

# Bayesian data analysis using JASP

Dani Navarro



[compcogscisydney.com/jasp-tute.html](http://compcogscisydney.com/jasp-tute.html)

## *Part 1: Theory*

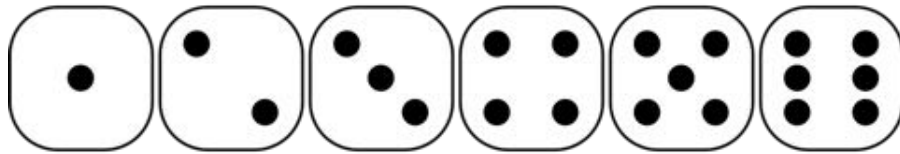
- Philosophy of probability
- Introducing Bayes rule
- Bayesian reasoning
- A simple example
- Bayesian hypothesis testing

## *Part 2: Practice*

- Introducing JASP
- Bayesian ANOVA
- Bayesian t-test
- Bayesian regression
- Bayesian contingency tables
- Bayesian binomial test

## 1.1 Philosophy of probability

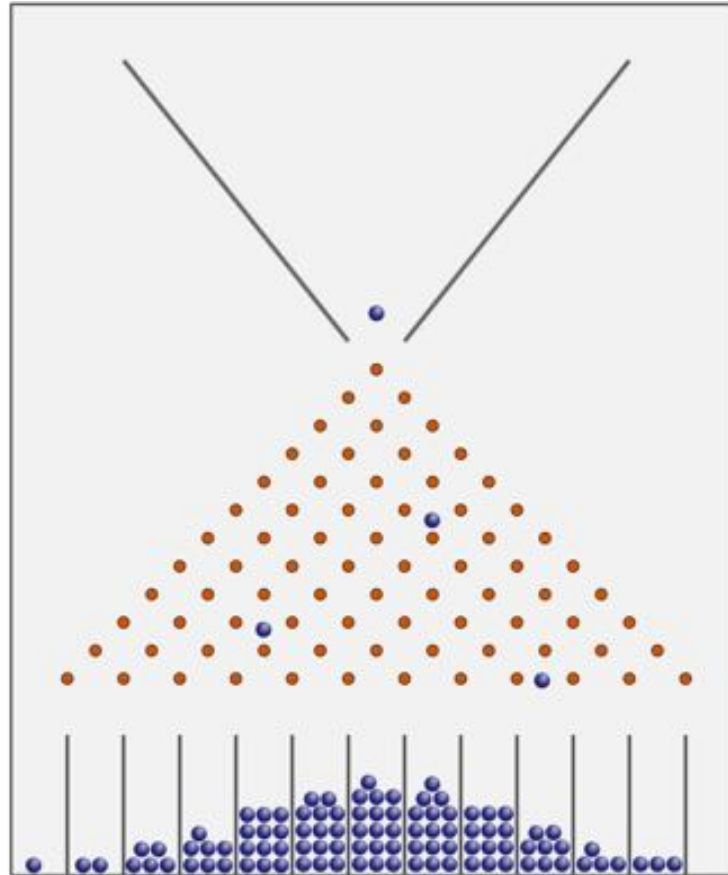
# Idea #1: “Aleatory” processes

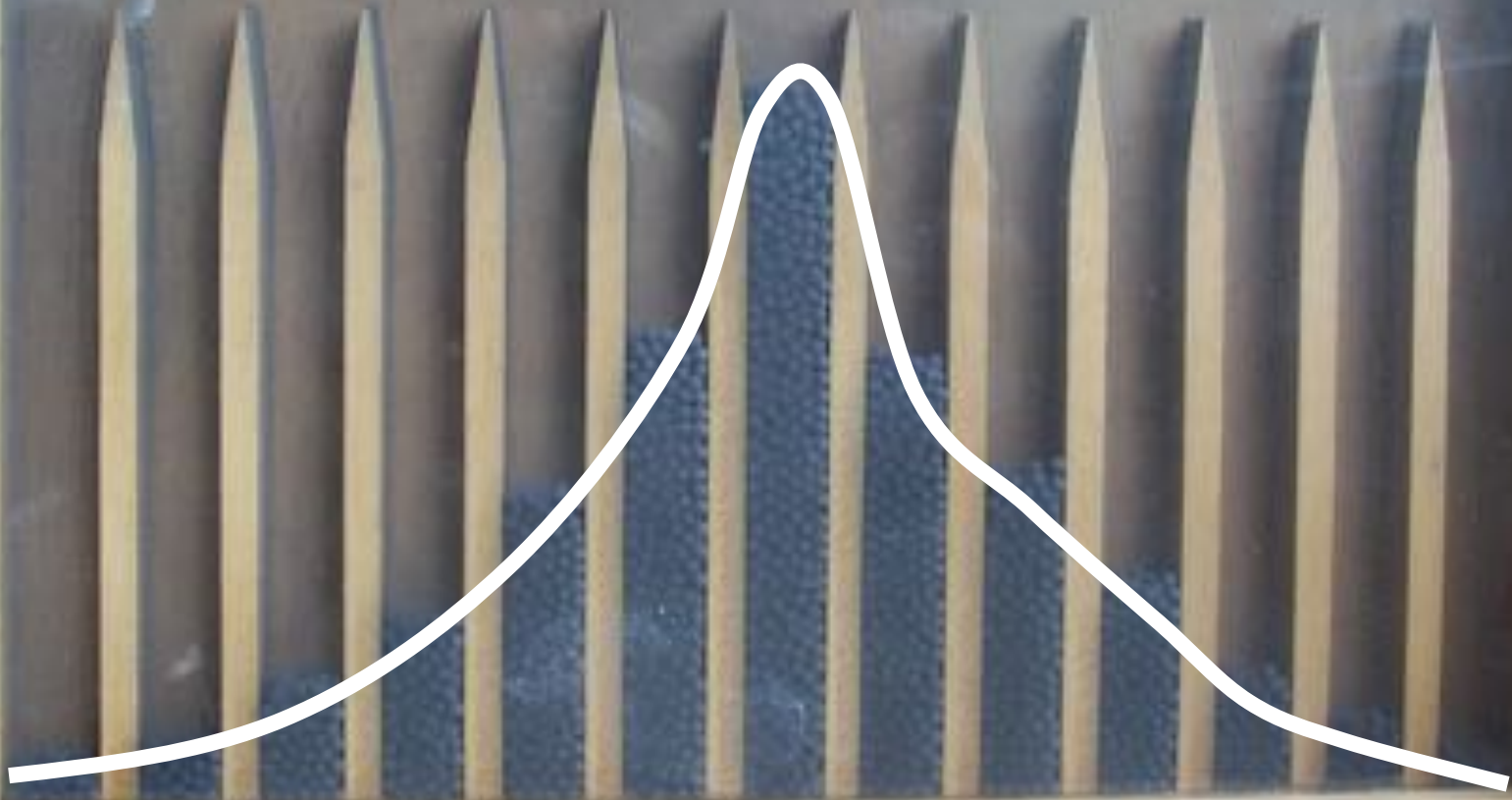
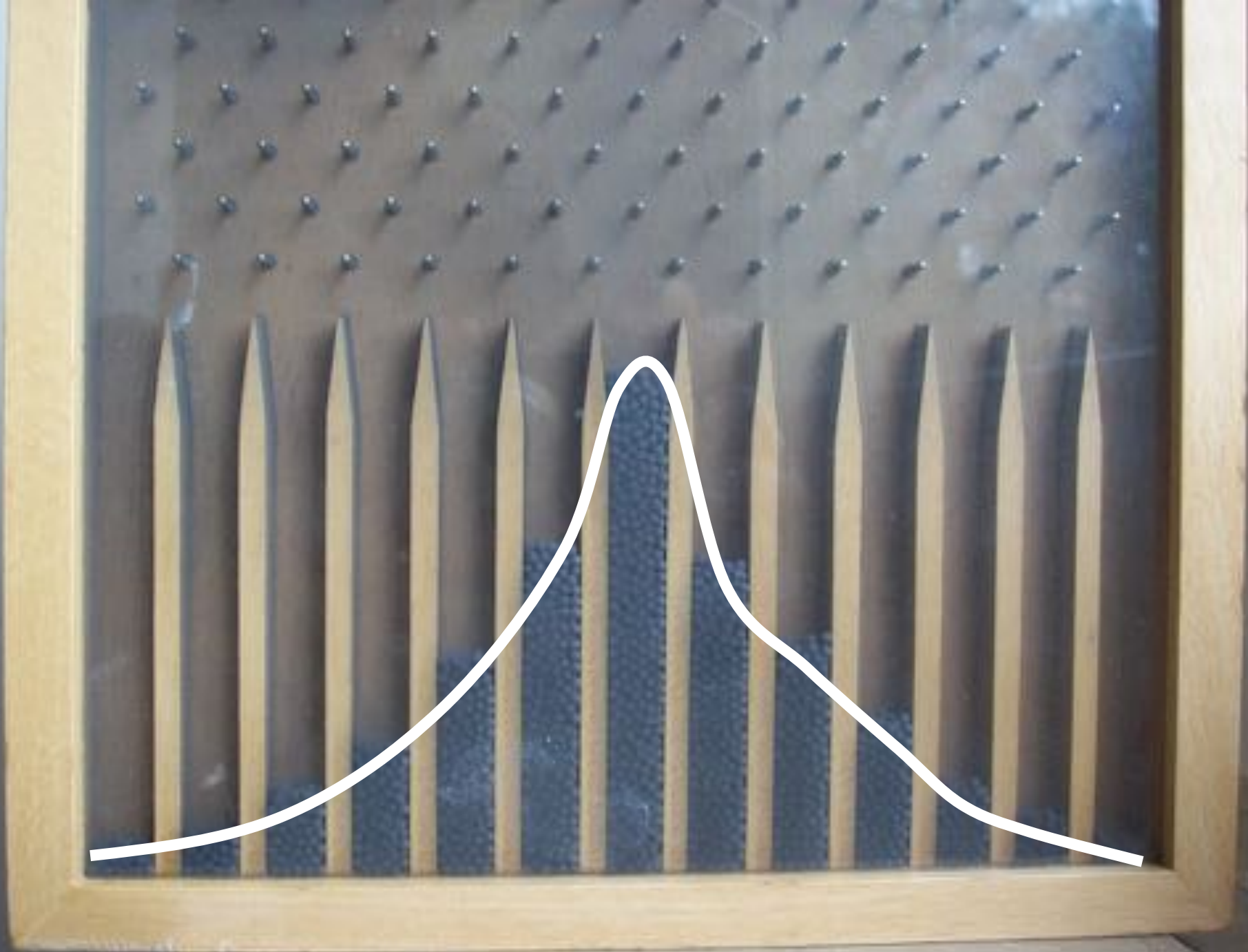


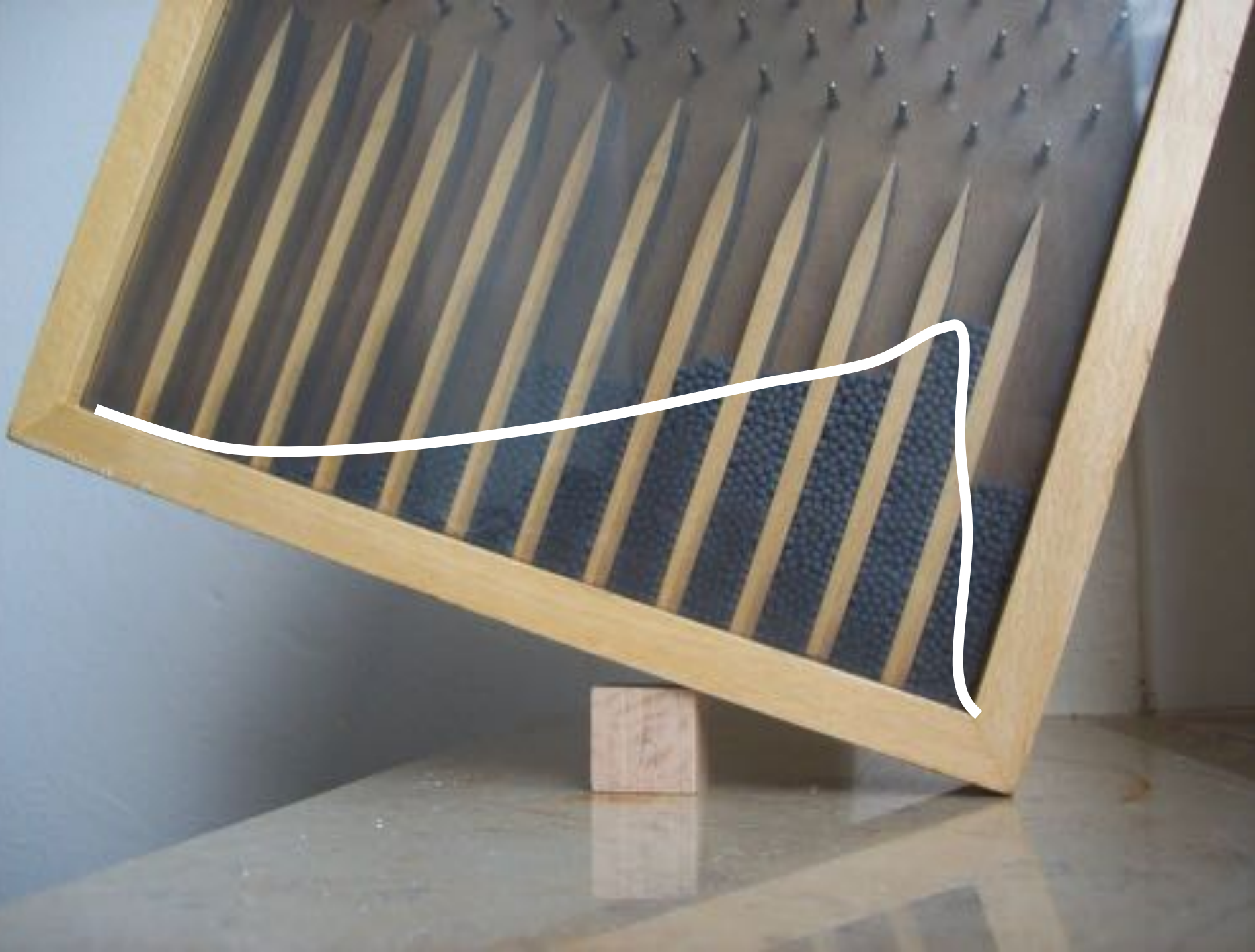
Probability is an objective characteristic associated with physical processes, defined by counting the relative frequencies of different kinds of events when that process is invoked



# “Aleatory” processes



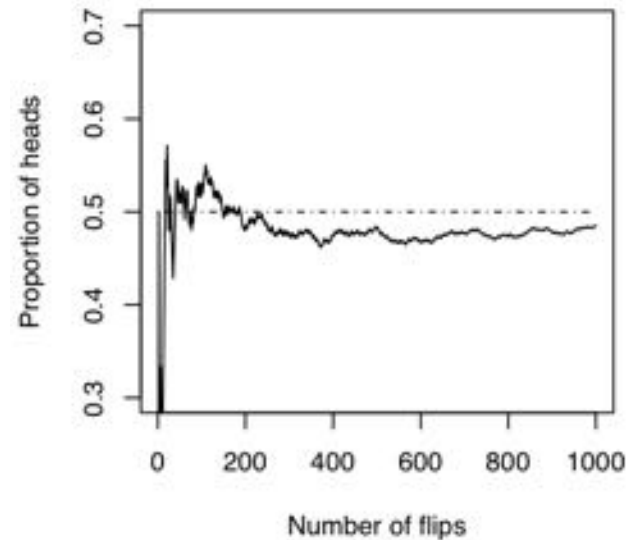




# Frequentist statistics



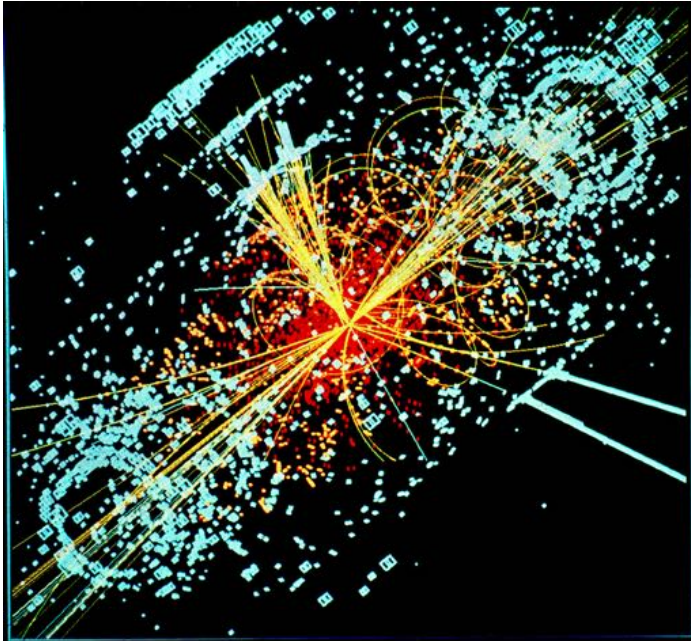
Coin flipping is an aleatory process, and can be repeated as many times as you like



The probability of a head is defined as the long-run frequency



# Frequentist statistics



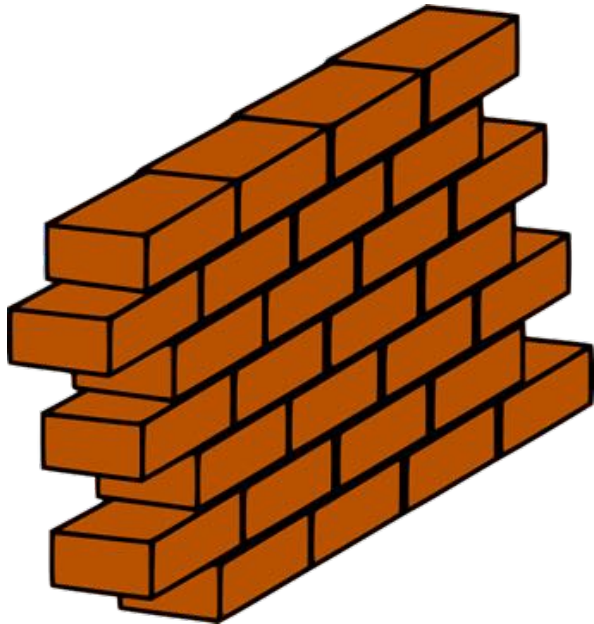
A particle physics experiment is a repeatable procedure, and thus a frequentist probability can be constructed to describe its outcomes

mass →	$\approx 2.3 \text{ MeV}/c^2$	$\approx 1.275 \text{ GeV}/c^2$	$\approx 173.07 \text{ GeV}/c^2$	0	$\approx 126 \text{ GeV}/c^2$
charge →	$2/3$	$2/3$	$2/3$	0	0
spin →	$1/2$	$1/2$	$1/2$	1	0
	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon	<b>H</b> Higgs boson
<b>QUARKS</b>	$\approx 4.8 \text{ MeV}/c^2$	$\approx 95 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
	$-1/3$	$-1/3$	$-1/3$	0	
	$1/2$	$1/2$	$1/2$	1	
	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b><math>\gamma</math></b> photon	
	$0.511 \text{ MeV}/c^2$	$105.7 \text{ MeV}/c^2$	$1.777 \text{ GeV}/c^2$	$91.2 \text{ GeV}/c^2$	
	-1	-1	-1	0	
	$1/2$	$1/2$	$1/2$	1	
	<b>e</b> electron	<b><math>\mu</math></b> muon	<b><math>\tau</math></b> tau	<b>Z</b> Z boson	
<b>LEPTONS</b>	$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 15.5 \text{ MeV}/c^2$	$80.4 \text{ GeV}/c^2$	
	0	0	0	$\pm 1$	
	$1/2$	$1/2$	$1/2$	1	
	<b><math>\nu_e</math></b> electron neutrino	<b><math>\nu_\mu</math></b> muon neutrino	<b><math>\nu_\tau</math></b> tau neutrino	<b>W</b> W boson	
					<b>GAUGE BOSONS</b>

A scientific theory is not a repeatable procedure, and cannot be assigned a probability: there is no such thing as “the probability that my theory is true”

# Idea #2: “Epistemic” uncertainty

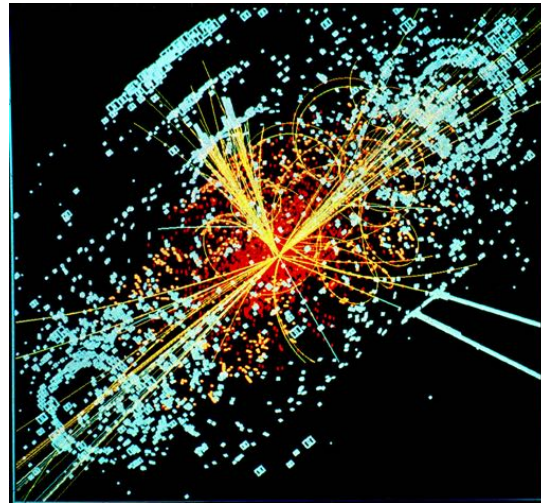
Probability is a subjective characteristic associated with rational agents, defined by assessing the strength of belief that the agent holds in different propositions



# “Bayesian” statistics



Probabilities can be attached to any proposition that an agent can believe

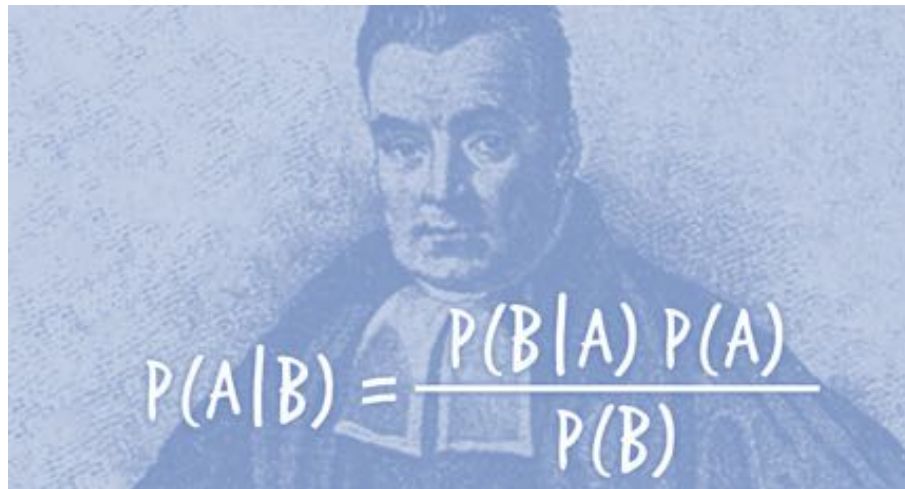


A particle physics experiment generates observable events about which a rational agent might hold beliefs

mass →	≈2.3 MeV/c <sup>2</sup>	≈1.275 GeV/c <sup>2</sup>	≈173.07 GeV/c <sup>2</sup>	0	≈126 GeV/c <sup>2</sup>
charge →	2/3	2/3	2/3	0	0
spin →	1/2	1/2	1/2	1	0
	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon	<b>H</b> Higgs boson
<b>QUARKS</b>	≈4.8 MeV/c <sup>2</sup>	≈95 MeV/c <sup>2</sup>	≈4.18 GeV/c <sup>2</sup>	0	
	-1/3	-1/3	-1/3	0	
	1/2	1/2	1/2	1	
	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b>γ</b> photon	
	0.511 MeV/c <sup>2</sup>	105.7 MeV/c <sup>2</sup>	1.777 GeV/c <sup>2</sup>	91.2 GeV/c <sup>2</sup>	
	-1	-1	-1	0	
	1/2	1/2	1/2	1	
	<b>e</b> electron	<b>μ</b> muon	<b>τ</b> tau	<b>Z</b> Z boson	
<b>LEPTONS</b>	<2.2 eV/c <sup>2</sup>	<0.17 MeV/c <sup>2</sup>	<15.5 MeV/c <sup>2</sup>	80.4 GeV/c <sup>2</sup>	
	0	0	0	±1	
	1/2	1/2	1/2	1	
	<b>ν<sub>e</sub></b> electron neutrino	<b>ν<sub>μ</sub></b> muon neutrino	<b>ν<sub>τ</sub></b> tau neutrino	<b>W</b> W boson	
					<b>GAUGE BOSONS</b>

A scientific theory contains a set of propositions about which a rational agent might hold beliefs

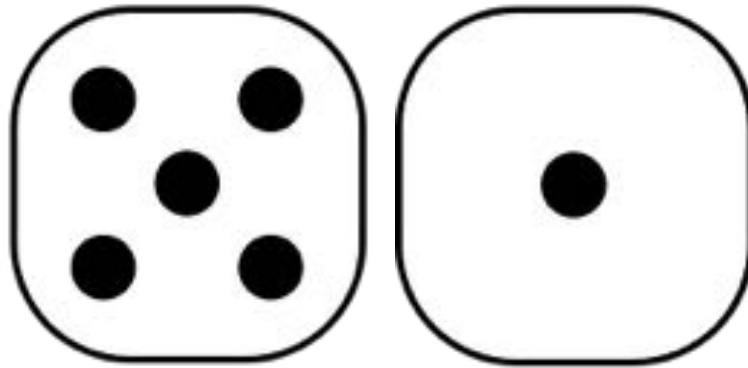
## 1.2 Introducing Bayes rule

A blue-tinted portrait of Thomas Bayes, a mathematician and Presbyterian minister, is shown. Overlaid on the lower part of the portrait is the mathematical formula for Bayes' rule: 
$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

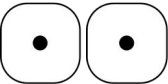
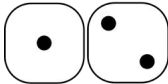
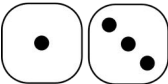
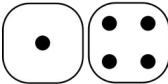
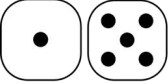
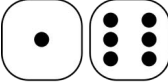
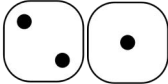
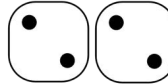
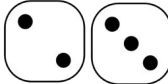
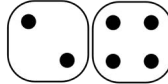
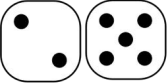

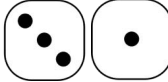
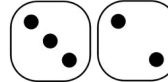
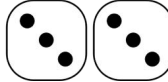
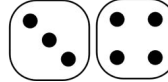
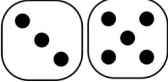
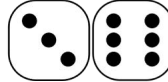
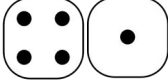
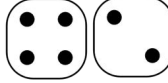
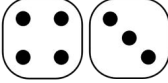
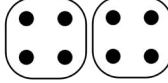
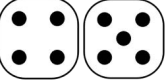
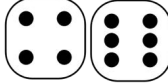
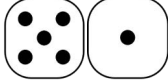
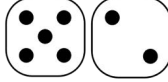
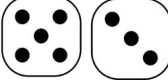
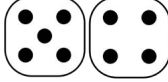
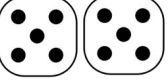
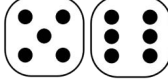
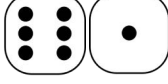

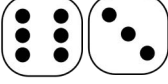
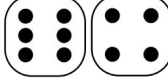
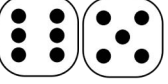
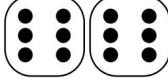
The image features a blue-tinted portrait of Thomas Bayes, a mathematician and Presbyterian minister. Overlaid on the lower part of the portrait is the mathematical formula for Bayes' rule: 
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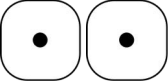
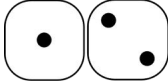
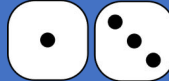
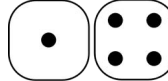
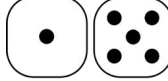
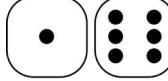




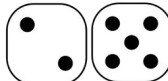





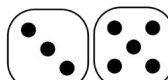



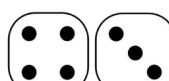















**Roll two dice...**



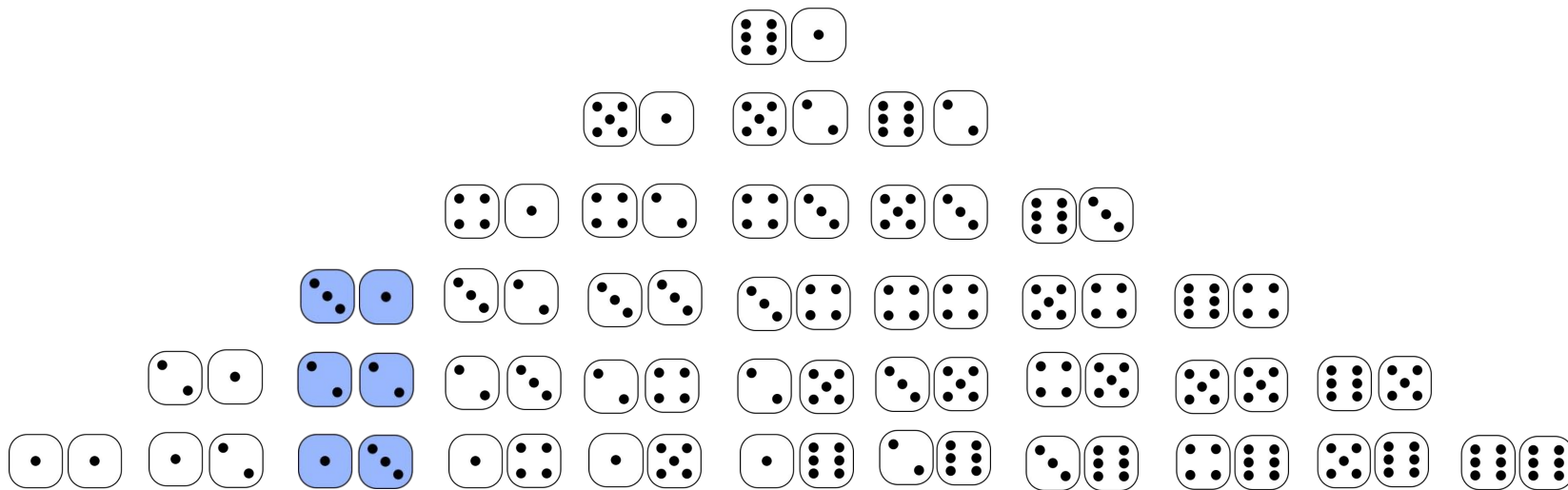
# Thirty six possible cases

Three cases where  
the dice add up to 4

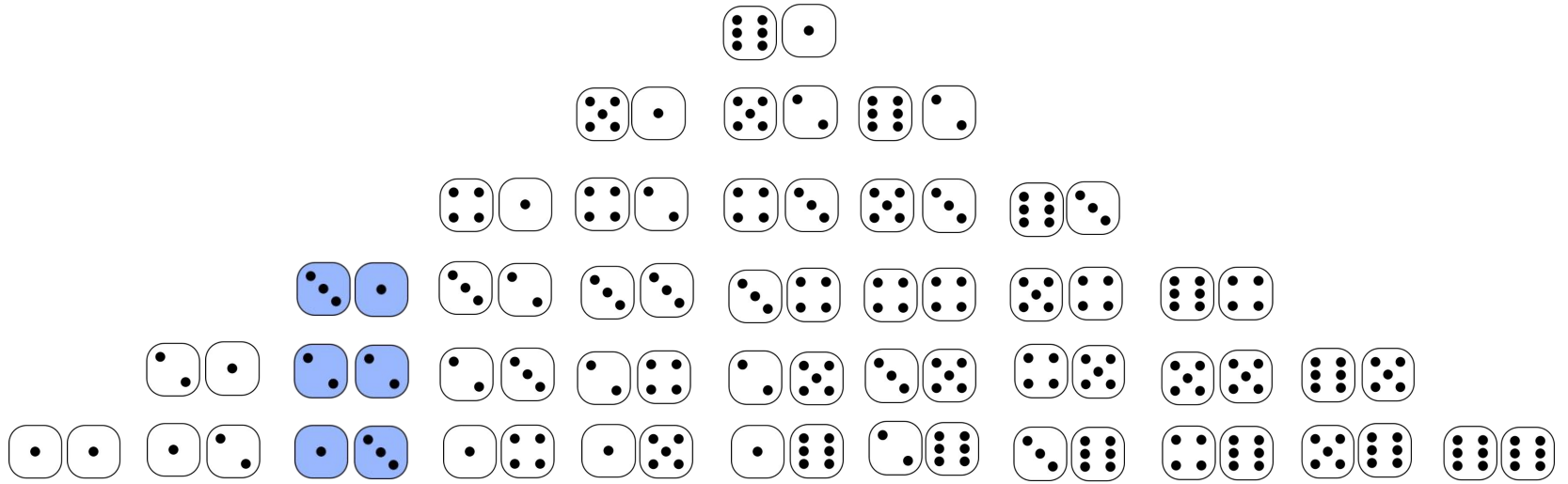
					
					
					
					
					
					





<b>Roll</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>
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<b>N</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>5</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>
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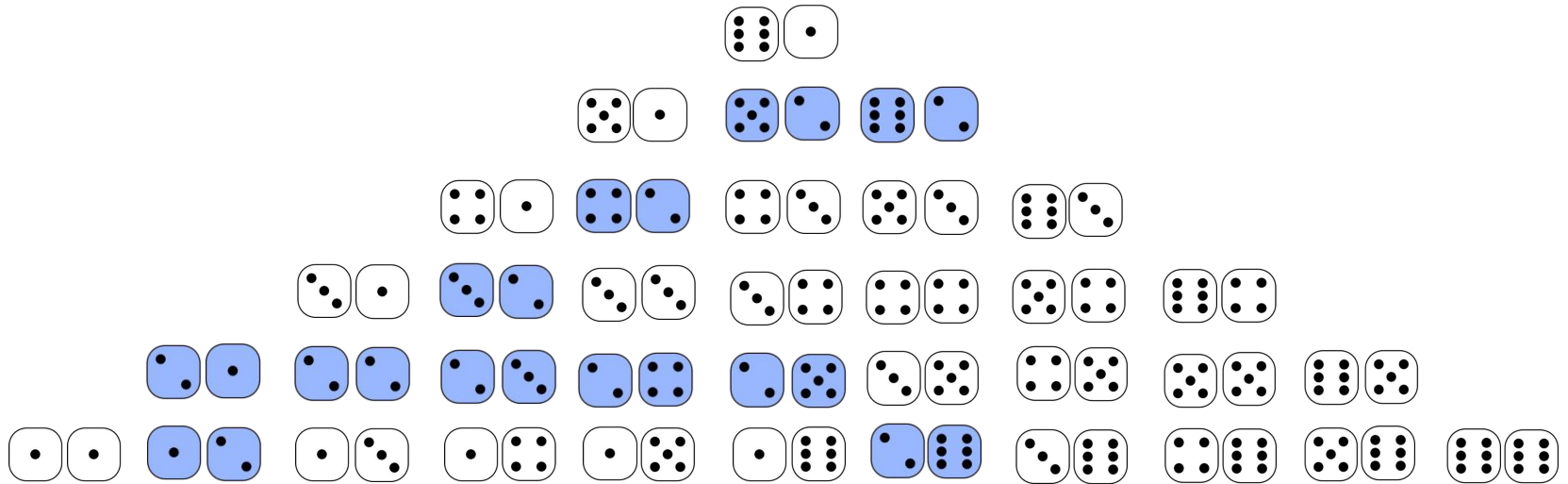


Roll	2	3	4	5	6	7	8	9	10	11	12
N	1	2	3	4	5	6	5	4	3	2	1
Prob	.028	.056	.083	.111	.139	.167	.139	.111	.083	.056	.028



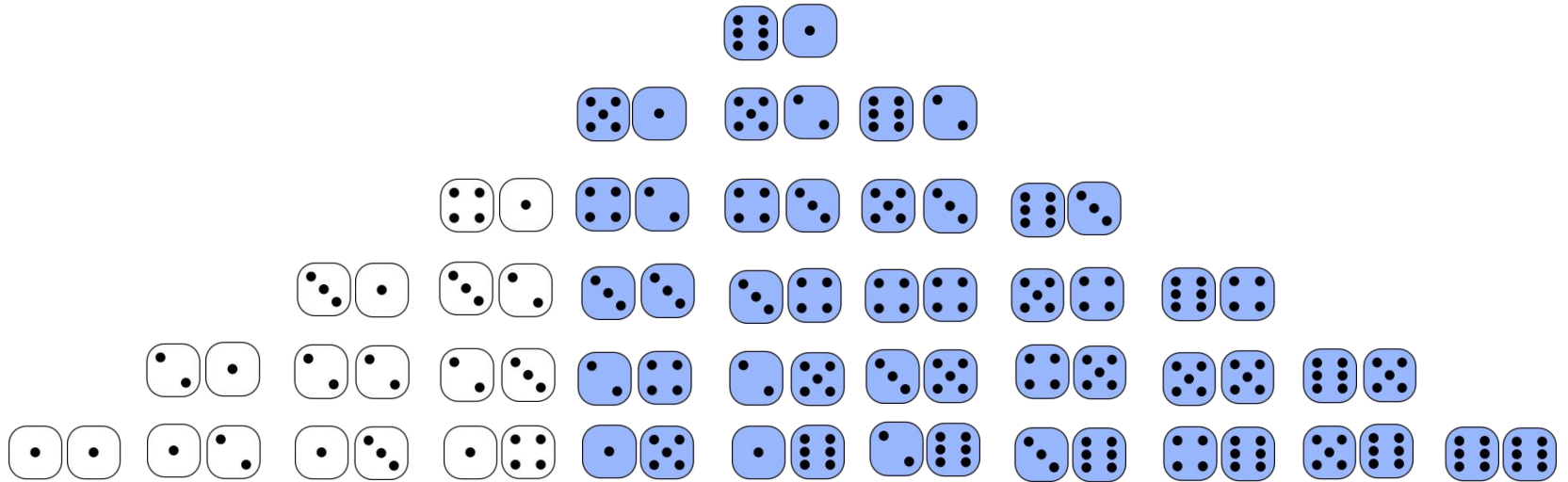
Probability =  $3/36 = .083$

A: “at least one die has a value of 2”



$$P(A) = \frac{11}{36} = .31$$

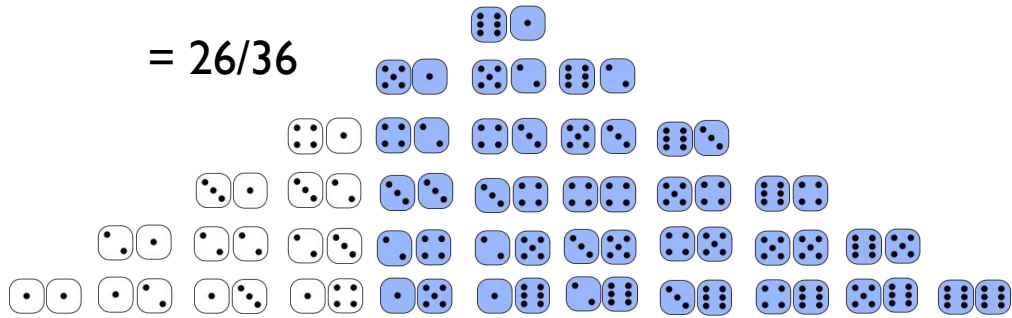
B: “the total is at least six”



$$P(B) = \frac{26}{36} = .72$$



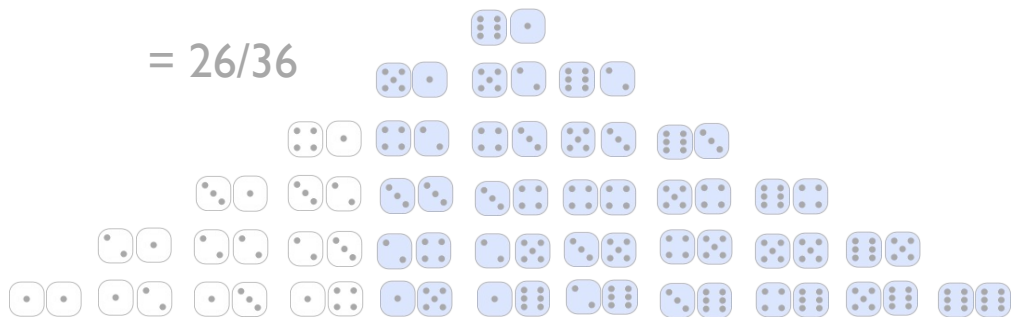
$$= 26/36$$



Probability that the total is at least 6

$$P(B)$$

$$= 26/36$$

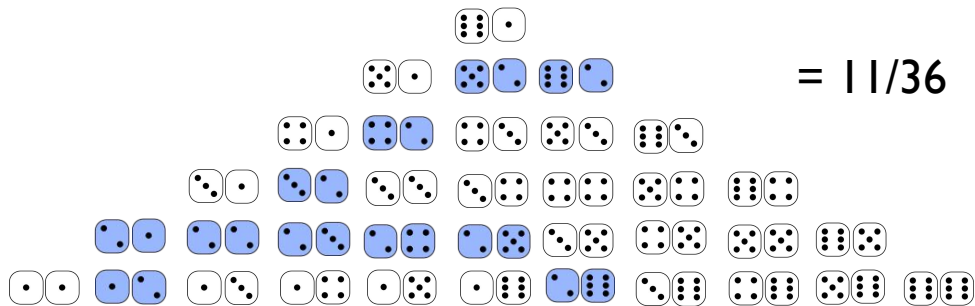


Probability that the total is at least 6

$P(B)$

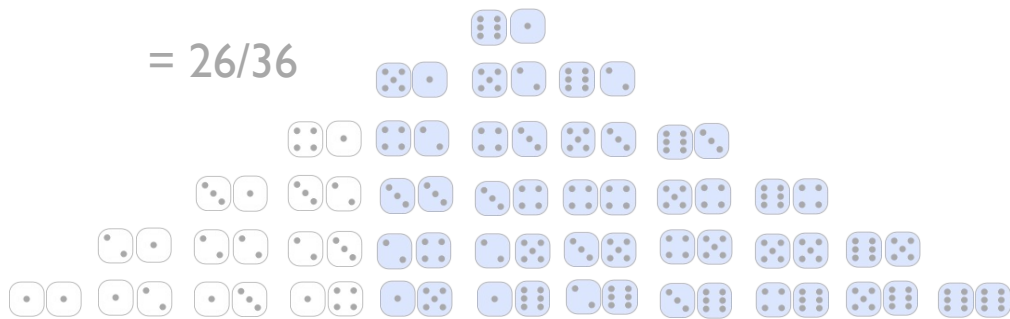
$P(A)$

Probability that at least one die has a 2



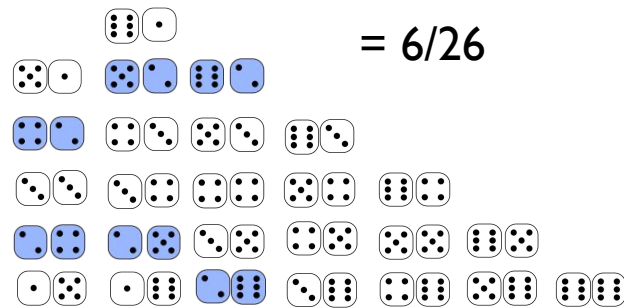
$$= 11/36$$

$$= 26/36$$



Probability that the total is at least 6

$$= 6/26$$



Probability that at least one die has a 2 **given** that the total is at least 6

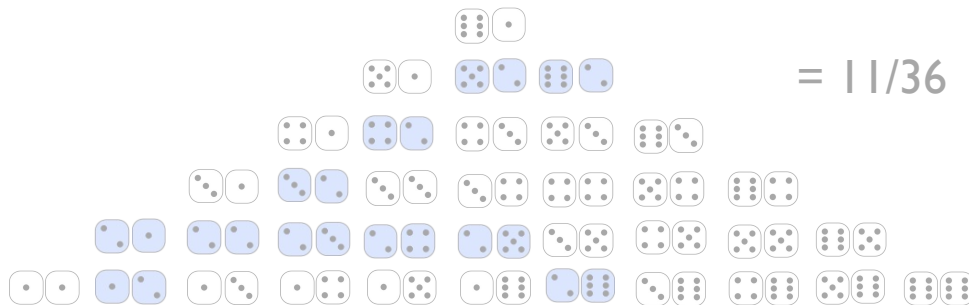
$$P(B)$$

$$P(A|B)$$

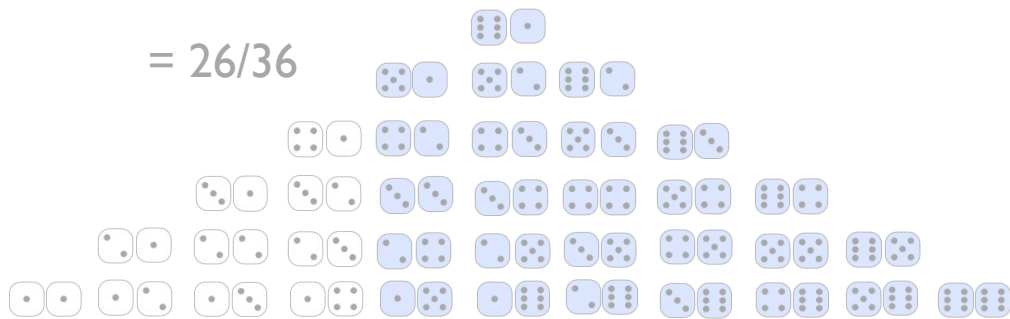
$$P(A)$$

Probability that at least one die has a 2

$$= 11/36$$

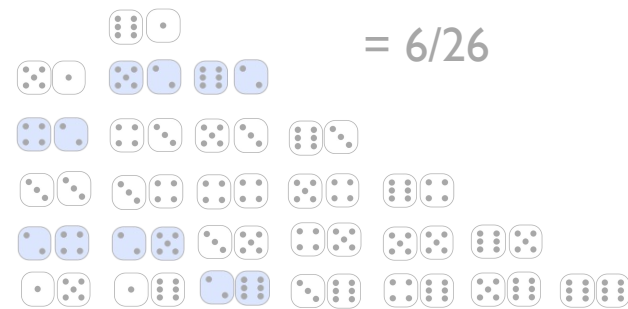


$$= 26/36$$



Probability that the total is at least 6

$$= 6/26$$



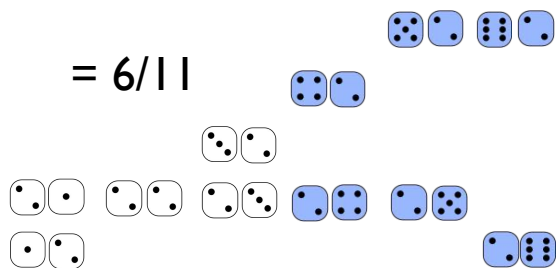
Probability that at least one die has a 2 given that the total is at least 6

$$P(B|A)$$



Probability that the total is at least 6 **given** that at least one die has a 2

$$= 6/11$$



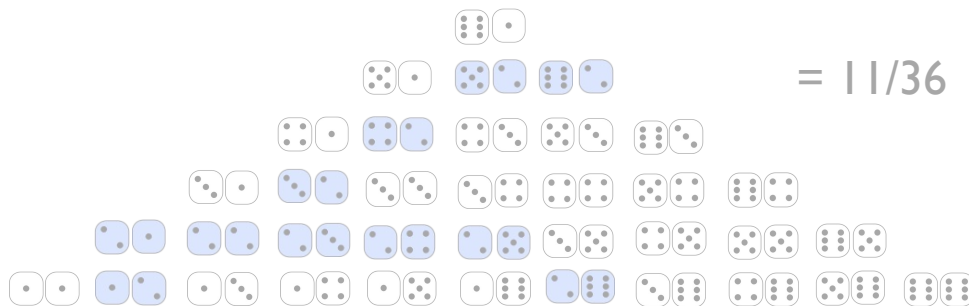
$$P(B)$$

$$P(A|B)$$

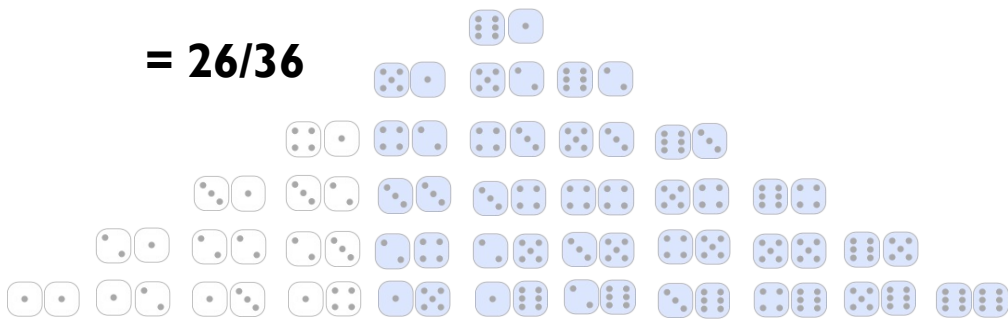
$$P(A)$$

Probability that at least one die has a 2

$$= 11/36$$



**= 26/36**



Let's check that:

$$P(A|B)$$



$$\frac{26}{36} \times \frac{6}{26} \div \frac{11}{36}$$



$$P(B)$$



$$P(A)$$

Let's check that:

$$\begin{array}{ccccccc} & P(A|B) & & & & & P(B|A) \\ & \downarrow & & & & & \downarrow \\ \frac{26}{36} & \times & \frac{6}{26} & \div & \frac{11}{36} & = & \frac{26}{36} & \times & \frac{6}{26} & \times & \frac{36}{11} & = & \frac{6}{11} \\ \uparrow & & & & \uparrow & & & & & & & & & \\ P(B) & & & & P(A) & & & & & & & & & \end{array}$$

## 1.3 Bayesian reasoning



**Bayes' rule** is a mathematical fact that probabilities must obey

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

The diagram illustrates the components of the equation. Blue arrows point from the fractions  $26/36$  and  $6/26$  to the numerator  $P(B) \times P(A|B)$ . Blue arrows point from the fractions  $6/11$  and  $11/36$  to the denominator  $P(A)$ .

**Bayesian reasoning** happens when we combine this mathematical rule with epistemic probability

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

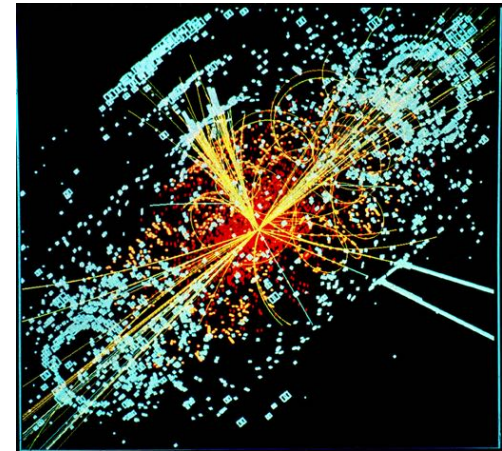




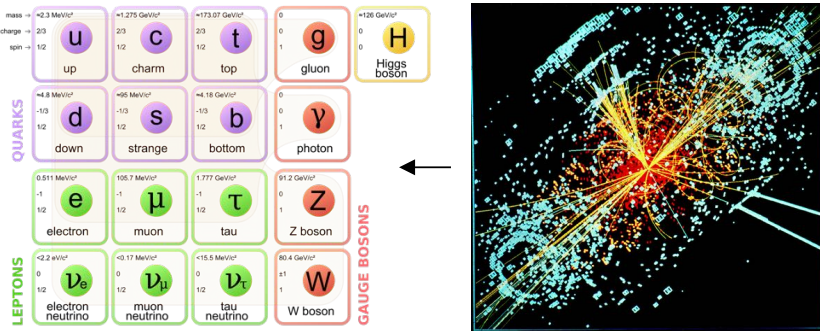
How strongly should I believe  
in this hypothesis...

... given that I have  
observed these data?

mass →	$\approx 2.3 \text{ MeV}/c^2$	$\approx 1.275 \text{ GeV}/c^2$	$\approx 173.07 \text{ GeV}/c^2$	0	$\approx 126 \text{ GeV}/c^2$
charge →	$2/3$	$2/3$	$2/3$	0	0
spin →	$1/2$	$1/2$	$1/2$	1	0
	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon	<b>H</b> Higgs boson
	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b><math>\gamma</math></b> photon	
<b>QUARKS</b>					
	$0.511 \text{ MeV}/c^2$	$105.7 \text{ MeV}/c^2$	$1.777 \text{ GeV}/c^2$	$91.2 \text{ GeV}/c^2$	
	-1	-1	-1	0	
	$1/2$	$1/2$	$1/2$	1	
	<b>e</b> electron	<b><math>\mu</math></b> muon	<b><math>\tau</math></b> tau	<b>Z</b> Z boson	
<b>LEPTONS</b>					<b>GAUGE BOSONS</b>
	$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 15.5 \text{ MeV}/c^2$	$80.4 \text{ GeV}/c^2$	
	0	0	0	$\pm 1$	
	$1/2$	$1/2$	$1/2$	1	
	<b><math>\nu_e</math></b> electron neutrino	<b><math>\nu_\mu</math></b> muon neutrino	<b><math>\nu_\tau</math></b> tau neutrino	<b>W</b> W boson	



$h|d$



The **posterior probability** that my hypothesis is true given that I have observed these data...

$$P(h|d) = \frac{P(d|h) \times P(h)}{P(d)}$$

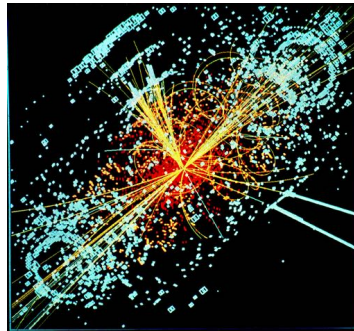
h

mass →	~2.3 MeV/c <sup>2</sup>	~1.275 GeV/c <sup>2</sup>	~173.07 GeV/c <sup>2</sup>	0	~126 GeV/c <sup>2</sup>
charge →	2/3	2/3	2/3	0	0
spin →	1/2	1/2	1/2	1	0
	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon	<b>H</b> Higgs boson
	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b>γ</b> photon	
<b>QUARKS</b>					
	0.511 MeV/c <sup>2</sup>	105.7 MeV/c <sup>2</sup>	1.777 GeV/c <sup>2</sup>	0	~91.2 GeV/c <sup>2</sup>
	-1	-1	-1	0	0
	1/2	1/2	1/2	1	1
	<b>e</b> electron	<b>μ</b> muon	<b>τ</b> tau	<b>Z</b> Z boson	
	<b>ν<sub>e</sub></b> electron neutrino	<b>ν<sub>μ</sub></b> muon neutrino	<b>ν<sub>τ</sub></b> tau neutrino	<b>W</b> W boson	
<b>LEPTONS</b>					<b>GAUGE BOSONS</b>

The **prior probability** that I assigned to this hypothesis before observing the data

$$P(h|d) = \frac{P(d|h) \times P(h)}{P(d)}$$

$d|h$



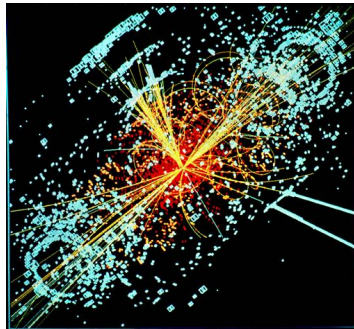
mass →	2.3 MeV/c <sup>2</sup>	1.275 GeV/c <sup>2</sup>	173.07 GeV/c <sup>2</sup>	0	126 GeV/c <sup>2</sup>
charge →	2/3	2/3	2/3	0	0
spin →	1/2	1/2	1/2	1	0
	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon	<b>H</b> Higgs boson
<b>QUARKS</b>	4.8 MeV/c <sup>2</sup>	95 MeV/c <sup>2</sup>	4.18 GeV/c <sup>2</sup>	0	
	-1/3	-1/3	-1/3	0	
	1/2	1/2	1/2	1	
	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b>γ</b> photon	
	0.511 MeV/c <sup>2</sup>	105.7 MeV/c <sup>2</sup>	1.777 GeV/c <sup>2</sup>	91.2 GeV/c <sup>2</sup>	
	-1	-1	-1	0	
	1/2	1/2	1/2	1	
	<b>e</b> electron	<b>μ</b> muon	<b>τ</b> tau	<b>Z</b> Z boson	
<b>LEPTONS</b>	<2 eV/c <sup>2</sup>	<0.17 MeV/c <sup>2</sup>	<15.5 MeV/c <sup>2</sup>	80.4 GeV/c <sup>2</sup>	
	0	0	0	±1	
	1/2	1/2	1/2	1	
	<b>ν<sub>e</sub></b> electron neutrino	<b>ν<sub>μ</sub></b> muon neutrino	<b>ν<sub>τ</sub></b> tau neutrino	<b>W</b> W boson	
					<b>GAUGE BOSONS</b>

The likelihood that I would have observed these data if the hypothesis is true

$$P(h|d) = \frac{P(d|h) \times P(h)}{P(d)}$$

$$P(h|d) = \frac{P(d|h) \times P(h)}{P(d)}$$

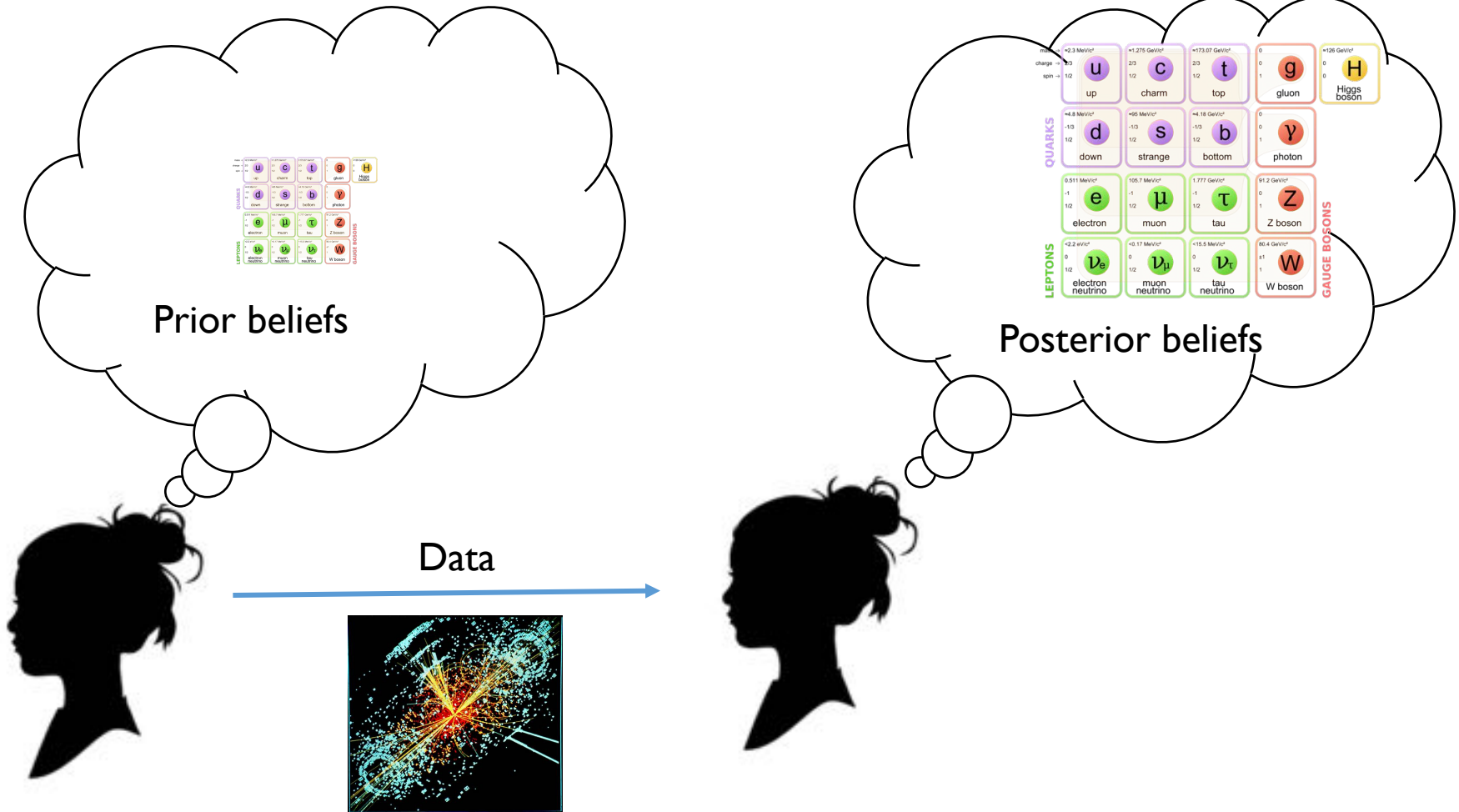
d



The “marginal” probability of observing these particular data (more on this shortly)



# Belief revision!



$P(d|h)$  : the likelihood of observing  $d$  if  $h$  is true

$P(h)$  : the prior probability that  $h$  is true

$P(h|d)$  : the posterior probability that  $h$  is true

$$P(h|d) = \frac{P(d|h)P(h)}{P(d)}$$

$P(d)$  : discussed later

## 1.4 Example of Bayesian reasoning



# Many possibilities



dropped a wine glass



broke a window



psychic explosion



earthquake



a wizard did it

etc...

# Let's compare two of them



I dropped a wine glass



Kids broke the window

# “Prior odds”

$$\frac{P(h_1)}{P(h_2)} = \frac{\text{[Cracked Window Image]}}{\text{[Broken Wine Glass Image]}} = 0.1$$

Before learning anything else I think “wine glass dropping” is 10 times more plausible than “broken window”

# Some data



There is a cricket ball  
next to the broken glass

# Likelihood of the data

When I drop a wine glass...



... It's very unlikely that I just happen to do so right next to a cricket ball

$$P(d|h) = 0.001$$



# Likelihood of the data

When the kids break a window...



... It's not at all uncommon for a cricket ball to end up near the glass

$$P(d|h) = 0.15$$

# Bayes factor

(a.k.a. likelihood ratio)

$$\frac{P(d|h_1)}{P(d|h_2)} = \frac{\text{Cricket ball} \leftarrow \text{Broken window}}{\text{Cricket ball} \leftarrow \text{Broken wine glass}} = \frac{0.15}{0.001} = 150$$

I think it is 150 times more likely that I would find a cricket ball when a window breaks than when a wine glass is broken

# Posterior odds

$$\frac{P(h_1|d)}{P(h_2|d)} = \frac{P(d|h_1)}{P(d|h_2)} \times \frac{P(h_1)}{P(h_2)}$$

Posterior odds

= 15

Likelihood ratio

= 150

Prior odds

= .1



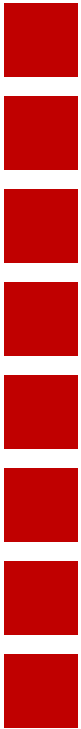
In light of the evidence, I now think the window-breaking hypothesis is 15 times more likely than the wine-glass hypothesis



## 1.5 Bayesian hypothesis testing



8 red



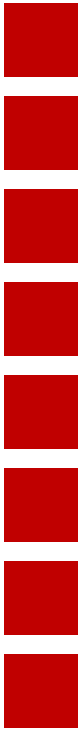
2 black

# Is this roulette wheel unbalanced?



We're ignoring the zero

8 red



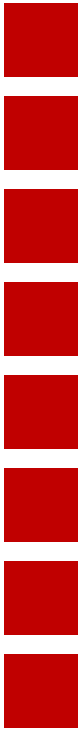
2 black

Null model,  $h_0$

The roulette wheel has an equal probability of producing red and black



8 red



2 black

Null model,  $h_0$

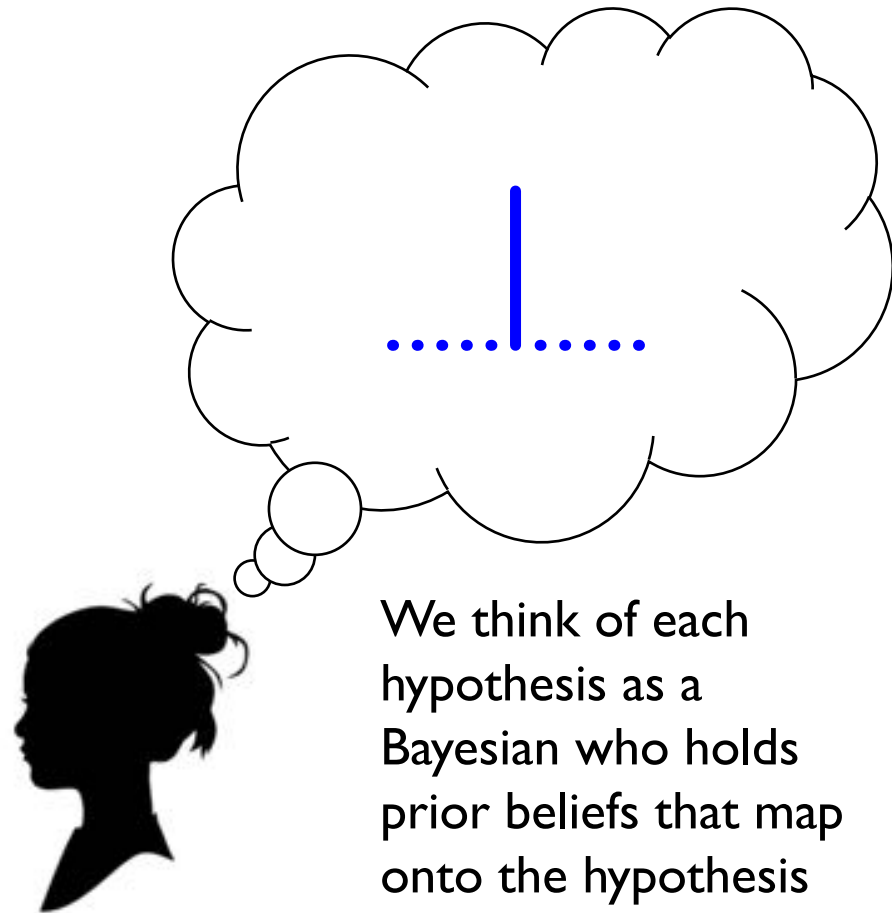
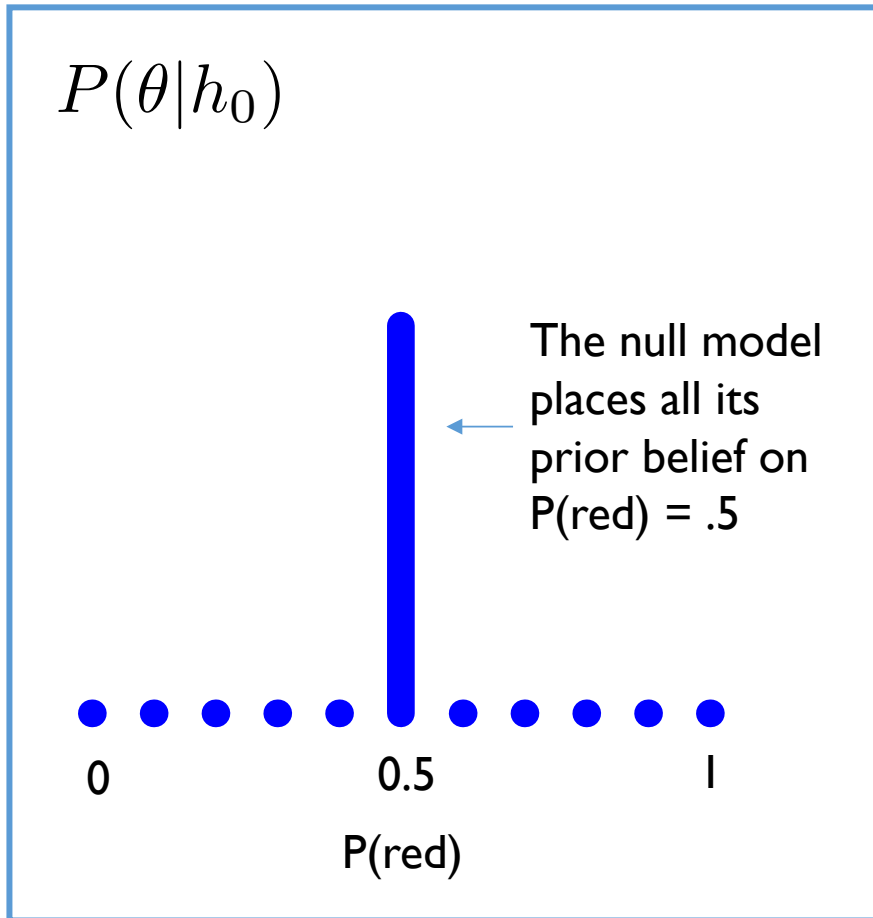
The roulette wheel has an equal probability of producing red and black

Alternative model,  $h_1$

The roulette wheel has a bias, but we don't know what it is



## Null hypothesis

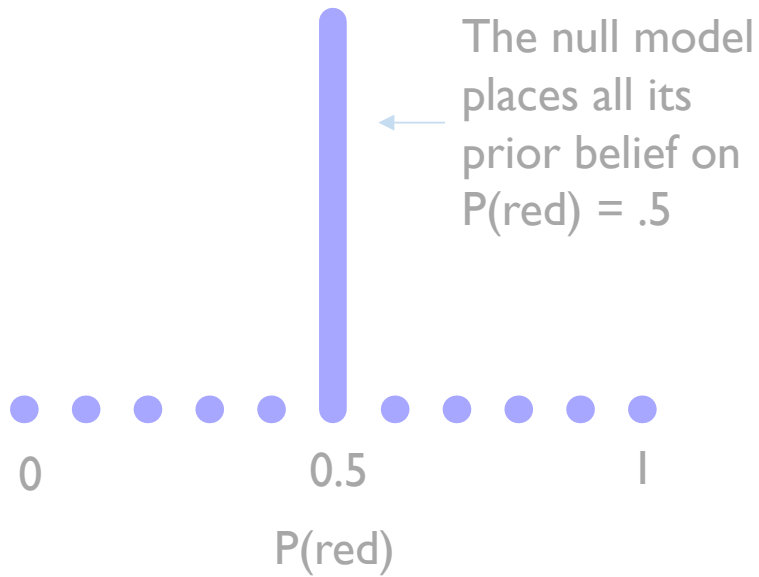


Let's pretend that there's no such thing as "continuous numbers", and act as if the only possible values for  $P(\text{red})$  are 0, 0.1, 0.2, ..., 1.0 😊



## Null hypothesis

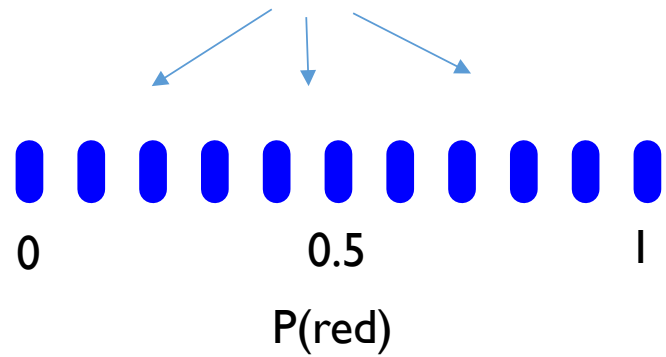
$$P(\theta|h_0)$$



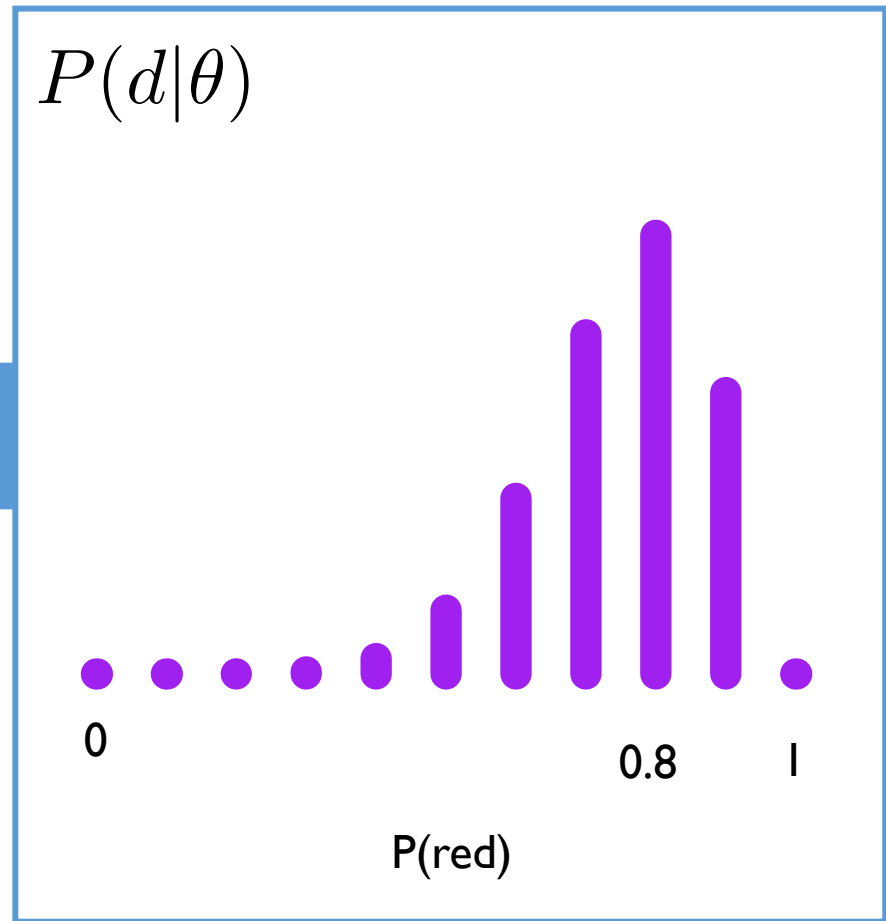
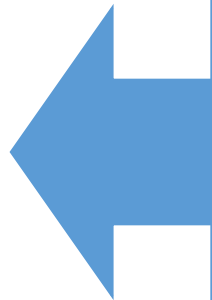
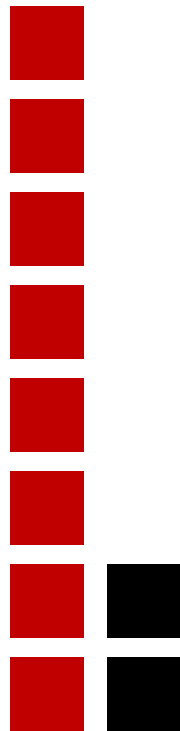
## Alternative hypothesis

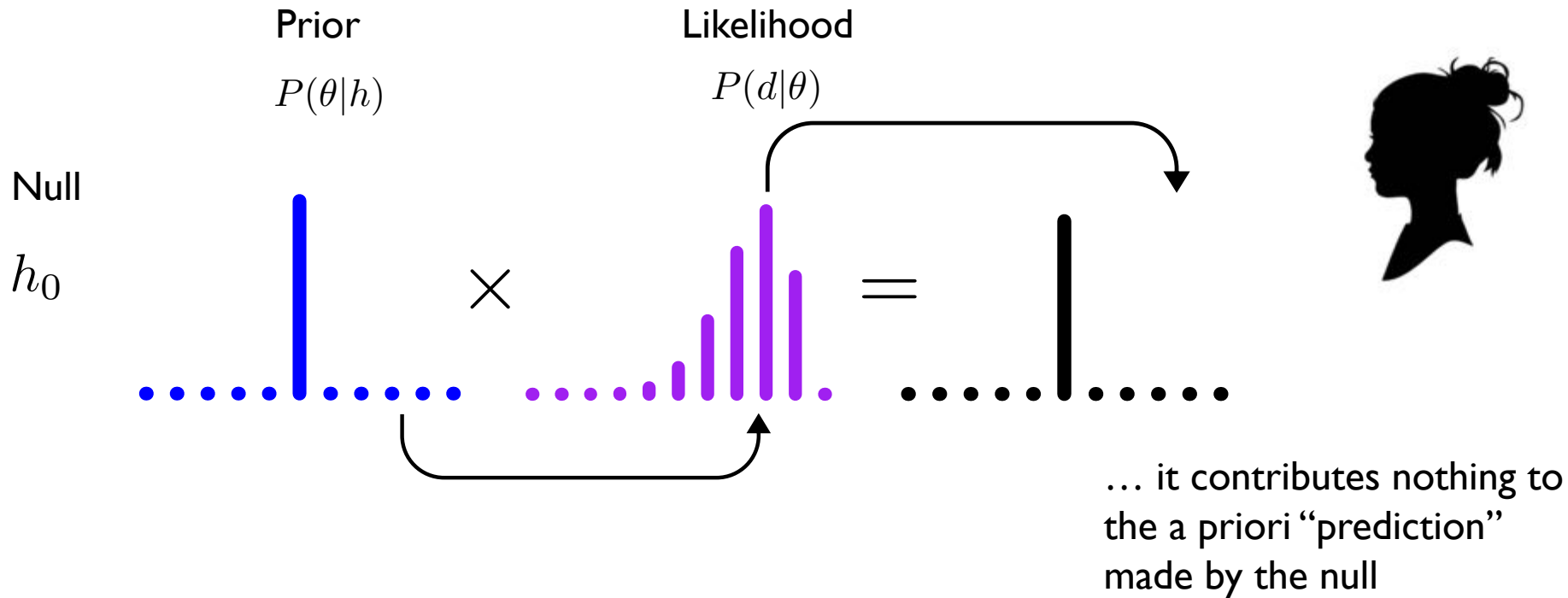
$$P(\theta|h_1)$$

The alternative model spreads its prior belief equally across all possibilities



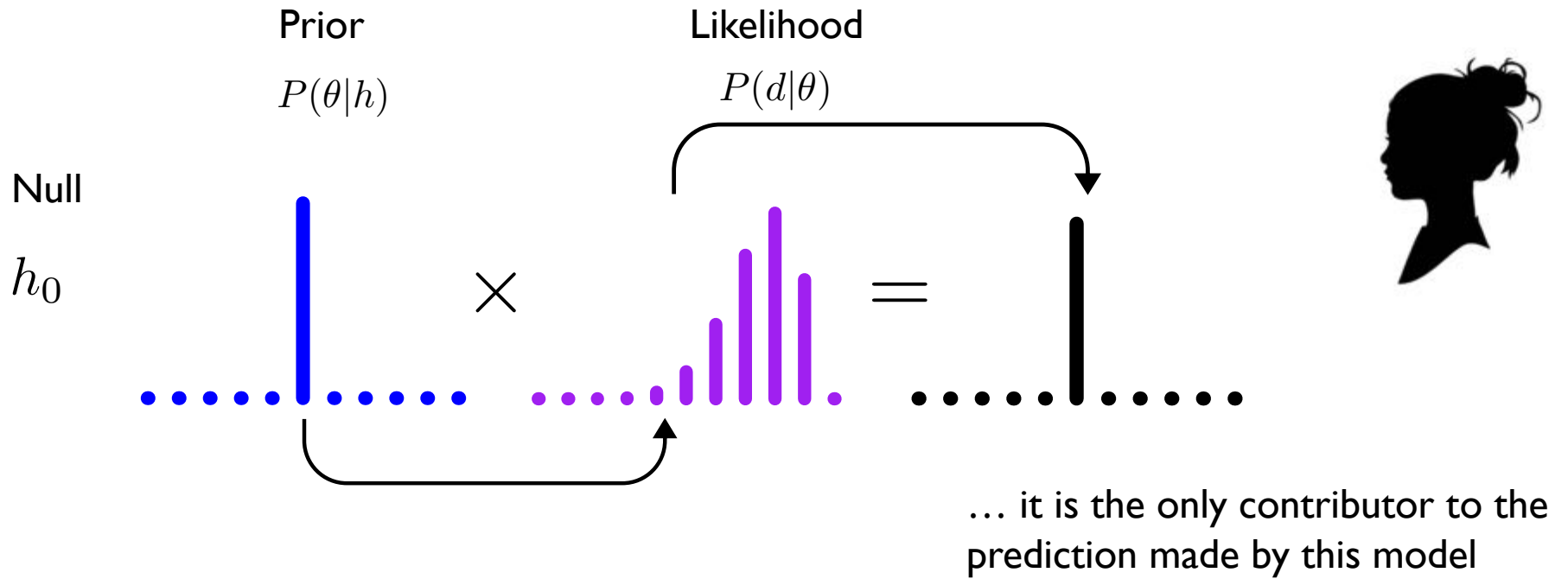
Likelihoods ... the probability of the data given every possible value of  $P(\text{red})$





The null hypothesis assigns prior probability 0 to the possibility that  $P(\text{red}) = 0.8$  ...

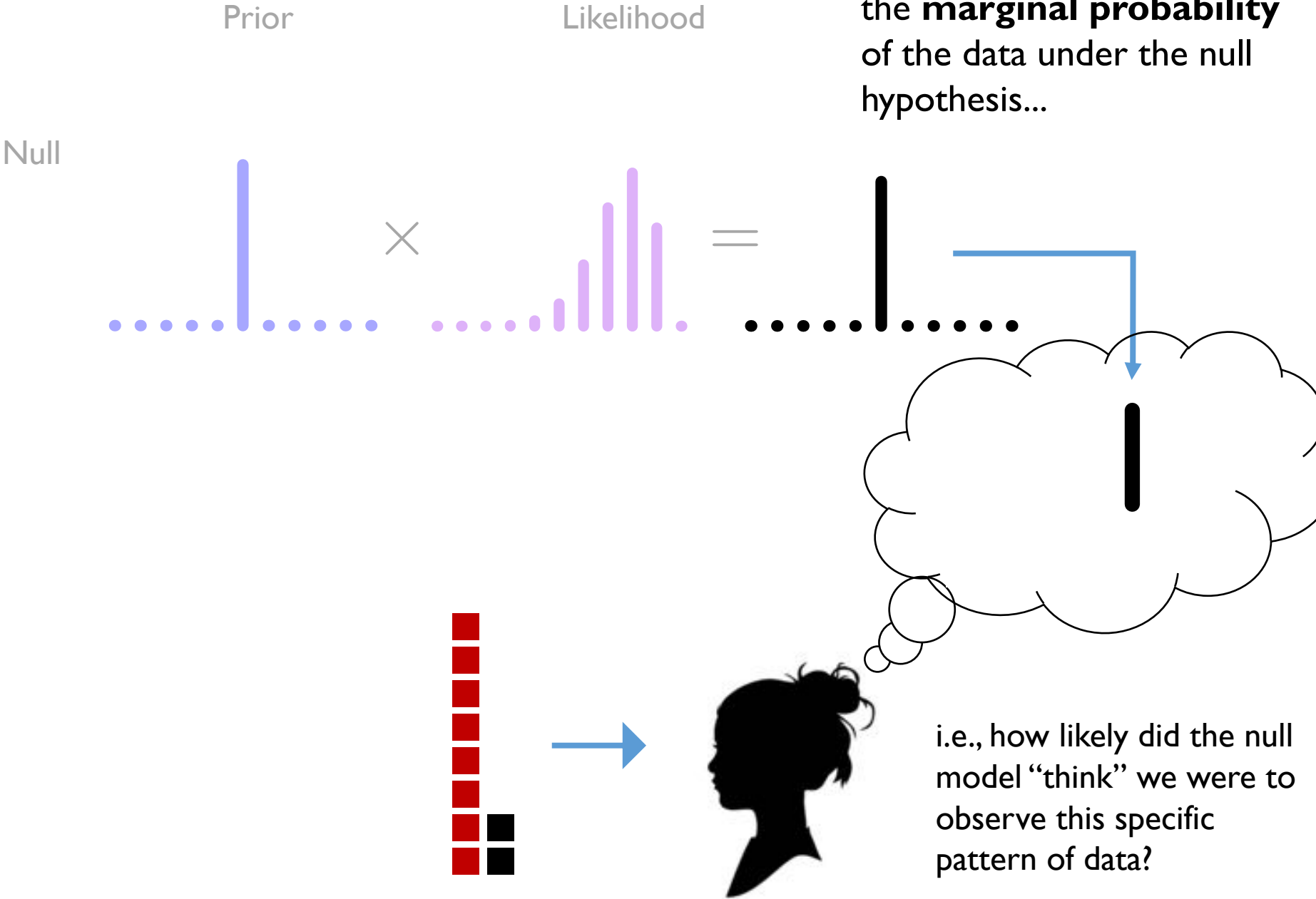
... so even though it assigns highest likelihood to the observed data ....



The null hypothesis assigns prior probability 1 to the possibility that  $P(\text{red}) = 0.5$  ...

... so even though it assigns a pretty small likelihood to the observed data ....

Summing these values gives the **marginal probability** of the data under the null hypothesis...



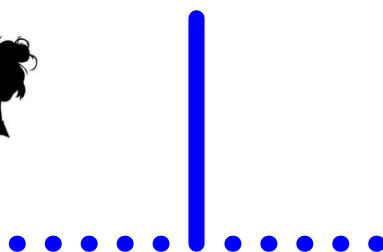
Prior  
 $P(\theta|h)$

Likelihood  
 $P(d|\theta)$

Marginal probability of  
the data according to  
both models

Null

$h_0$



$\times$



$=$



$P(d|h_0)$

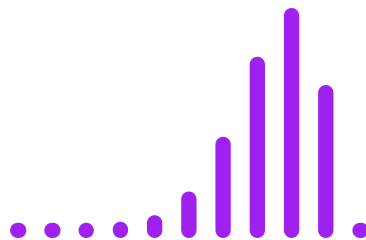


Alternative

$h_1$



$\times$



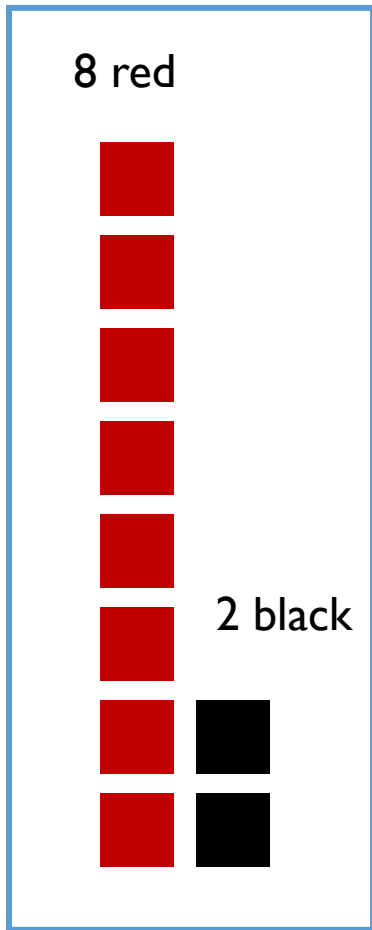
$=$



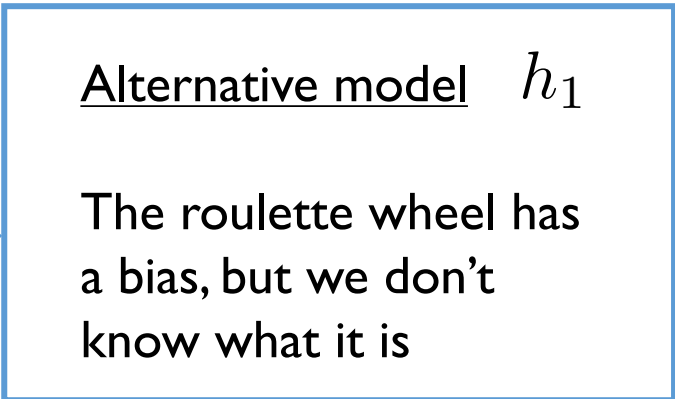
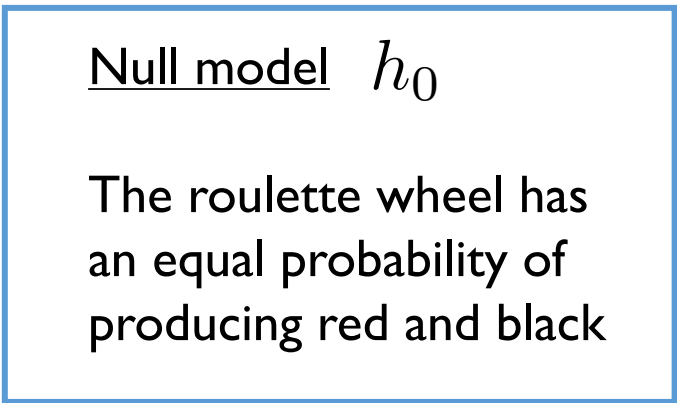
$P(d|h_1)$



# Data



# Models



# Bayes factor

$P(d|h_0)$



$P(d|h_1)$



... evidence of about 2:1 in favour of the alternative

$$BF_{10} = \frac{P(d|h_1)}{P(d|h_0)} = \frac{\sum_{\theta} P(d|\theta) \times P(\theta|h_0)}{\sum_{\theta} P(d|\theta) \times P(\theta|h_1)} = 1.87$$

## 2.1 Just another stats package

<https://jasp-stats.org>







# A Fresh Way to Do Statistics

[Download](#)



# Illustrating the JASP workflow

## What?

open a CSV file

descriptive statistics

run a frequentist ANOVA

save data and results to JASP file

## Where?

**File > Open**

**Common > Descriptives**

**Common > ANOVA > ANOVA**

**File > Save As**

# Here's a real data set with many variables!

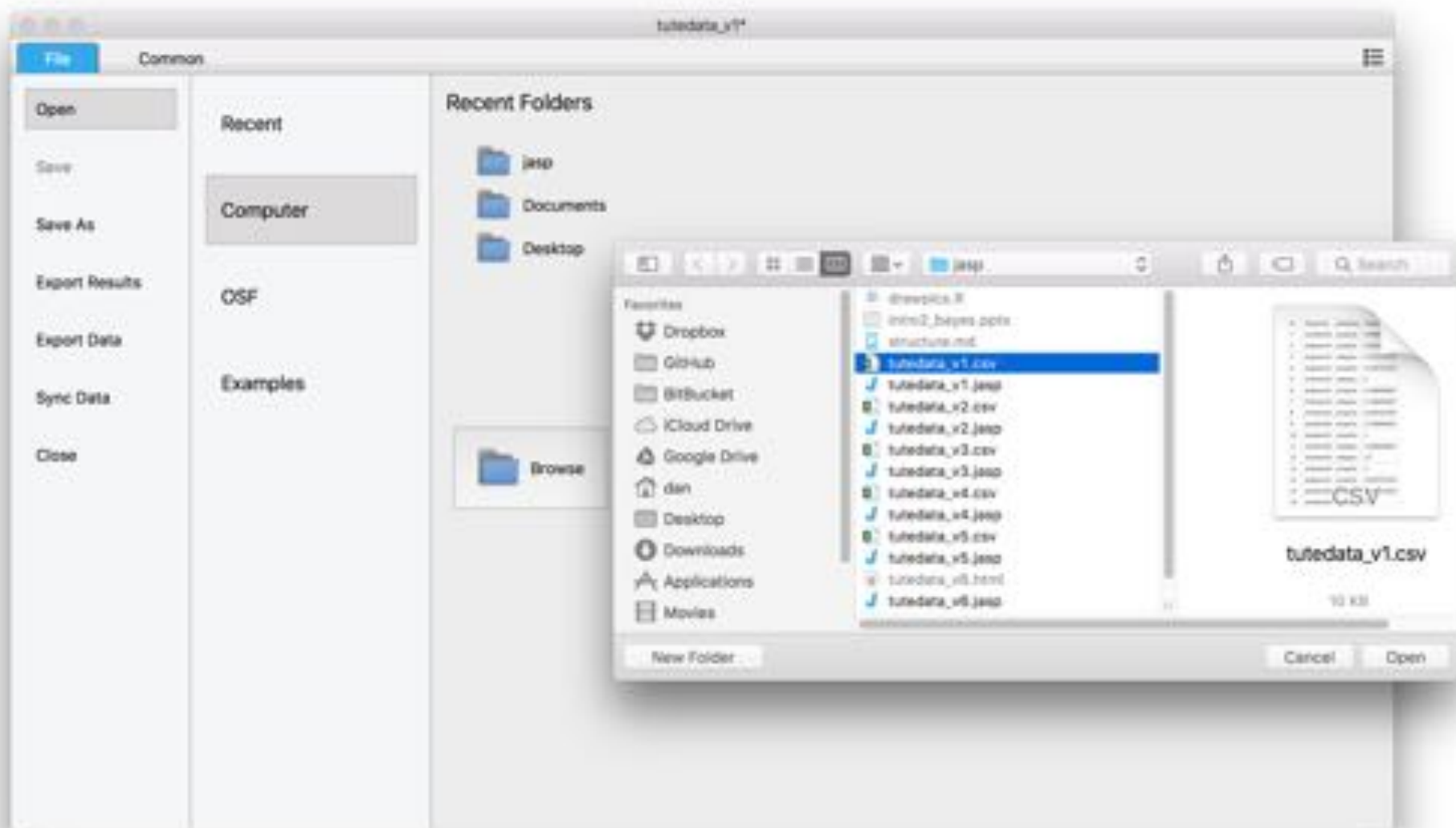
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	id	age	gender	frequency	sampling	gen_smallbr	gen_largebr	gen_smallgr	gen_largegr	gen_smallmj	gen_largemj	mean	smallworld	largeworld	property	category	condition	smallprop
2	1	21	female	smallworld	property	10	4	8	1	4	1	4.6666667	property	NA	smallworld	NA	smallworldproperty	yes
3	2	19	female	largeworld	property	9	4	6	3	5	2	4.8333333	NA	property	largeworld	NA	largeworldproperty	no
4	3	20	female	largeworld	category	9	4	3	3	4	3	4.3333333	NA	category	NA	largeworld	largeworldcategory	no
5	4	19	male	largeworld	property	9	3	5	2	5	2	4.3333333	NA	property	largeworld	NA	largeworldproperty	no
6	5	21	female	smallworld	category	3	5	8	9	4	7	6	category	NA	NA	smallworld	smallworldcategory	no
7	6	31	female	largeworld	property	8	3	5	5	5	5	5.1666667	NA	property	largeworld	NA	largeworldproperty	no
8	7	21	female	smallworld	category	10	5	5	1	5	5	5.1666667	category	NA	NA	smallworld	smallworldcategory	no
9	8	24	female	smallworld	property	10	5	5	1	10	10	6.8333333	property	NA	smallworld	NA	smallworldproperty	yes
10	9	19	female	smallworld	property	9	2	2	2	2	2	3.1666667	property	NA	smallworld	NA	smallworldproperty	yes
11	10	20	male	largeworld	property	8	5	2	2	4	3	4	NA	property	largeworld	NA	largeworldproperty	no
12	11	21	female	smallworld	category	10	10	1	6	1	6	5.6666667	category	NA	NA	smallworld	smallworldcategory	no
13	12	20	female	smallworld	category	8	5	4	4	5	5	5.5	category	NA	NA	smallworld	smallworldcategory	no
14	13	20	male	smallworld	property	10	2	2	1	2	1	3	property	NA	smallworld	NA	smallworldproperty	yes
15	14	19	female	largeworld	property	10	1	8	1	8	1	4.8333333	NA	property	largeworld	NA	largeworldproperty	no
16	16	21	male	smallworld	category	9	3	3	3	4	1	3.8333333	category	NA	NA	smallworld	smallworldcategory	no
17	18	24	female	smallworld	category	9	6	3	3	3	3	4.5	category	NA	NA	smallworld	smallworldcategory	no
18	19	20	male	smallworld	category	8	4	2	2	2	3	3.5	category	NA	NA	smallworld	smallworldcategory	no
19	20	20	male	smallworld	property	10	7	4	4	4	4	5.5	property	NA	smallworld	NA	smallworldproperty	yes
20	21	23	male	smallworld	property	10	5	5	5	5	5	5.8333333	property	NA	smallworld	NA	smallworldproperty	yes
21	25	21	female	smallworld	category	10	5	1	2	2	2	3.6666667	category	NA	NA	smallworld	smallworldcategory	no
22	26	19	male	largeworld	category	9	8	2	5	2	2	4.6666667	NA	category	NA	largeworld	largeworldcategory	no
23	27	19	male	smallworld	property	10	7	7	8	3	3	6	property	NA	smallworld	NA	smallworldproperty	yes
24	29	23	female	largeworld	category	10	9	4	4	5	5	6.1666667	NA	category	NA	largeworld	largeworldcategory	no
25	30	21	male	largeworld	property	10	1	7	1	7	1	4.5	NA	property	largeworld	NA	largeworldproperty	no
26	32	20	female	smallworld	property	10	5	2	2	2	2	3.8333333	property	NA	smallworld	NA	smallworldproperty	yes
27	33	19	female	smallworld	property	8	6	4	4	4	4	5	property	NA	smallworld	NA	smallworldproperty	yes
28	34	19	female	smallworld	property	9	2	3	3	3	3	3.8333333	property	NA	smallworld	NA	smallworldproperty	yes
29	35	20	male	smallworld	property	10	9	2	3	2	2	4.6666667	property	NA	smallworld	NA	smallworldproperty	yes
30	36	23	female	largeworld	property	9	3	3	1	3	1	3.3333333	NA	property	largeworld	NA	largeworldproperty	no
31	37	19	female	smallworld	category	10	7	2	2	4	2	4.5	category	NA	NA	smallworld	smallworldcategory	no
32	38	20	male	smallworld	property	10	8	2	2	2	2	4.3333333	property	NA	smallworld	NA	smallworldproperty	yes
33	39	20	female	largeworld	category	9	5	5	5	5	5	5.6666667	NA	category	NA	largeworld	largeworldcategory	no
34	40	23	female	smallworld	property	9	9	7	2	8	2	5.3333333	property	NA	smallworld	NA	smallworldproperty	yes
35	43	19	male	smallworld	category	10	8	7	6	7	7	7.5	category	NA	NA	smallworld	smallworldcategory	no
36	43	21	female	largeworld	category	9	5	3	6	6	6	5.8333333	NA	category	NA	largeworld	largeworldcategory	no
37	44	19	male	smallworld	property	6	5	3	3	3	4	4	property	NA	smallworld	NA	smallworldproperty	yes

JASP isn't (currently?) good for computing new variables, so it's best to do that in Excel or whatever you prefer

A	B	C	D
<b>id</b>	<b>frequency</b>	<b>sampling</b>	<b>meangen</b>
1	smallworld	property	4.67
2	largeworld	property	4.83
3	largeworld	category	4.33
4	largeworld	property	4.33
5	smallworld	category	6.00
6	largeworld	property	5.17
7	smallworld	category	5.17
8	smallworld	property	6.83
9	smallworld	property	3.17
10	largeworld	property	4.00
11	smallworld	category	5.67
12	smallworld	category	5.50
13	smallworld	property	3.00
14	largeworld	property	4.83
16	smallworld	category	3.83
18	smallworld	category	4.50
19	smallworld	category	3.50
20	smallworld	property	5.50

For simplicity I'll use small CSV files with only the relevant variables

# File > Open



# Common

The screenshot shows the JASP software interface. The window title is "tutedata\_v1". The menu bar includes "File" and "Common". The toolbar contains icons for Descriptives, T-Tests, ANOVA, Regression, Frequencies, and Factor. The main area is divided into two panes. The left pane displays a data table with 18 rows and 5 columns: "id", "frequency", "sampling", and "meanen". The right pane shows a welcome message for JASP, including the version number "Version 0.10" and a list of features: Free, Friendly, and Inclusive. A tooltip at the bottom of the right pane says "Double-click to edit data".

	id	frequency	sampling	meanen
1	1	smallworld	property	4.66667
2	2	largeworld	property	4.83333
3	3	largeworld	category	4.33333
4	4	largeworld	property	4.33333
5	5	smallworld	category	6
6	6	largeworld	property	5.16667
7	7	smallworld	category	5.16667
8	8	smallworld	property	6.83333
9	9	smallworld	property	3.16667
10	10	largeworld	property	4
11	11	smallworld	category	5.66667
12	12	smallworld	category	5.5
13	13	smallworld	property	3
14	14	largeworld	property	4.83333
15	16	smallworld	category	3.83333
16	18	smallworld	category	4.5
17	19	smallworld	category	3.5
18	20	smallworld	property	5.8

Version 0.10

## JASP

### Welcome to JASP

A Fresh Way to Do Statistics: Free, Friendly, and Inclusive

- Free:** JASP is an open-source project with structural support from the University of Amsterdam.
- Friendly:** JASP has an intuitive interface that was designed with the user in mind.
- Inclusive:** JASP offers standard analysis procedures in both their classical and Bayesian manifestations.

So open a data file and take JASP for a spin!

Double-click to edit data

# Common > Descriptives

The image shows a screenshot of the SPSS software interface. The main window is titled 'tutedata\_y11'. The 'Common' menu is open, and the 'Descriptives' option is selected. The 'Descriptives' dialog box is open, showing a list of variables: 'id', 'frequency', 'sampling', and 'meangen'. The 'Display frequency tables (nominal and ordinal variables)' checkbox is checked. Below the list, there are expandable sections for 'Plots' and 'Statistics'. The 'Results' window is open, displaying the 'Descriptives' output. The output includes a table of Descriptive Statistics for the variables 'id', 'frequency', 'sampling', and 'meangen'. The table shows the number of valid and missing cases, the mean, standard deviation, minimum, and maximum for each variable. A note at the bottom states: 'Note. Not all values are available for Nominal Text variables.'

**Results**

**Descriptives**

Descriptive Statistics

	id	frequency	sampling	meangen
Valid	286	286	286	286
Missing	0	0	0	0
Mean	173.0			4.937
Std. Deviation	99.19			1.152
Minimum	1.000			2.333
Maximum	342.0			9.000

Note. Not all values are available for Nominal Text variables.



# Common > ANOVA

The screenshot shows a software window titled "Tutorial1\_v11". The interface includes a menu bar with "File" and "Common", and a toolbar with icons for "Descriptives", "T-Tests", "ANOVA", "Regression", "Frequencies", and "Factor". The "ANOVA" menu is open, displaying options: "ANOVA", "Repeated Measures ANOVA", "ANCOVA", "Bayesian ANOVA", "Bayesian Repeated Measures ANOVA", and "Bayesian ANCOVA". Below the menu is a data table with columns "id", "frequency", "property", and "value".

	id	frequency	property	value
1	1	smallworld		
2	2	largeworld		
3	3	largeworld		
4	4	largeworld	property	4.33333
5	5	smallworld	category	6
6	6	largeworld	property	5.16667
7	7	smallworld	category	5.16667
8	8	smallworld	property	6.83333
9	9	smallworld	property	3.16667
10	10	largeworld	property	4
11	11	smallworld	category	5.66667
12	12	smallworld	category	5.5
13	13	smallworld	property	3
14	14	largeworld	property	4.83333
15	15	smallworld	category	3.83333
16	16	smallworld	category	4.5
17	17	smallworld	category	3.5
18	18	smallworld	property	5.8

Results



# Common > ANOVA > ANOVA

The screenshot shows the SPSS ANOVA dialog box and the resulting ANOVA table. The dialog box is titled "ANOVA" and has a "Common" tab selected. The "Dependent Variable" is set to "frequency". The "Fixed Factor(s)" list is empty. The "WLS Weights" list is empty. The "Model" section is expanded, showing "Model", "Assumption Checks", "Contrasts", "Post Hoc Tests", "Descriptives Plots", and "Additional Options". The "Results" window shows the ANOVA table with columns for Cases, Sum of Squares, df, and Mean Squares. The table shows a Residual with a Sum of Squares of 0, df of 0, and Mean Squares of 0. A note below the table states "Note. Type III Sum of Squares".

	id	frequency
1	1	smallworld
2	2	largeworld
3	3	largeworld
4	4	largeworld
5	5	smallworld
6	6	largeworld
7	7	smallworld
8	8	smallworld
9	9	smallworld
10	10	largeworld
11	11	smallworld
12	12	smallworld
13	13	smallworld
14	14	largeworld
15	15	smallworld
16	15	smallworld
17	19	smallworld

**ANOVA**

ANOVA	Cases	Sum of Squares	df	Mean Squ
Residual		0	0	0

Note. Type III Sum of Squares

# Common > ANOVA > ANOVA

The screenshot shows the SPSS ANOVA dialog box and the resulting ANOVA table. The dialog box is titled "ANOVA" and has "meangen" selected as the dependent variable. "frequency" and "sampling" are listed as fixed factors. The results window shows the ANOVA table for "meangen".

**ANOVA Dialog Box Settings:**

- Dependent Variable: meangen
- Fixed Factors: frequency, sampling
- WLS Weights: (empty)

**ANOVA Results Table:**

	Cases	Sum of Squares	df
frequency		3.947	1
sampling		55.762	1
frequency * sampling		5.429	1
Residual		313.523	282

Note. Type III Sum of Squares

# Common > ANOVA > ANOVA > Descriptive Plots

The image shows the SPSS ANOVA: Descriptive Plots dialog box and the Results window. The dialog box is open to the 'Descriptives Plots' section, showing the 'Factors' list with 'frequency' and 'sampling' selected. The 'Display' section has 'Confidence interval' selected with a 95% interval. The Results window shows the ANOVA table for 'meangen'.

**ANOVA: Descriptive Plots**

Model:  OK

Assumption Checks:

Contrasts:

Post Hoc Tests:

Descriptives Plots:

Factors:

- frequency
- sampling

Horizontal axis:

Separate lines:

Separate plots:

Display:

- Error bars displaying
- Confidence interval  
Interval: 95 %
- Standard error

Additional Options:

**Results**

**ANOVA**

ANOVA - meangen

Cases	Sum of Squares	df
frequency	3.947	1
sampling	55.762	1
frequency * sampling	5.429	1
Residual	313.523	282

Note. Type III Sum of Squares

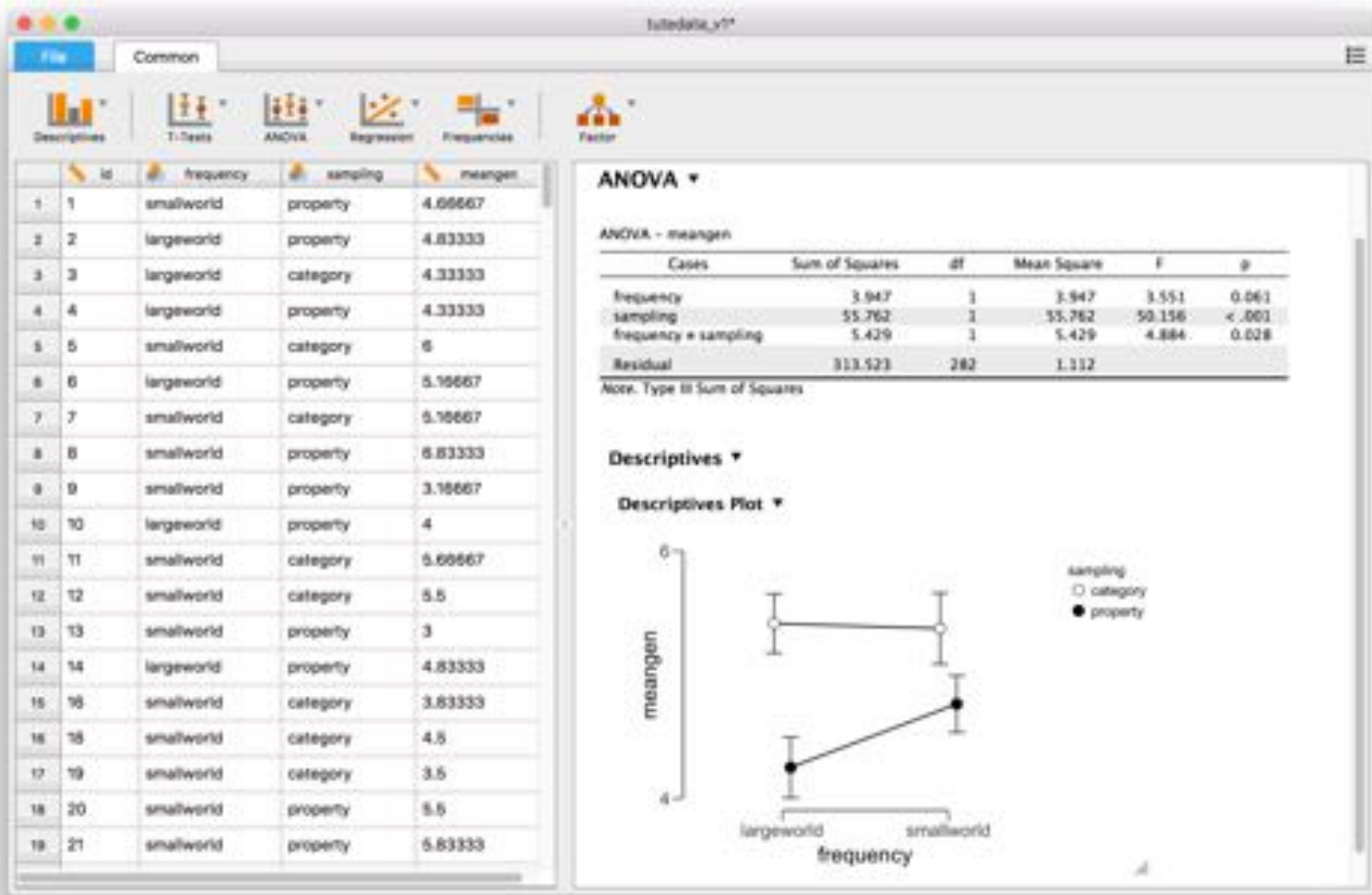
# Common > ANOVA > ANOVA > Descriptive Plots

The screenshot shows the SPSS 'ANOVA' dialog box with the 'Descriptives Plots' section expanded. The 'Horizontal axis' is set to 'frequency', and 'Separate lines' is selected for the 'sampling' factor. The 'Display' section has 'Error bars displaying' and 'Confidence interval' checked, with a 95% interval. The 'ANOVA' summary table on the right shows the following data:

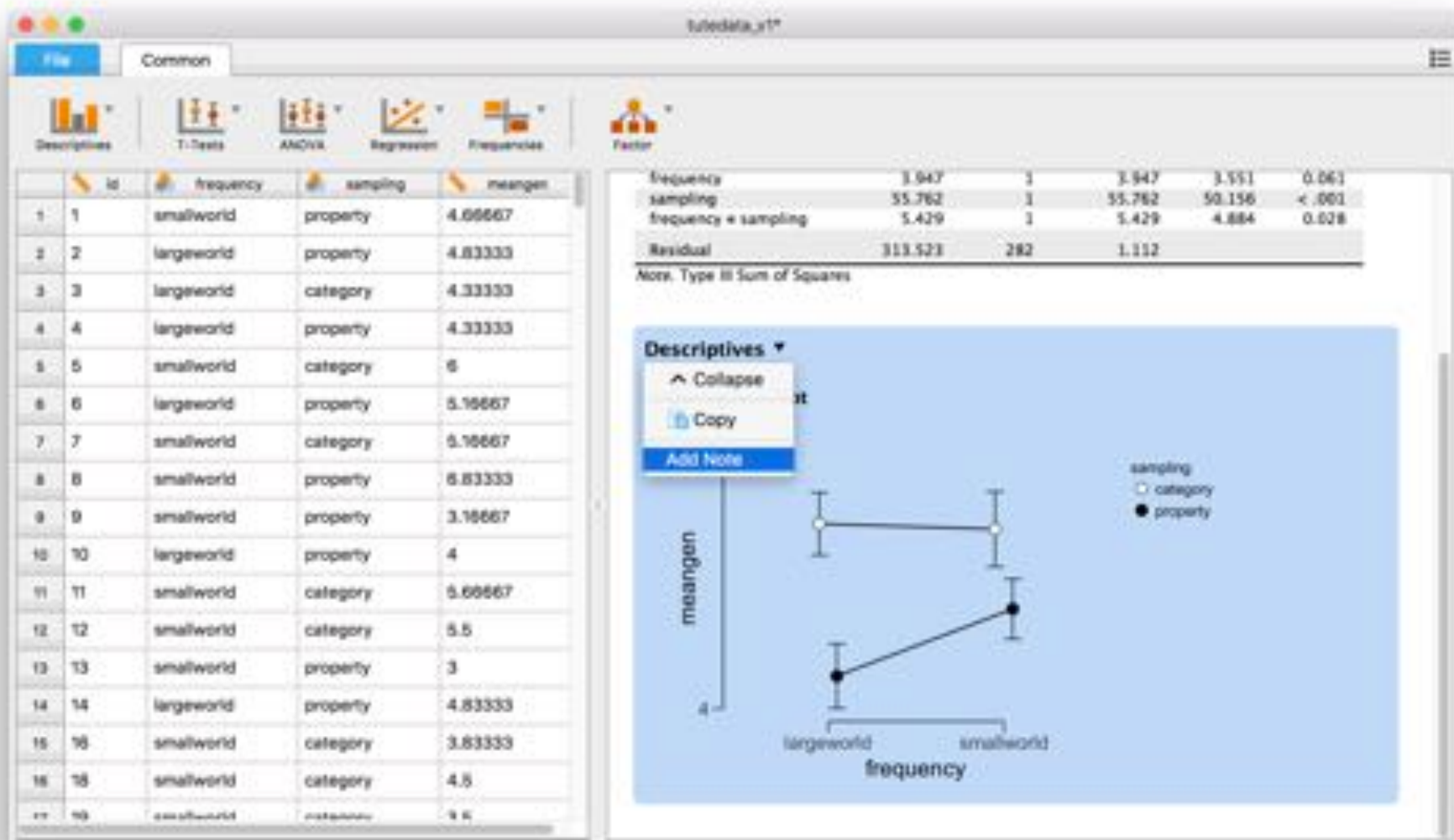
ANOVA - meangen			
	Cases	Sum of Squares	df
frequency		3.947	
sampling		55.762	
frequency * sampling		5.429	
Residual		313.523	28

Below the ANOVA table, the 'Descriptives' section shows a 'Descriptives Plot' with error bars for the 'meangen' variable. The plot shows two lines representing the interaction between 'frequency' and 'sampling'.

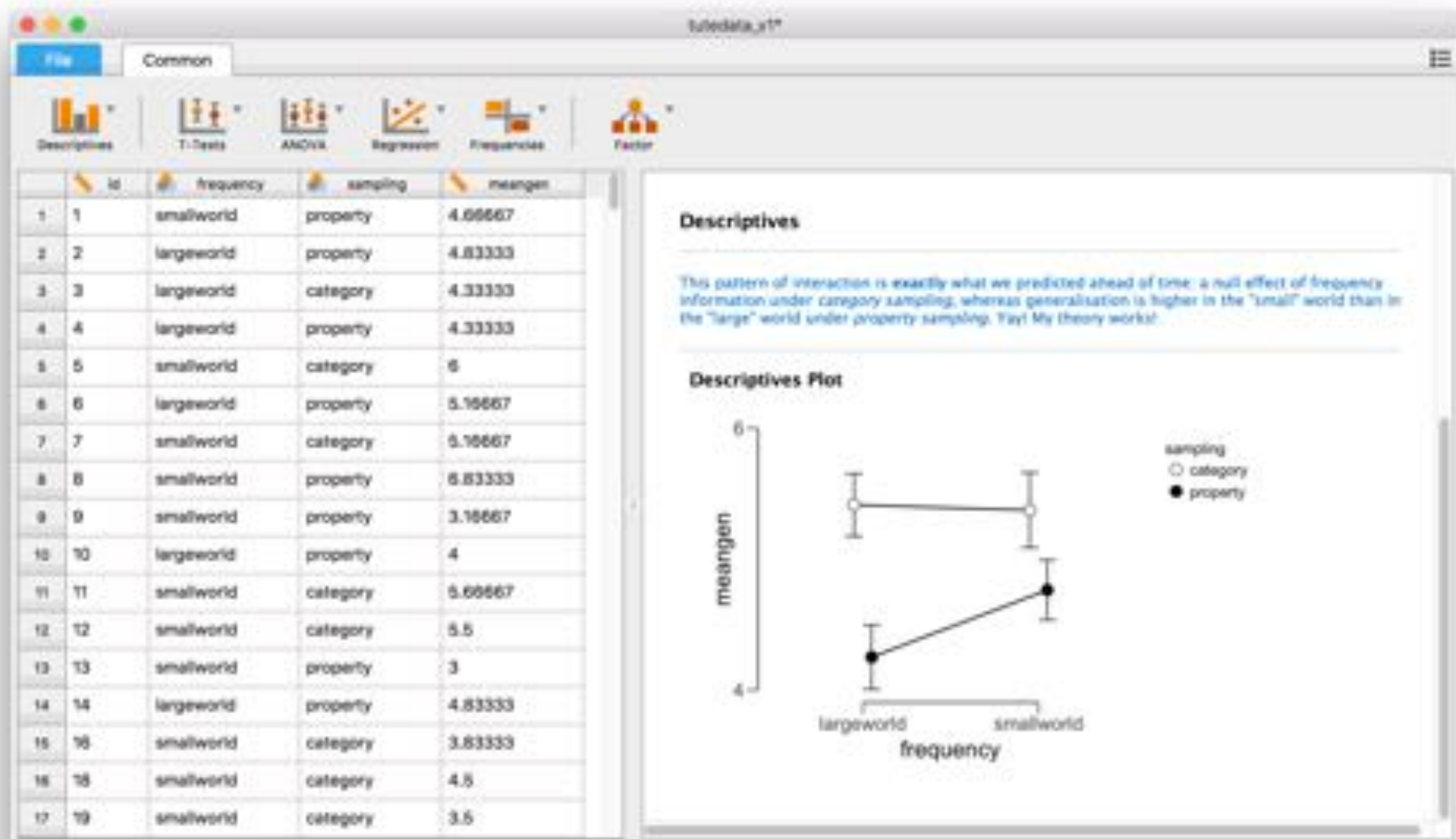
# Common



# Common

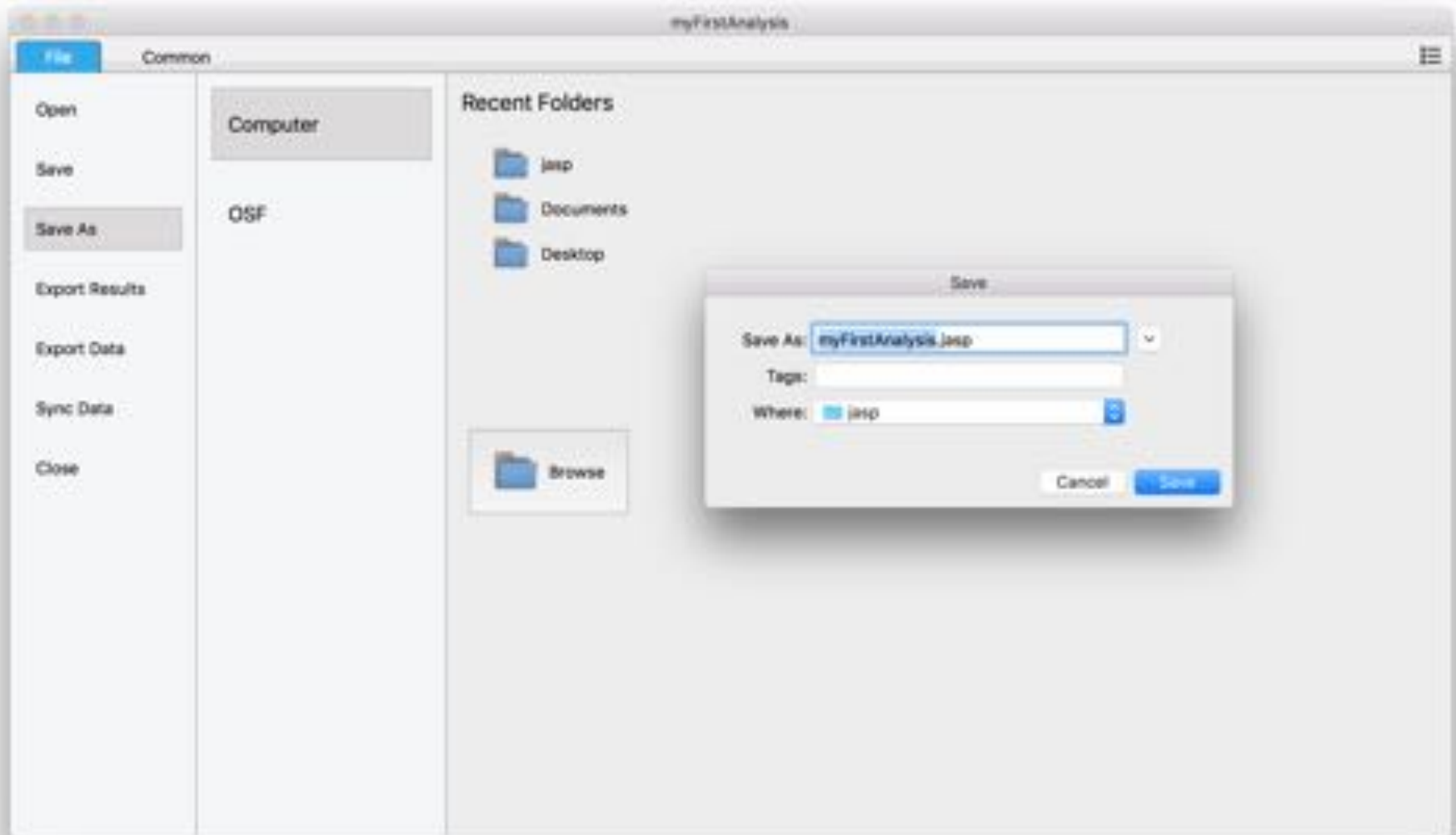


# Common



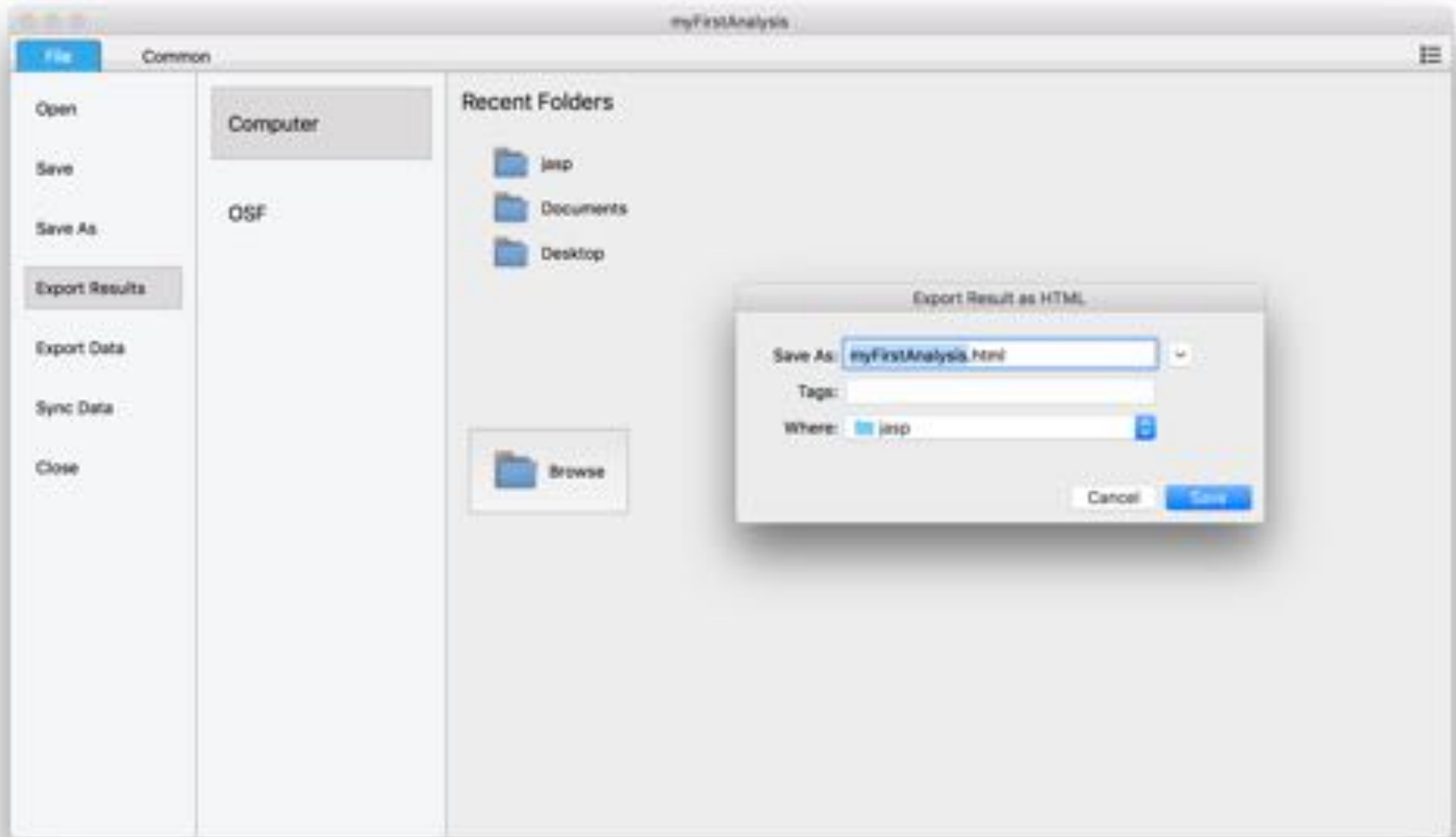


## File > Save As





## File > Export Results



## 2.2 Bayesian ANOVA



# Common > ANOVA > Bayesian ANOVA

The screenshot displays a software interface for Bayesian ANOVA. On the left is a data table with 19 rows and 5 columns. The columns are labeled 'id', 'frequency', 'sampling', and 'meangr'. The 'id' column contains values from 1 to 21. The 'frequency' column contains 'smallworld' or 'largeworld'. The 'sampling' column contains 'property' or 'category'. The 'meangr' column contains numerical values ranging from 3 to 6.83333.

The central panel shows the analysis configuration. The dependent variable is 'meangr'. Fixed factors are 'frequency' and 'sampling'. Random factors are empty. Under 'Bayes Factor', 'BF<sub>10</sub>' is selected. Under 'Output', 'Effects' is selected. Under 'Order', 'Compare to null model' is selected. There are expandable sections for 'Model', 'Descriptives Plots', and 'Advanced Options'.

On the right, the 'Results' panel shows the 'Bayesian ANOVA' model comparison for 'meangr'. It lists three models: 'Null model', 'frequency + sampling', and 'frequency + sampling + frequency \* sampling'. The 'Analysis of Effects - meangr' table shows that the main effects of 'frequency' and 'sampling' have a probability of 0, while the interaction effect 'frequency \* sampling' has a probability of 0.

id	frequency	sampling	meangr
1	smallworld	property	4.66667
2	largeworld	property	4.83333
3	largeworld	category	4.33333
4	largeworld	property	4.33333
5	smallworld	category	6
6	largeworld	property	5.16667
7	smallworld	category	5.16667
8	smallworld	property	6.83333
9	smallworld	property	3.16667
10	largeworld	property	4
11	smallworld	category	5.66667
12	smallworld	category	5.5
13	smallworld	property	3
14	largeworld	property	4.83333
15	smallworld	category	3.83333
16	smallworld	category	4.5
17	smallworld	category	3.5
18	smallworld	property	5.5
19	smallworld	property	5.83333

Models	BF <sub>10</sub>
Null model	1
frequency + sampling	0
frequency + sampling + frequency * sampling	0

Effects	Pr
frequency	0
sampling	0
frequency * sampling	0

# Common > ANOVA > Bayesian ANOVA

The screenshot shows a software window titled "tutodata\_v1" with a menu bar (File, Common) and a toolbar with icons for Descriptives, T-tests, ANOVA, Regression, Frequencies, and Factor. A data table is visible on the left, and the main area displays ANOVA and Bayesian ANOVA results.

### ANOVA

ANOVA - meangen

Cases	Sum of Squares	df	Mean Square	F	p
frequency	3.947	1	3.947	3.551	0.061
sampling	55.762	1	55.762	50.156	< .001
frequency * sampling	5.429	1	5.429	4.884	0.028
Residual	313.523	282	1.112		

Note: Type III Sum of Squares

### Bayesian ANOVA

Model Comparison - meangen

Models	P(M)	P(M data)	BF <sub>M</sub>	BF <sub>10</sub>	error %
Null model	0.200	1.195e -9	4.780e -9	1.000	
frequency	0.200	3.823e -10	1.520e -9	0.320	1.317e -5
sampling	0.200	0.309	1.792	2.590e +8	2.988e -14
frequency + sampling	0.200	0.255	1.367	2.132e +8	0.849
frequency + sampling + frequency * sampling	0.200	0.436	3.089	3.647e +8	1.130

Analysis of Effects - meangen

Effects	P(inc)	P(inc data)	BF <sub>inclusion</sub>
frequency	0.600	0.693	1.488
sampling	0.600	1.000	4.227e +8
frequency * sampling	0.200	0.436	3.089

## Common > ANOVA > Bayesian ANOVA

### Model Comparison - meangen

Models	P(M)	P(M data)	BF <sub>M</sub>	BF <sub>10</sub>	error %
Null model	0.200	1.195e -9	4.780e -9	1.000	
frequency	0.200	3.823e -10	1.529e -9	0.320	1.317e -5
sampling	0.200	0.309	1.792	2.590e +8	2.988e -14
frequency + sampling	0.200	0.255	1.367	2.132e +8	0.849
frequency + sampling + frequency*sampling	0.200	0.436	3.089	3.647e +8	1.130

### Analysis of Effects - meangen

Effects	P(incl)	P(incl data)	BF <sub>Inclusion</sub>
frequency	0.600	0.691	1.488
sampling	0.600	1.000	4.227e +8
frequency * sampling	0.200	0.436	3.089

## 2.3 Bayesian t-test



# Planned analysis #1:

## Null effect under category sampling?

id	frequency	sampling	meangen	smallworld	largeworld	property	category
1	smallworld	property	4.67	property		smallworld	
2	largeworld	property	4.83		property	largeworld	
3	largeworld	category	4.33		category		largeworld
4	largeworld	property	4.33		property	largeworld	
5	smallworld	category	6.00	category			smallworld
6	largeworld	property	5.17		property	largeworld	
7	smallworld	category	5.17	category			smallworld
8	smallworld	property	6.83	property		smallworld	
9	smallworld	property	3.17	property		smallworld	
10	largeworld	property	4.00		property	largeworld	
11	smallworld	category	5.67	category			smallworld
12	smallworld	category	5.50	category			smallworld
13	smallworld	property	3.00	property		smallworld	

# Common > T-Test > Bayesian Independent Samples T-Test

id  
frequency  
sampling  
smallworld  
largeworld  
property

Dependent Variables  
meangen

Grouping Variable  
category

Hypothesis  
 Group 1  $\neq$  Group 2  
 Group 1 > Group 2  
 Group 1 < Group 2

Bayes Factor  
  $BF_{10}$   
  $BF_{01}$   
  $\text{Log}(BF_{10})$

Additional Statistics  
 Descriptives

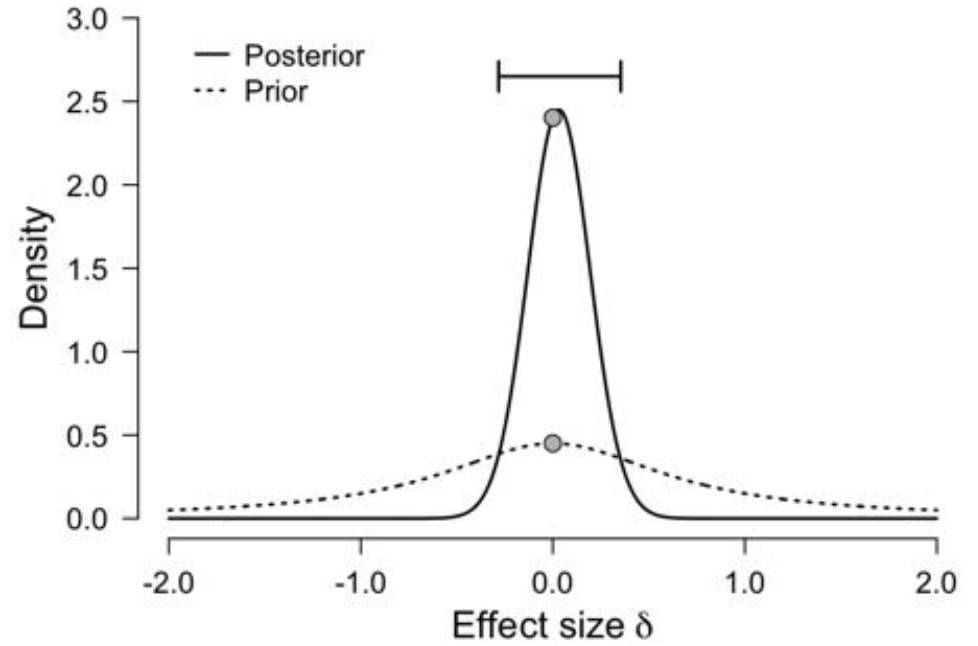
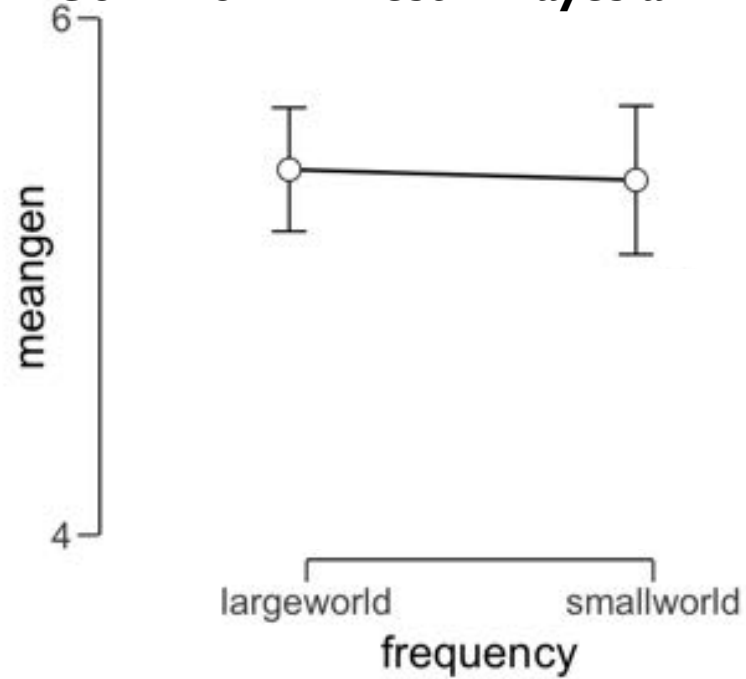
Plots  
 Prior and posterior  
 Additional info  
 Bayes factor robustness check  
 Sequential analysis  
 Robustness check  
 Descriptives plots  
Credible interval 95 %

Missing Values  
 Exclude cases analysis by analysis  
 Exclude cases listwise

Prior



# Common > T-Test > Bayesian Independent Samples T-Test



## Bayesian Independent Samples T-Test

	$BF_{01}$	error %
meangen	5.305	$9.941e^{-7}$

## Planned analysis #2:

large < small under property sampling

id	frequency	sampling	meangen	smallworld	largeworld	property	category
1	smallworld	property	4.67	property		smallworld	
2	largeworld	property	4.83		property	largeworld	
3	largeworld	category	4.33		category		largeworld
4	largeworld	property	4.33		property	largeworld	
5	smallworld	category	6.00	category			smallworld
6	largeworld	property	5.17		property	largeworld	
7	smallworld	category	5.17	category			smallworld
8	smallworld	property	6.83	property		smallworld	
9	smallworld	property	3.17	property		smallworld	
10	largeworld	property	4.00		property	largeworld	
11	smallworld	category	5.67	category			smallworld
12	smallworld	category	5.50	category			smallworld
13	smallworld	property	3.00	property		smallworld	

# Common > T-Test > Bayesian Independent Samples T-Test

**Dependent Variables**  
meangen

**Grouping Variable**  
property

**Hypothesis**  
 Group 1 ≠ Group 2  
 Group 1 > Group 2  
 Group 1 < Group 2

**Bayes Factor**  
 BF<sub>10</sub>  
 BF<sub>01</sub>  
 Log(BF<sub>10</sub>)

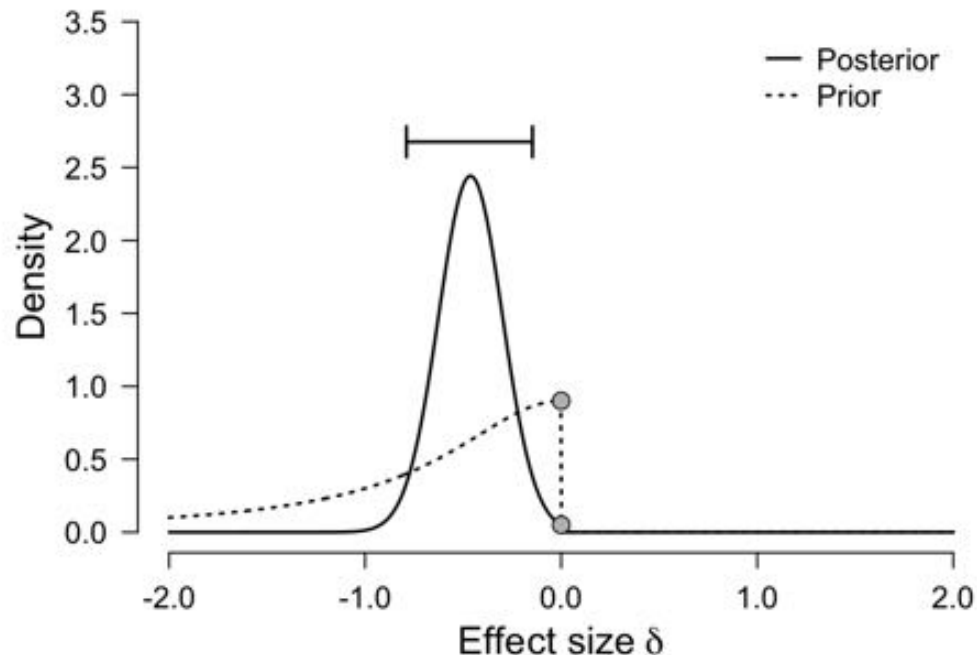
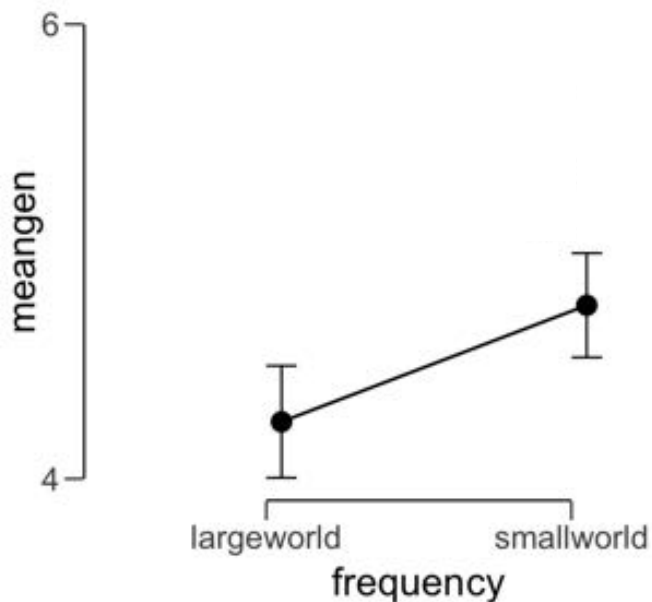
**Additional Statistics**  
 Descriptives

**Plots**  
 Prior and posterior  
 Additional info  
 Bayes factor robustness check  
 Sequential analysis  
 Robustness check  
 Descriptives plots  
Credible interval 95 %

**Missing Values**  
 Exclude cases analysis by analysis  
 Exclude cases listwise

Prior

# Common > T-Test > Bayesian Independent Samples T-Test



## Bayesian Independent Samples T-Test ▼

	BF <sub>-0</sub>	error %
meangen	22.49	~ 3.662e -6

*Note.* For all tests, the alternative hypothesis specifies that group *largeworld* is less than group *smallworld*.

## 2.4 Bayesian regression



id	age	small	property	female	meangen
1	21	1	1	1	4.67
2	19	0	1	1	4.83
3	20	0	0	1	4.33
4	19	0	1	0	4.33
5	21	1	0	1	6.00
6	31	0	1	1	5.17
7	21	1	0	1	5.17
8	24	1	1	1	6.83
9	19	1	1	1	3.17
10	20	0	1	0	4.00
11	21	1	0	1	5.67
12	20	1	0	1	5.50
13	20	1	1	0	3.00
14	19	0	1	1	4.83
16	21	1	0	0	3.83
18	24	1	0	1	4.50
19	20	1	0	0	3.50
20	20	1	1	0	5.50

# Common > Regression > Bayesian Linear Regression

The screenshot shows a software interface for Bayesian Linear Regression. It features a central workspace with two panels: a left panel containing the variable 'id' and a right panel containing the dependent variable 'meangen' and covariates 'age', 'small', 'property', and 'female'. Below the workspace are three sections: 'Bayes Factor' with radio buttons for  $BF_{10}$ ,  $BF_{01}$ , and  $\text{Log}(BF_{10})$ ; 'Output' with a checked checkbox for 'Effects'; and 'Order' with radio buttons for 'Compare to null model' and 'Compare to best model'. Three green arrows point to the  $BF_{10}$  option, the 'Effects' checkbox, and the 'Compare to best model' option.

id

Dependent Variable  
meangen

Covariates  
age  
small  
property  
female

Bayes Factor

- $BF_{10}$
- $BF_{01}$
- $\text{Log}(BF_{10})$

Order

- Compare to null model
- Compare to best model

Output

- Effects

## Common > Regression > Bayesian Linear Regression

Model Comparison - meangen ▼

Models	P(M)	P(M data)	BF <sub>M</sub>	BF <sub>10</sub>	error %
property	0.063	0.326	7.243	1.000	
small + property	0.063	0.234	4.572	0.717	0.012
age + small + property	0.063	0.151	2.663	0.463	0.012
age + property	0.063	0.141	2.457	0.432	0.012
property + female	0.063	0.050	0.791	0.154	0.013
small + property + female	0.063	0.043	0.678	0.133	0.012
age + small + property + female	0.063	0.030	0.471	0.093	0.013
age + property + female	0.063	0.025	0.392	0.078	0.012
Null model	0.063	6.055e -10	9.083e -9	1.860e -9	0.012
age	0.063	3.438e -10	5.157e -9	1.056e -9	0.012
small	0.063	1.745e -10	2.617e -9	5.358e -10	0.012
age + small	0.063	1.697e -10	2.546e -9	5.211e -10	0.013
female	0.063	1.023e -10	1.535e -9	3.142e -10	0.012
age + female	0.063	7.768e -11	1.165e -9	2.385e -10	0.014
age + small + female	0.063	4.557e -11	6.835e -10	1.399e -10	0.012
small + female	0.063	4.301e -11	6.451e -10	1.321e -10	0.015



## Common > Regression > Bayesian Linear Regression

### Analysis of Effects - meangen ▼

Effects	P(incl)	P(incl data)	BF <sub>Inclusion</sub>
age	0.500	0.347	0.532
small	0.500	0.458	0.845
property	0.500	1.000	6.402e +8
female	0.500	0.149	0.175

## 2.5 Bayesian contingency tables



id	age	small	property	female	meangen
1	21	1	1	1	4.67
2	19	0	1	1	4.83
3	20	0	0	1	4.33
4	19	0	1	0	4.33
5	21	1	0	1	6.00
6	31	0	1	1	5.17
7	21	1	0	1	5.17
8	24	1	1	1	6.83
9	19	1	1	1	3.17
10	20	0	1	0	4.00
11	21	1	0	1	5.67
12	20	1	0	1	5.50
13	20	1	1	0	3.00
14	19	0	1	1	4.83
16	21	1	0	0	3.83
18	24	1	0	1	4.50
19	20	1	0	0	3.50
20	20	1	1	0	5.50

# Common > Frequencies > Bayesian Contingency Tables

The screenshot displays a software interface for configuring a Bayesian Contingency Table. On the left, a list of variables is shown with corresponding icons: 'id' (orange pencil), 'age' (blue and orange person), 'female' (blue and orange person), and 'meangen' (orange pencil). On the right, there are two panels: 'Rows' and 'Columns'. The 'Rows' panel contains the variable 'small' (blue and orange person icon) and a small bar chart icon in the bottom right corner. The 'Columns' panel contains the variable 'property' (blue and orange person icon) and a similar small bar chart icon in the bottom right corner. Play buttons are visible to the left of each panel.

## Common > Frequencies > Bayesian Contingency Tables

▼ | Statistics

**Sampling**

- Poisson
- Joint multinomial
- Indep. multinomial, rows fixed
- Indep. multinomial, columns fixed
- Hypergeometric (2x2 only)

**Hypothesis**

- Group one  $\neq$  Group two
- Group one  $>$  Group two
- Group one  $<$  Group two

**Bayes Factor**

- $BF_{10}$
- $BF_{01}$
- $\text{Log}(BF_{10})$

## Common > Frequencies > Bayesian Contingency Tables

### Bayesian Contingency Tables ▼

small	property		Total
	0	1	
0	73	71	144
1	62	78	140
Total	135	149	284

### Bayesian Contingency Tables Tests

	Value
BF <sub>01</sub> joint multinomial	2.540
N	284

## 2.6 Bayesian binomial test



<b>spin</b>	<b>outcome</b>
1	red
2	red
3	red
4	black
5	red
6	red
7	red
8	black
9	red
10	red



# Common > Frequencies > Bayesian Binomial Test

spin outcome OK

Test value: 0.5

**Hypothesis**

≠ Test value

> Test value

< Test value

**Plots**

Prior and posterior

Additional info

Sequential analysis

**Bayes Factor**

$BF_{10}$

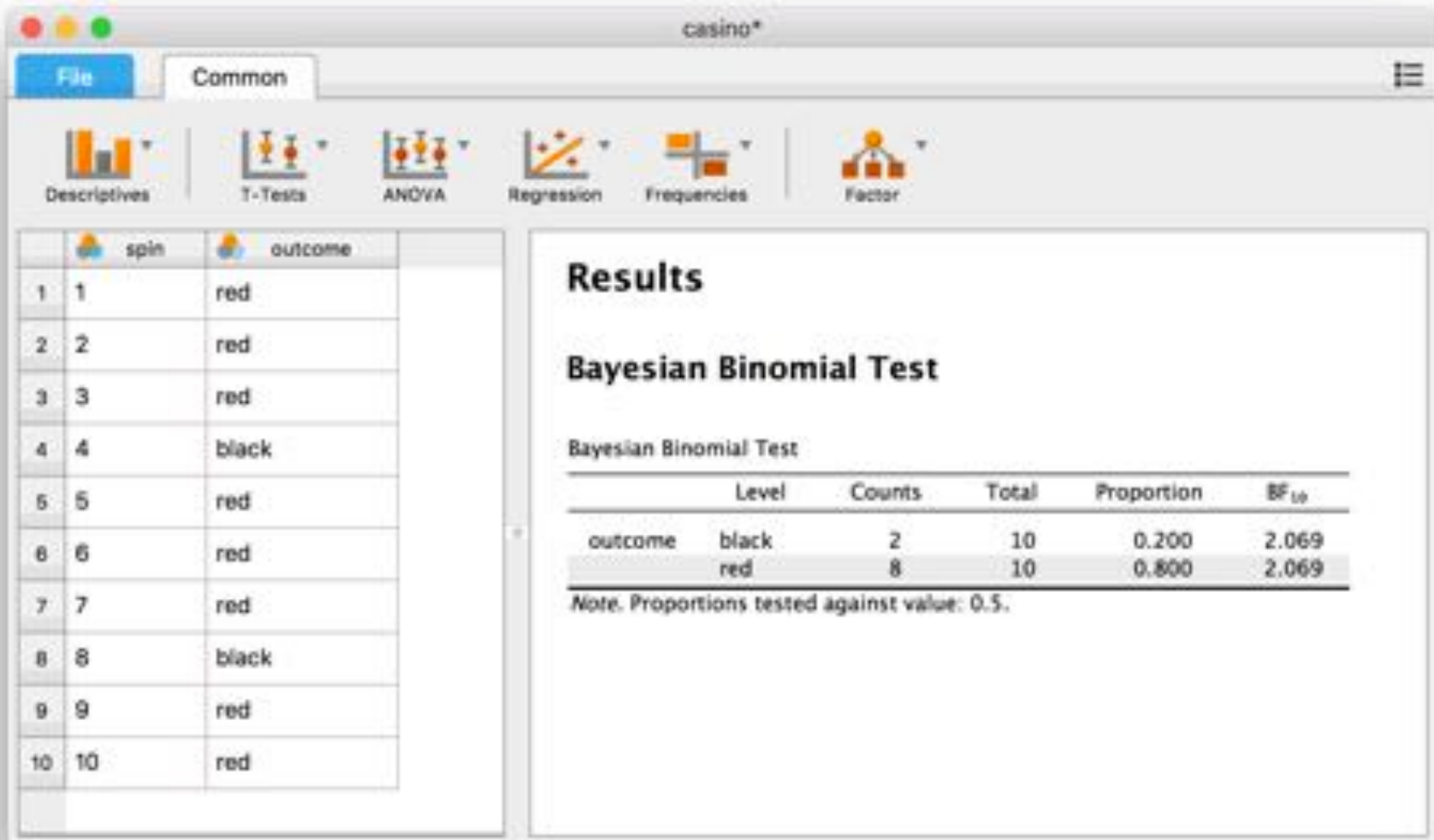
$BF_{01}$

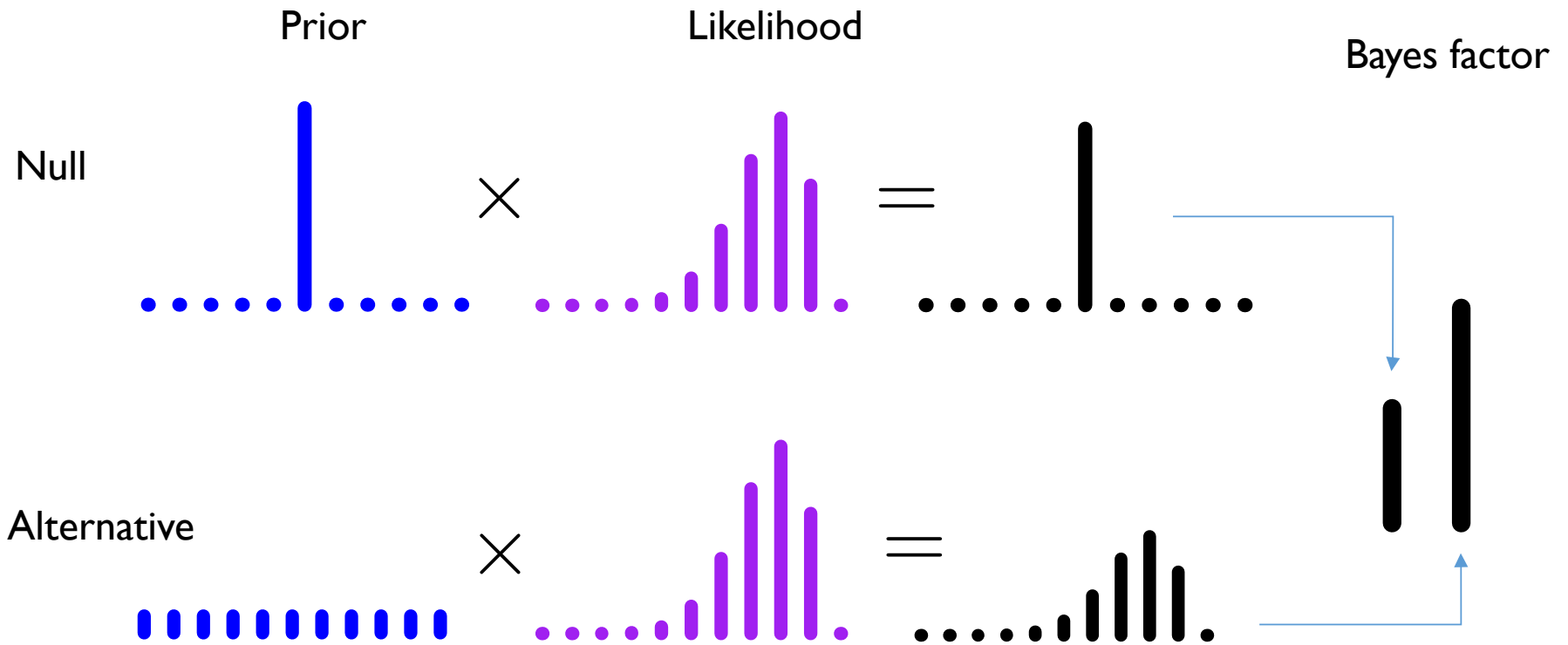
$\text{Log}(BF_{10})$

**Prior**

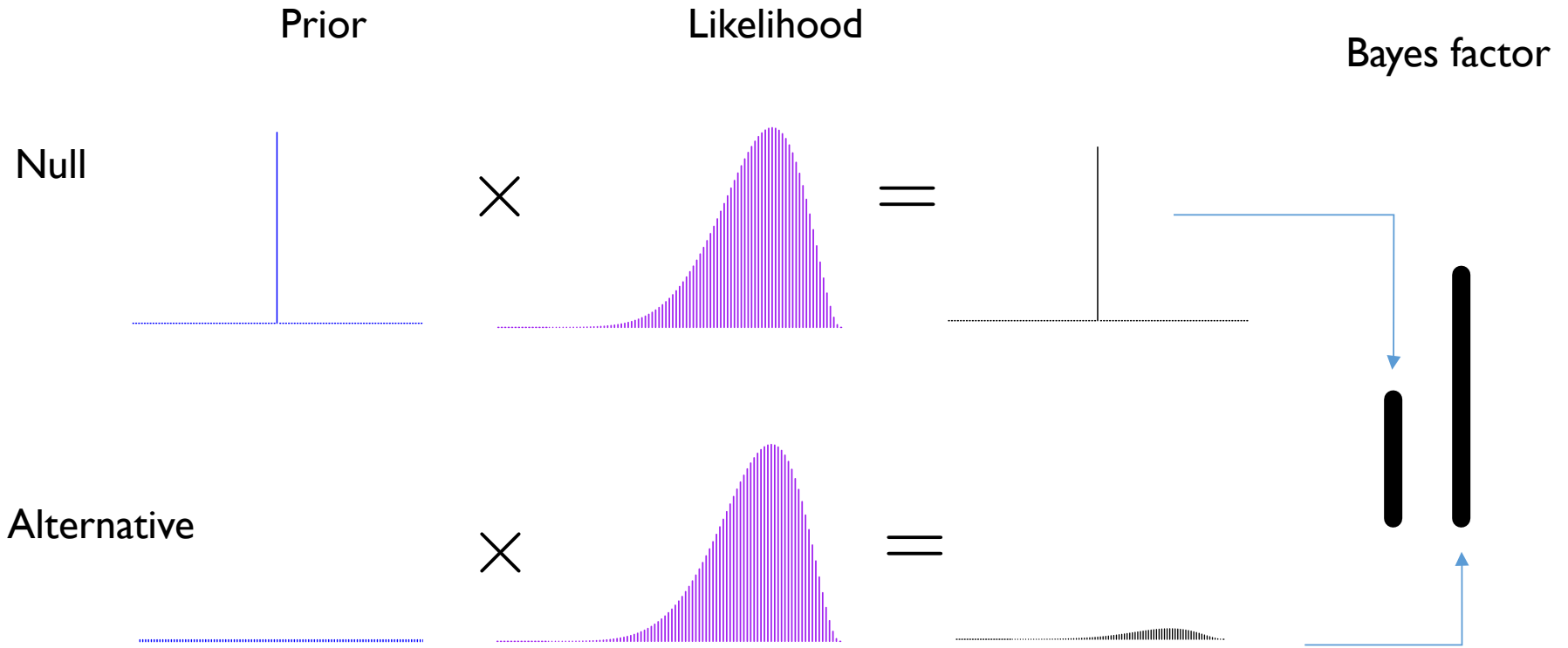
Beta prior: parameter a 1

Beta prior: parameter b 1





Wait... we got 1.87 for this Bayes factor and JASP says 2.07



It's just an approximation error... if we use finer-grained approximation to "continuous numbers" we get 2.05

## 2.7 Beyond basics



... to be added at a later stage!

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

**Done!**