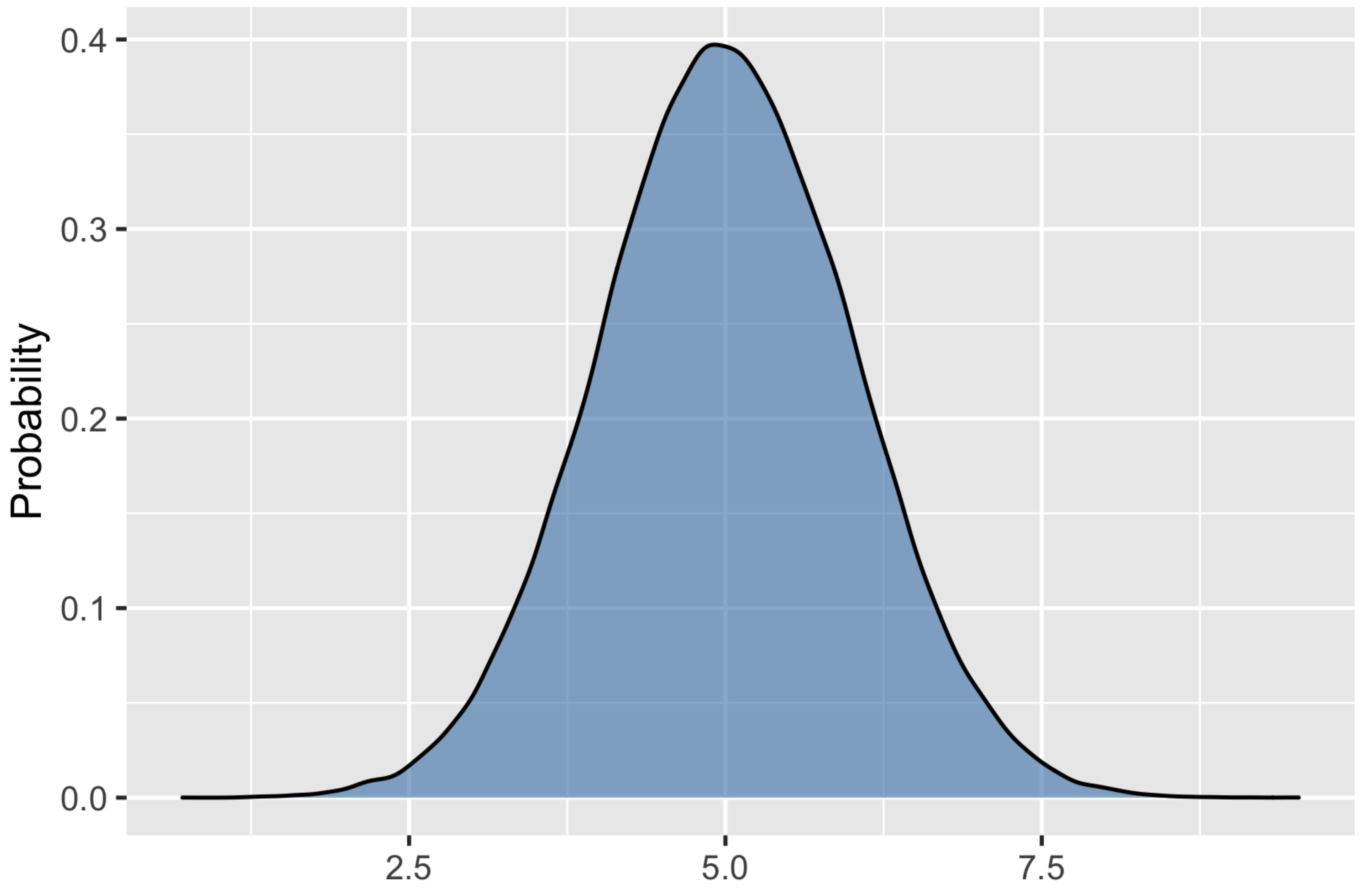
$$P(\text{wait time} \geq 7) = \frac{5}{12} = 41.67\%$$



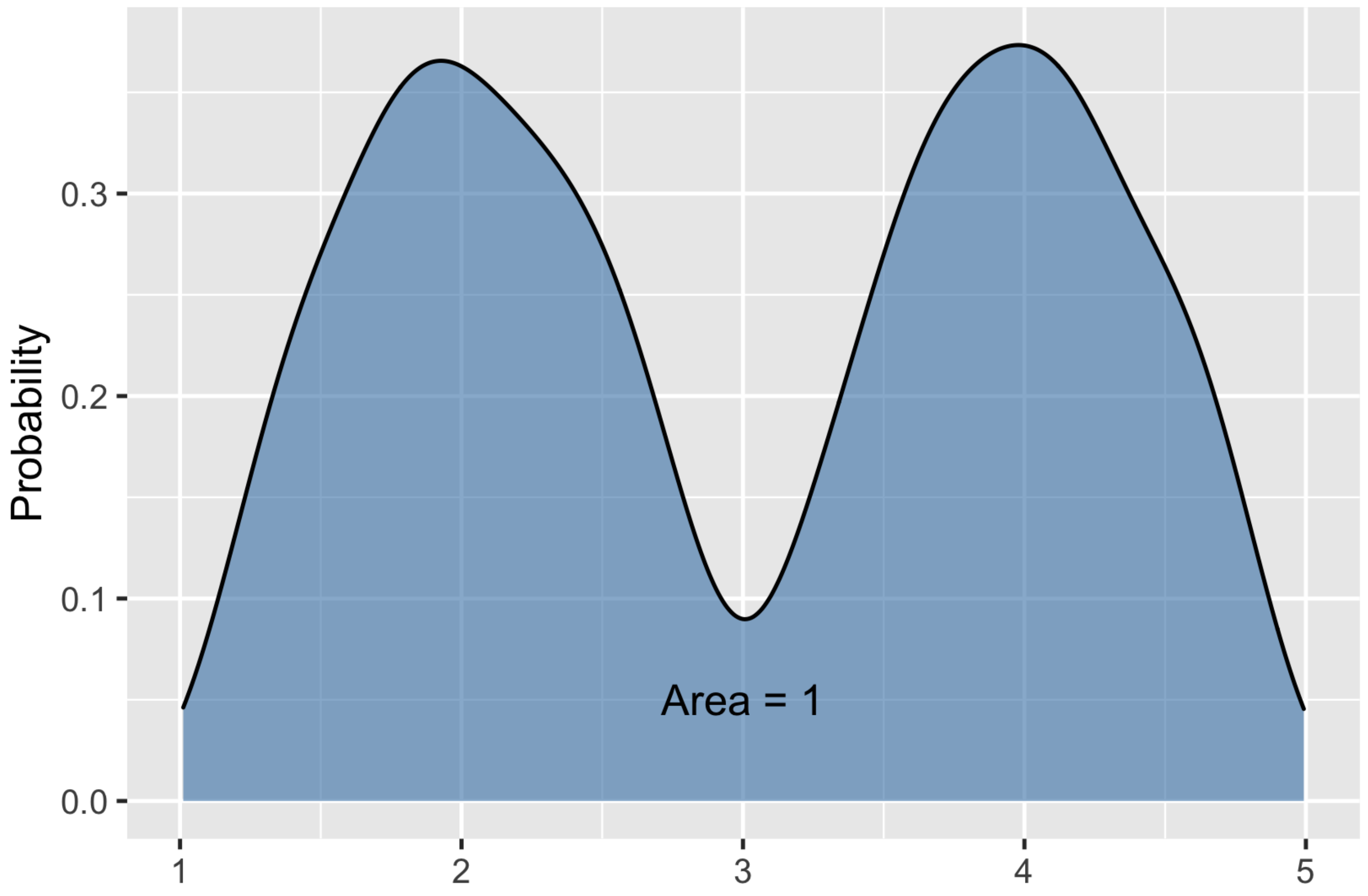
Bimodal distribution

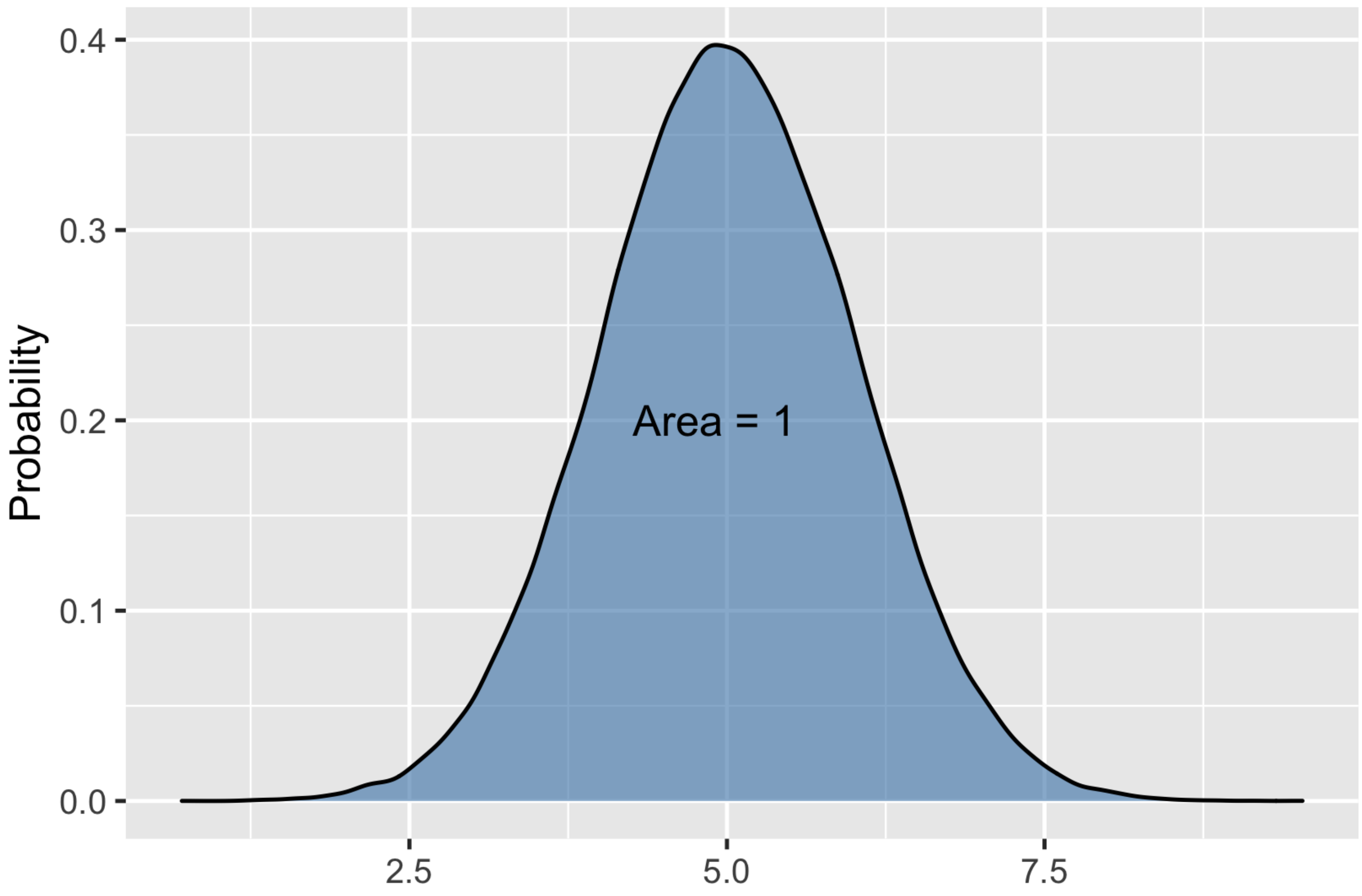


The normal distribution



Total area still = 1





Let's practice!

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