

On keeping secrets from yourself with consistent histories

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1 The problem

If you're playing an RPG solo it seems like there can be no secrets. Take the simplest of situations in a solo game: you arrive at a door. Maybe the scenario description says there is a 50% chance of there being something behind the door. You roll percentile dice to see what happens as you open it. In a weak sense there was a secret: you didn't know there was a dragon behind the door before you opened it. But if you were playing with a GM you could do more – you could listen at the door first in order to find out if there was anything behind it.

Let's say that if something lies behind the door then you have a 50% chance of hearing it, but when roll to listen you hear nothing. Maybe there is nothing there. But maybe there's a dragon and you just didn't hear it. The GM can keep you in suspense. They are able to keep a secret about what's behind the door, and by listening you learn something about their secret. But when playing solo you can't simulate this. It's hard to simulate give yourself clues about something you aren't supposed to know.

Except you can! For one thing, there's a standard “textbook” approach we could take. We're not going to take it but for completeness I think I ought to sketch it. It goes like this: assuming the 50%'s I hypothesised above, we can use Bayes' theorem to compute that if you listen at the door and hear nothing then there's now a $1/3$ chance of there being something there. So you could roll for this new probability. The outcome is, probabilistically speaking, the same as if a GM was present using their knowledge of what is lurking there. But nobody wants to use theorems to compute probabilities during a

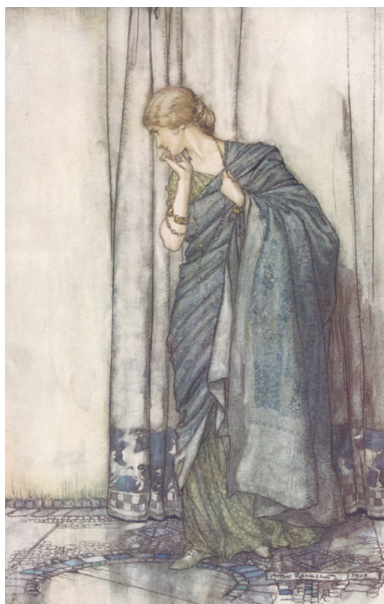


Figure 1: Helena Listening by Arthur Rackham

game (do they?), and even if they could, the resulting probabilities are likely to be tricky to roll for. In the example above we started with percentiles (50%'s in fact) and yet we need a $1/3$ probability which is awkward using percentile dice.

The alternative I propose is using the dice to do the calculations for us. Not only can we do this but we can do it in a way that's not all that weird, once you get used to it.

2 Hidden variables and observables

In any scenario there are the *hidden variables*, things we're not sure of, like whether or not there is a dragon behind the door. And there are *observables*, things we know for sure, like what we hear or what we see when we finally open the door. What typically happens in a game is that a GM comes prepared with some hidden facts, or generates some facts randomly and keeps them secret from you. Those are the hidden variables, and based on those hidden facts (and some die rolls) the GM describes some observations. The

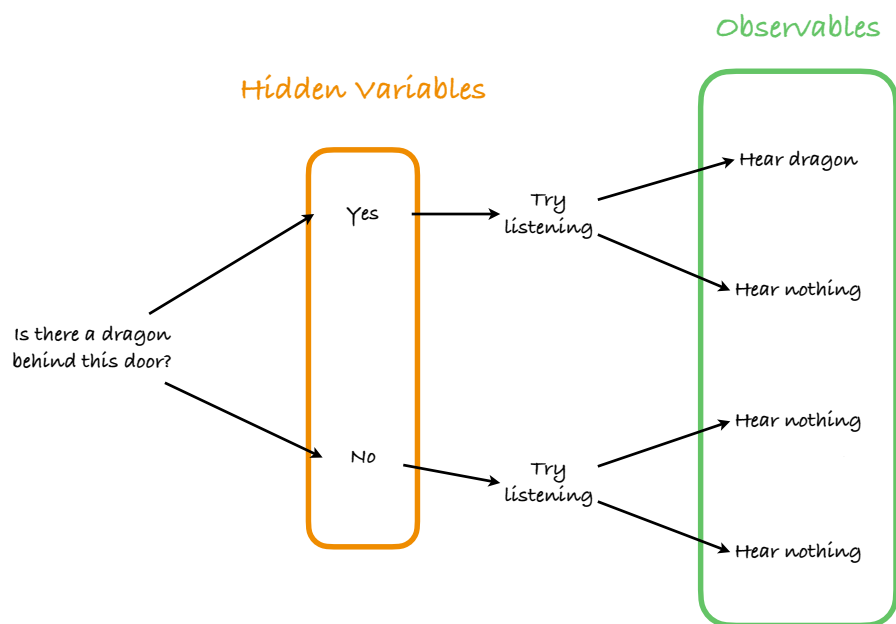


Figure 2: The mechanics of listening at a door

problem is that in order to generate the observations in a solo situation we seem to need to know the hidden variables.

The approach we take here starts ordinarily enough: you play the scenario generating the hidden variables as usual so that you can generate the observations. Observations are considered fixed and unchanging. If you heard a noise, you heard a noise. But after the observations are generated, any hidden variables you generated are considered ephemeral and are discarded. Whatever values they took, these are not the values that will be used going forward. Only the observations remain. If at some future point you need to make another observation based on those hidden variables you're going to generate new values for them – and do so with the correct probabilities, taking into account the observations you made. Knowing the value of a hidden variable is of no use to you because any time you make a decision based on your apparent knowledge of a hidden variable it's going to be replaced with a new roll. And, maybe surprisingly, there's a straightforward scheme for getting the same probabilities that you'd get with a GM. This makes it possible to collect clues about something despite not knowing everything about it.

The system

Here is the system: if you want to make an observation of something new, generate all the hidden variables in the usual way as if you were the GM, and then generate the observations. For example, roll to see if a dragon is behind the door, and then roll to see if your listening skills reveal something. If you do hear something (or not), that's it, that's the observation you make. But the hidden variable does not tell you if the dragon is present. It might or might not be. That information is discarded. You only use the observable outcome from this pair of rolls: the sound you heard.

Now suppose you want to make a second observation – eg, opening the door and actually looking. Generate the hidden variables again, and now roll *again* for the *first* observation you made. This may sound weird, rerolling for something in the past. But that makes the mathematics work out. When you reroll, if the observation is consistent with what happened before (eg. in this example, you hear nothing again), you can use the hidden variable and go on with the second observation, using its outcome. If you get an inconsistency you start rolling again from the beginning, generating a new hidden variable. Keep doing this until you achieve consistency, and then make the

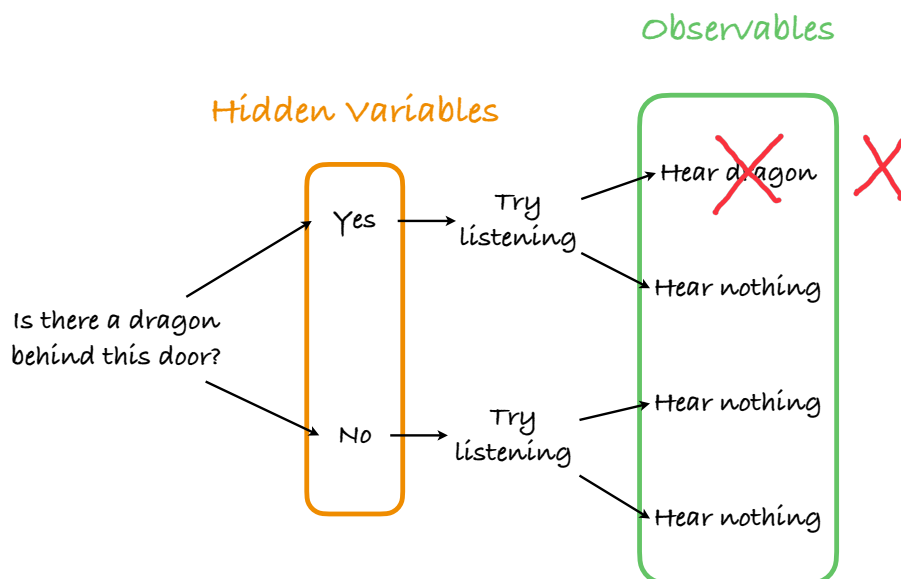


Figure 3: If we heard nothing, then to get the correct probability of there being a dragon we need to reject outcomes that lead to hearing something.

new observation based on whatever hidden variables you just generated.

The rerolling, with its possible rejections, is what biases the odds to match what would happen if a GM was keeping track of the hidden variables.

See Figure 1 showing two possible outcomes, but four different ways of getting there. Suppose we hear nothing, then the situation is now like in Figure 2 with only three possibilities. To generate new hidden variables consistent with what we heard before we need to generate the hidden variables in a way that makes the dragon less likely. We follow the same tree again but reroll if we end up on the disallowed branch. The presence, or not, of the dragon, will have the correct probability.

Let's try the door listening example with real rolls to illustrate the process. And I'll do it a few times just to illustrate the variations. (And I've put many more examples the appendices.) I'll use **bold** for the individual rolls and *italic* for actual observed outcomes.

Listening once and opening door

Let's say there's a 45% chance of a dragon behind the door and that if you listen at a door you have a 65% chance of hearing whatever is there.

Simulation 1

I arrive at the door and listen. So I generate the hidden variable. I roll **19**. So we pretend there is something behind the door. Now I try to listen. I roll **58**. *I hear something*. Well that's that, I know for sure there is something behind the door.

Simulation 2

I arrive and listen. I roll **43**, so (temporarily) something is present. I try to listen and get **78** which means *I hear nothing*. It's important to understand that the observation "I hear nothing" is fixed, but that roll of 43 does not mean something will be present when I open the door. Feeling confident, I now open the door. So again, I roll to see if the monster is present and get **87**. This is consistent with hearing nothing. *There is no monster*.

There are lots more examples of this scenario in Appendix A.

Listening twice and opening door

Let's try again but with rules that allow two attempts at listening.

Simulation 1

We're going to make our first listening attempt. First the hidden variable, is there a monster behind the door? **90**. The hidden variable is "no monster". We don't even need to roll for the first attempt at listening. We know *we hear silence on the first attempt*.

Now we decide to listen again. Reroll for dragon presence: **22**. Maybe, but reroll the listen: **32**. That's inconsistent with our first attempt.

Restart the process: is dragon present? **33**. Yes. Listen: **85**. Silent. That's compatible. So we can now roll for the second listen: **41**. Our final observation is that *we hear the dragon on the second attempt* - and obviously, if we heard it, it'll be there when we open the door.

Simulation 2

Is dragon there? **94**. No. So *first attempt at listening gives silence*. Listen again. Reroll for dragon: **20**. Present. Reroll first listen: **85**. Silence, consistent, so now roll for second listen: **24**. *Final observation: we hear the dragon!*

See Appendix B for more examples of this scenario.

3 Design Considerations

The question now is how to design scenarios with these new possibilities in mind. We can now allow solo players to make strategic use of things like detection abilities. These can add to the fun and also the sense of agency – you feel like you're making decisions based on evidence.

Here are some examples I've tested:

1. multiple treasure chests, all but one with a trap, one with a magic item, and the player has a detect magic scroll.
2. a healing potion that has a 50% chance of having worked but the player doesn't know for sure. (Can you always feel the difference if you just took an ibuprofen?)
3. Fighting monsters (like the D&D one based on van Vogt's Black Destroyer) that generate illusions that are dispelled on the first hit.
4. Fighting monsters with an unknown number of hit points(!)

But things can get messy. For example, we could have a potion that restores an unknown number of hit points determined by d6. This is perfectly playable but it might require frequently regenerating the hidden d6 and, this might not be obvious at first, checking the player's entire HP history each

time there is the possibility of being reduced to zero hit points. And what if there are two such potions available? It gets really messy. So scenarios need to be designed in such a way that multiple hidden variables don't interact.

The probabilities ought to be near the middle of the range – 50%. If not, you run the risk that you will have to reroll many times to reproduce a consistent history. This could be pretty unpleasant when fighting monsters with an unknown number of hit points so I really wouldn't use that example!

I would just use this technique in occasional places of special interest rather than everywhere. And I'd probably mostly stick with simple detection scenarios, especially if a scenario is distributed as a self-contained unit with all of its rules.

But not that I've described some of these more complex scenarios as some of them can be made much more playable by the use of suitable player aids. I leave their design as an exercise.

4 Mathematical notes

The method I describe here is essentially a form of rejection sampling.

It's also reminiscent of a technique used for something in computer science called *consistent distributed hashing* described in *A Fast, Minimal Memory, Consistent Hash Algorithm*.

In essence, for reasons of fairness, you assign certain responsibilities to computers in a network by throwing darts at a dartboard. But as time goes by you need to shift responsibilities by redrawing the lines around the darts and noting which regions the darts end up in. Lamping and Veach¹ came up with a trick involving not bothering to retain the position of the dart, just what region it was in, and arranging that the probability of it changing region is the same as if your policy was to track the exact dart positions.

I also want to mention *Capturing the Future by Replaying the Past* by Koppel et al. It's about the idea that sometimes you want a computer program to continue from an earlier state but that facility isn't available to you so instead you start again from the beginning. (Reminiscent of video games in the old days.) That's what we're doing here and the similarity is more than superficial.

¹ Veach invented the original auction method used by Google to allow advertisers to bid for having their ads appear according to what keywords you type. He also invented a crucially important method to render glossy surfaces in 3D graphics.

5 Final word

Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns—the ones we don't know we don't know.

Donald Rumsfeld, 2002

The observables correspond to known knowns and the hidden variables are the known unknowns. But I've nothing to say about unknown unknowns.

6 Appendices

Appendix A

More examples of listening once and opening door

Simulation 3

Arrive and listen. Roll to see if Dragon is there: **50**. There's no need to bother with the listening roll, as *nothing is heard*. But we still can't take this as meaning there is no dragon because the presence of the dragon is a hidden variable.

Let's open the door. Roll to see if the monster is present: **47**. Just misses 45, and it's not. Trying to listen now would give no sound, consistent with the previous roll, so we can accept that 47 as saying *the dragon is absent when we open the door*.

Simulation 4

Arrive. Listen. Roll to see if the dragon is there? **06**. The hidden variable says yes. Now roll to listen: **41**. *You hear something. We know the dragon is there!* As this is an actual observation we know it will actually be there when the door is opened.

Simulation 5

Arrive. Is Dragon there? **26**. Yes. Try listening: **90**. Hear nothing. So the actual observation is that *you hear nothing*.

Now we open open door. Reroll for dragon presence: **09**. Now we need to reroll for listening: **96**. We hear nothing. That's consistent with the previous roll. So we have to accept that 09 as meaning *the dragon is there* despite not hearing it. Ouch! Important note: you're not allowed to bail out after rerolling for the dragon presence. That's called cheating.

Simulation 6

Arrive. Is Dragon there? **44**. The hidden variables says yes. Listen: **08**. Yes, *you observe it is there*.

Simulation 7

Is the Dragon there? **56**. No. Try listening: **88**. The actual observation is to *hear nothing*.

Now open the door. Reroll for dragon presence: **41**. It's there (as a hidden variable), but reroll for listening: **37**. So you hear it. But that's inconsistent with before. Roll again for dragon presence: **72**. It's not there. No need to roll for listening again as the outcome will be silence. So we can take that 72 as meaning *there is no dragon observed behind the door*.

Note how in my seven trials, the worst case required 5 rolls. It's theoretically possible that you could keep rolling for a long time - because when you first listen you hear nothing but every resimulation says a dragon is present and you hear it, forcing a reroll. But that's extremely unlikely.

Appendix B

More examples of listening twice and opening door

Simulation 3

Is the dragon there? **79**, no. *So listening gives silence*. Of course the dragon might be there when we open the door.

Listen again, rerolling for the presence of the dragon: **24**, it's present. Reroll first listening attempt: **76** silence. Consistent. Now roll second listen: **81**, silence. After *hearing silence twice* you choose to enter.

Again, roll for dragon: **56**, not present. We know that listening will give silence twice so this is consistent with previous observations. So we accept 56 as meaning there is no dragon when we open the door. That took 5 rolls.

Simulation 4

Is dragon there? **43**. Yes. Listen: **49**. *We hear it first time* so that ends our observations.

Simulation 5

Is dragon there? **62**, no dragon. *Listening first time gives silence.*

We choose to listen again: reroll for dragon: **88**, no dragon so *we hear silence second time too.*

Now open door. Reroll for dragon: **29**, it's there (in the hidden variable). Reroll first time listening: **33**. We hear it. Inconsistent.

Reroll for dragon: **46**. This means we get silence twice and we can take the 46 as meaning there really was *no dragon*.

Simulation 6

37 dragon may be present. Listen: **20** so *you hear it first time!*

Simulation 7

92 no dragon present so *first listen gives silence.*

Listen again so reroll for dragon: **73** and *silence again.*

Now open door: reroll for dragon: **22**, so maybe present, reroll first listen: **87** silence, consistent with before. Reroll second listen: **98**, silence again, so now we can accept the 22 as meaning

the dragon really was present despite the fact that we got silence twice! Bad luck.

That last simulation took 5 rolls. If a GM was present it would have been just 3 rolls.