# 305 Lecture 25 - Learning from Evidence

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- The next two weeks are about probability.
- But I'm going to start with an interesting example that might not seem to have much to do with probability at all.
- Instead it's an interesting, and somewhat famous, story about learning.

# Abraham Wald



Figure 1: Abraham Wald

We're going to do a bit of math, but we'll start with a point made by someone who was a mathematician (and a good one) that doesn't require any math.

# Surviving Gunfire

- The backstory is that during WWII the Allies were losing a lot of planes to German artillery.
- They were thinking about how to add armor to the planes in order to defend them better.
- So they investigated the planes that had come back to see where they were getting most bullet holes, and planned to add extra armor to those parts.

Figure 2: Bulletholes
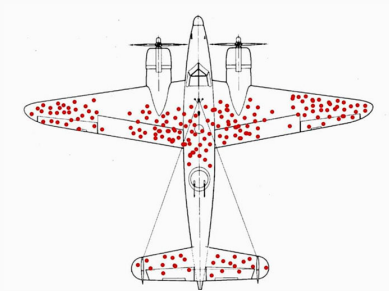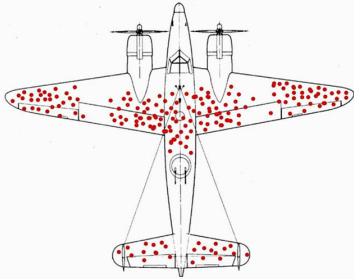
Here's a representation of where they found holes in the planes.

Figure 3: Bulletholes

Where should they add the armor?

Figure 4: Bulletholes

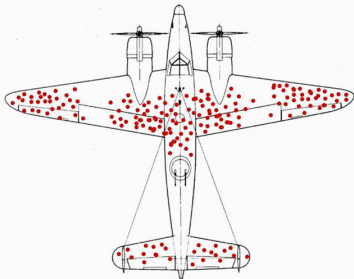You should put the extra armor where the holes aren't.

- The planes coming back are our best sample of the planes in the field.
- The bullet holes in them are asymmetrically distributed.
- So that's evidence that certain parts of the planes are more likely to get hit.
- And that's where we should add extra protection.

- Bullet holes are almost surely randomly distributed.
- The planes coming back are not a random sample of the planes in the air.
- They do not include all of the planes that crashed.
- The best explanation of the asymmetry is that the 'missing' bullet holes are for the planes that crashed.
- And the best explantion in turn for that is that those are the places where bullet holes are fatal to the plane.

- We nowadays think Wald was.
- Artillery, especially artillery of that era, is really a random process.
- Moreover, the places with no holes - the engines and the cockpit - are just where you'd expect fatal injuries to occur.
- So the thing to do was to protect those areas, and try to turn fatal injuries into non-fatal ones.

When you see that $p$ is true, there are two different possible lessons to learn.

1. $p$ is true.
2. I'm seeing that $p$ is true.

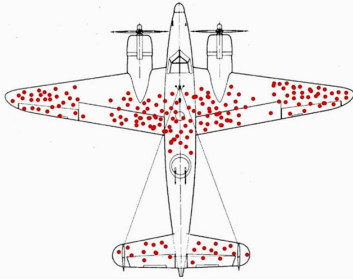Very often, the second is the right lesson to draw.

Figure 5: Bulletholes

- A plane comes back with a bullethole in its left wing.
- That tells us that this plane got shot in the left wing.
- It also tells us, from the fact that we can see that this plane got shot in the left wing, that this damage is non-fatal.

- We want to learn from our evidence.
- But sometimes that requires thinking about why we got just this evidence.
- And to do that it helps to have a theory about how to think about how evidence bears on uncertainty.

We'll start looking at the mathematics of probability.