Bayesian Thinking for Toddlers



Eric-Jan Wagenmakers Illustrations by Viktor Beekman

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For Theo and Leanne

Once upon a time, in a land far, far away, Kate and Miruna were debating who knows the most about **dinosaurs**...





'I can name each and every dinosaur! And I can say "Huehuecanauhtlus" really fast.'



'Look at my **crown**! Also, I have watched a lot of television. And my dad can buy me as many dinosaurs as I like.'

— 6 —

- 7

Whoever knows the most about dinosaurs gets 14 homemade cookies from Aunt Agatha.



— 8 –

Aunt Agatha

Aunt Agatha cannot tell whether Kate or Miruna knows the most about dinosaurs, so she considers to divide the cookies **evenly**.



But wait! Aunt Agatha has an idea. She will ask a **question** to help her determine who knows the most about dinosaurs.





The question is: 'How many **horns** does a Triceratops have on its head?'





'Three! I am absolutely sure!'





'Oh, this is **difficult**! I am not sure. It could be *none*, or *one*, or *two*, or *three*, or *four*, or *five* – all of these are equally likely to me!'







'The correct answer is *three*. A Triceratops has three horns on its head.'



How well did Kate and Miruna predict the correct answer?







Completely correct!

Correct for *one out of six* of her predictions!

Kate **outpredicted** Miruna by a factor of **six**. So now Aunt Agatha considers giving Kate six times as many cookies as Miruna.







But wait! Aunt Agatha has another idea. She will ask a **second** question about dinosaurs! Are you ready?









The second question is: 'How many **spikes** does a Stegosaurus have on its tail?'





'Hmmm. I am **not sure**. *Four* or *six* spikes – both options seem equally plausible to me.'





'Four! No doubt about it!'





'The correct answer is *four*. A Stegosaurus has four spikes on its tail.'





How well did Kate and Miruna predict the correct answer?



Correct for *one out of two* of her predictions!



Completely correct!

For the Triceratops question, Kate **out-predicted** Miruna by a factor of **six**.



For the Stegosaurus question, Miruna **outpredicted** Kate by a factor of **two**.







Overall then, Kate **outpredicted** Miruna by a factor of 6/2 = 3. Based on what she now knows, Aunt Agatha feels that Kate should get *three* times as many cookies as Miruna.







What have we learned?

1 A Triceratops has *three* horns on its head.



2 A Stegosaurus has *four* spikes on its tail.



3 Cookies measure *confidence*.

Kate out-predicted Miruna on the dinosaur test, and that's why Aunt Agatha believes that Kate knows the most about dinosaurs – but Aunt Agatha is *not completely* sure. This is why Miruna still gets some cookies, even though she did *worse* on the test

than Kate.



4 Over time, Aunt Agatha *adjusted* her confidence that Kate knows the most about dinosaurs.

At first, Aunt Agatha was *completely unsure*. After the Triceratops question, she felt that Kate *probably* knows the most. And then, after the Stegosaurus question, she started to have more *doubts* again.



5 Kate did better than Miruna on the Triceratops question, but Miruna did better than Kate on the Stegosaurus question.

Each did better because knowing the answer *precisely* is more **impressive** than knowing it *vaguely*.



Knowing it *precisely*





Knowing it *vaguely*









Students and researchers can use JASP for more realistic Bayesian analyses. Download JASP for free at jaspstats.org.

JASP



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Bayesian thinking is easy. The fundamental principle is learning from experience: hypotheses that predict the data well receive a boost in plausibility, whereas hypotheses that predictthe data poorly suffer a decline. For example, hypothesis A could state "At 6 am my parents will generally be asleep" and hypothesis B could state "At 6 am my parents will generally be awake". When a child wakes up at 6 am and notices that both parents are still sound asleep, this observation increases the plausibility of hypothesis A and decreases that of hypothesis B. Easy!

Knowledgeable readers will discover that the dinosaur cover story hints at concepts such as Ockham's razor, coherent knowledge updating, and probability as degree of reasonable belief. Statisticians may recognize Phil Dawid's prequential principle in action.



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