N1: Welcome back, listeners! To the second installment of our deep dive into the world of scientific fraud. My name is Isaac.

N2: And I am Camila.

N1: In our last episode, we uncovered all the ways researchers commit fraud and the motivations that drive them along that path. Today, we're turning to the other side and talking about the tools we have at our disposal to combat scientific fraud.

N2: I don't know… I am feeling pretty down after the last episode. There seems to be so much fraud out there… even with all the checks and balances that peer reviews provide. Is all hope lost for science?

N1: Not at all. As you will soon find out, there are many tools in development that are very effective in detecting fraud. To start with, let's talk to our image forensic expert, Dr. Elizabeth Bik, whom you may remember from our last episode, and learn about the latest and greatest technologies in detecting image manipulations and duplications in papers.

N2: Let's get right to it!

[CTOR jingle]

N1: Hey Camila! Have you ever played the children's book games where you try to spot the difference between two images?

N2: Yeah! I remember doing those in kindergarten. It is really straining on the eyes. Maybe that's why my eyesight is so bad now.

N1: Well, all those years playing "Spot the difference" actually may have helped you become a better scientist - The same skill that helps you spot a missing hat or a different color can be applied to detecting fraud in images.

N2: Huh, I've never thought about it that way. So how does an expert like Dr. Bik detect fraud in paper**s?**

Elizabeth:

So I focus on photos and the reason is that line graphs are much easier to fake. I can look at a bar graph with a little error bar. They all look similar, right? One bar is a little bit higher than the other. Who knows if that is real data? It's very easy to fake. If you think about it, how easy it is to type in that number, make up some randomness generator in Excel, you can vet that out in five minutes and you have a beautiful bar graph that looks believable or an ordination plot or heat map. You can make up whatever.

But if you're a little bit smarter and a little bit more careful, you would remove that obviously and just generate copy-paste values and nobody would be able to detect it. So occasionally errors are made, uh, which is why these types of frauds are caught, but it's very rare. Looking at photos is a little bit, for me at least, easier. I can look at a photo and you can see a duplication. But if a person is a good Photoshopper, I would not be able to see that If you, not giving away any ideas, but if you brush away a band, it would not really be visible.

N1: Western blot images are notoriously easy to fake. For those who don't know, western blotting is a laboratory technique that is used to detect the presence of proteins. The proteins are stained and visualized as discrete dark bands on a sheet of membrane. So if you want to demonstrate that a protein is present in your sample, you can just paint a dark band over your original image in Photoshop.

Elizabeth:

If you copy-paste, if you stamp a part of the background over the band, it would leave, usually a visible area around it. And so those kinds of sloppy Photoshop jobs, I could catch, or duplications. I'm using the software, Image Twin, which is a program that can find these duplications between papers. It is not always finding them. But sometimes it has amazing finds. So those types of photos would be photos of microscopy like microscopy photos of tissues or cells. It would be photos of mice with tumors sometimes or the tumors themselves. Photos of plants, but also, uh, western blots and gels. And western blots seem to be the most popular thing to fake. They're usually little strips, I think people pay no attention to them.

N2: Ok. I am glad that people have developed software to help detect image duplication. I can't imagine sitting in front of a desktop all day and just staring at images all day long. So you can just feed all the images that look suspicious to you to the program and press run?

Elizabeth:

No, it's not that automatic. That would be wonderful if it would just say this is fake. But, no it detects duplications. It cannot detect manipulations per se. There needs to be some duplicated elements. Sometimes you see if you enhance contrast, you might see that some blurring tool has been used or so. But that's, that is rare because usually the photos don't have enough detail, resolution to see that. What Image Twin does is you can drag a pdf into it and it will extract all the photos and compare them against each other and against a database of publicly available papers or figures.

N1: A side note: if you want to dabble in some image forensics yourself, Dr. Bik posts fun minigames on Twitter (yes, I am calling it Twitter). She posts images that have been duplicated/manipulated, and you can try to spot which part of the image is problematic. You get a little trophy emoji from her if you win!

[Music]

N2: Now we have some handle on how to detect fraud in images but what about other types of fraud - what about someone copying and pasting numbers in an Excel file or keying in a specific number to fit the data to a particular trend? Let's shift our focus to ways to detect numbers that have been artificially altered after the fact.

N1: Let's talk to another one of our experts - Dr. Leif Nelson, who is the statistics guru in the field to find out what mathematical tools we have to detect these kinds of data anomalies.

N2: We talked to Dr. Elizabeth Bik and she uses a special program called Image Twin to detect image duplications. Do you also have specialized programs and tools to assist you in your analyses?

Leif:

The first tool is just keeping your eyes open, trusting your intuition. I study human behavior, and so it's choices people make or how much they report owning things or how often they visit places, or whether they choose the chocolate cake or the fruit salad, whatever. And the first pass is to say, is to basically not forget that I am also a human. And so I can say, well, how might I behave in that situation? Some fraud gets the first pass like not knowing it's fraud, but knowing it's worth looking deeper are findings that violate some of that human intuition.

N1: It's so interesting that even though we have so many sophisticated mathematical tools, the first tool that experts rely on is still human intuition.

N2: Yeah I guess there is just something unique about our sixth sense, and being able to sniff out signs of fraud when things don't quite align.

N1: But Dr. Nelson is an expert statistician, so aside from human intuition, he also employs mathematical algorithms to detect fraud.

Leif:

Some of the ones that have gotten a lot of attention in my field at a very nuanced statistical level will be looking for excessive similarity of different conditions. So I'll take a quasi medical example. When you randomly, as when you run a clinical trial and say we took a pool of patients and randomly assigned them to drug A versus drug B. And because of that randomization, I want, as a researcher, to find that on pretest variables, they are very similar. So the two groups have similar blood pressure, age, number of children, whatever.

But of course, by chance, there could be some differences. A distribution, sampling error, the core of our statistical training. And so when, when someone is committing fraud, one thing that they occasionally leave behind as evidence is a failure to account for that natural sampling error. And so they end up creating data for which they are too similar. So instead of the blood pressures in these two groups being off by six units, they're only off by two.

N2: Imagine a vast garden of data, where each flower is a unique and special piece of information collected from the wild. Now, picture a malicious gardener who, instead of collecting flowers in the wild, decides to create an illusion of abundance by cloning the same flower over and over again. This garden seems lush and thriving at first glance, but it lacks the diversity that should naturally exist. When fraudsters try to simulate fake datasets, they end up making their data too simple and uniform. This can be used as a telltale sign that the dataset is not real.

Leif:

And then for the work I'm in, a lot of it ends up being distributions of data that are inconsistent with how humans behave. And so for that two similar examples, if I ask you now, Isaac and Camila, if I said, all right, how much would you be willing to pay for a brand new toaster? You could think for a minute and you'd write down a number. It doesn't matter what the number is. It matters what the number's like. You would say, brand new toaster, I'd pay $20 for that. Or you'd say, I'd pay $50 for that. I like toasters. But what you wouldn't say is $14 or $27 because nonround numbers are really weird to report. And so sometimes you can find fake data that way. That is, if someone is reporting a distribution of willingness to pay and it's not all round numbers, you're like, that's weird. That is not how humans answer questions. They should be using more round numbers. And so that's more like instead of it looking uniform or normal, it's, it should have these weird spikes at at multiples of five.

N1: Interesting! I guess this goes back to the human intuition idea. If I was asked how much I spent last week, I wouldn't say $542.27. That is not how humans do. I would most likely say $500.

Leif:

There's a mathematical law that says when you have long numbers, so picture, how many dollars and cents are in your bank account right now, you'd say some number you might say, well, in my bank account right now it is $9,287 and 36 cents.

It's a relatively long number, the rightmost digit of that number, so long as there's a lot of them, if you get lots of samples, it should be distributed uniform. That is the number zero should occur just as often as the number one, as often as the number two and so on. So when someone's making up data, they might not know that. If they forget to have that as a feature of their data, you will get violations of what's called Benford's law.

N1: Ok… just keeping track here. We have excessive similarity…. And we also look at distributions … And we have Benford's law…. Wait, what is that one again? This is such a long list of things to look out for.

N2: Yeah for sure it is. And this is not accounting for the many other ways that data could appear to be problematic. How can we possibly perform all these checks?

N1: Good question. Do journals and reviewers run these statistical analyses when they are considering a manuscript for publication?

Leif:

I can't imagine that any journal or any reviewer does any of that, in part because it's, it's hard, right? So if I supply you a data set, some big data set, even small, even small, where you say it's like a hundred participants and there's or a hundred subjects and there's 10 observations per subject. You wouldn't even know what to look for. I wouldn't even know what to look for. You have to understand the study well enough to know this is one of those where they should be distributed uniformly or is this one of those ones where there should be weird spikes in it or should it have strange skew. Or should there be a predictable number of outliers or an unpredictable number of outliers?

Should it have a very small standard deviation or a large standard deviation? And those aren't things that you can just sort of wade into a paper with a central algorithm. You have to kind of understand what's being studied.

N1: Yeah, even for papers that are in my field of study, there are times that I just miss glaring mistakes There are just too many things to check for and too many ways that fraudsters can finesse their way out of the scrutiny of the reviewers.

N2: I guess one thing that does help is that funding agencies and grant organizations have begun requiring authors to publicly deposit their raw datasets. So anyone with the internet can go in and run these analyses themselves. So even though we may not catch all these, the fear of being caught can be a strong enough deterent to prevent fraud.

[Music]

N1: In addition to running deep statistical analyses on papers, Dr. Nelson is also quite involved in replication studies - which is another way to potentially check for fraud in papers.

Leif:

We all learned about science in like seventh grade, So someone says, this is the scientific method, asking questions, answering them maybe, maybe random assignment was mentioned, maybe experimental design. It all sounds great. But almost certainly what was mentioned was you then run the study again to make sure that you were right. That is, it should replicate that. Researchers know that and then proceed through careers where they don't run replications basically ever, right? Because that’s not actually what we do in most of our job. Most of our job is trying to discover new things, publish them as though they are new things, and then celebrate in the riches of our improved employment.

But we sort of believe that replications are going on somewhere, somewhere else.

N2: Hmmm yeah if you compare inventing a new treatment for cancer vs just replicating that a known experimental treatment works, replicating a result definitely sounds less exciting than showing a new result.

N1: We have to remember that funding application is an incredibly competitive process. And most funding agencies prefer innovative science that brings new discoveries, instead of replicative science that confirms previous results. Because of this, very few labs do replicative studies, if at all.

N2: Still, shouldn’t we put more funding towards these studies?

Leif:

Of course there should be more funding for that sort of thing, but I'll pitch why. So first, the first part is where, where does the funding come from?

Now, most of the time these replication projects are the ones I described that's kind of big and elaborate. There it's not super expensive, but it's real money. We got a specialized grant from the dean of my school to fund the project. So it's not from a regular grant agency but we still had to ask for money.

It is serving two interests. It is serving the "replications are good" sort of thing, but it's also just self-serving. If the next brilliant study I'm going to run needs this other study to replicate first, and so I run them for my own self-interest. And so by that standard, most replications I run are ones that are ones that are at the very final study of an entire endeavor. It's the first and the last. I run a replication of someone's study.

If it doesn't replicate, I move on with my life. And so it is a good use of money, which gets to, what should granting agencies be doing? They should be prioritizing at least a little, making sure that researchers both have the money to do that and that they are sufficiently rewarded for it. Now "sufficient reward" doesn't mean that every replicative study gets published in Nature. But it might mean more of them get funded.

So I think if I was in charge of NIH or NSF I would encourage them to earmark more funds in that way and basically include it as a plausible part of any grant proposal that say, it's okay, you should totally ask for 20% of your grant to be purely for replication purposes, because that's good for everybody.

N1: "Publish houses of brick, not mansions of straws". Going back and replicating past results is not necessarily a waste of resources. It all helps to build a solid foundation for future scientists to build their work on.

N2: You can build your next multimillion-dollar project on a shaky premise based on a flawed study - only to find out years later that the original study is deeply problematic. All that time, money, and resources is going to waste because you haven't properly validated the original finding.

Replication studies

N1: I actually haven't come across any replication studies myself - I guess they don't really make it to the headlines. Could you give us an example of a replication study?

Leif:

A researcher named Brian Nosek at University of Virginia organized a very large project where they randomly drew a hundred studies from one particular year in the field of psychology and replicated all of them and drew, you know, hundreds of lab groups from around the world to run.

And it was an amazing effort. And I think just totally groundbreaking in just being such a direct instrument of a replication audit. In any case, lots of things didn't replicate that

So like in my efforts just, in the last couple of years I was one of the leaders of a project where we ran a series of replications on a single topic area.

And this project that I headed up, what we wanted to do was simply take a sample of experiments from that literature from across what ended up being 20 different papers by totally different sets of authors.

And we would sample a study from each of those and then run a full replication of them, and then put those together as a single package as an empirical mini-audit of a research area. So not the field of psychology but a single topic that someone might study.

N2: What do you mean when you replicate a study? Are you starting from scratch and building everything from the ground up? Or just partially repeating the experiments?

Leif:

So in my case I mean going and getting when possible, using the exact original materials, sampling a new set of people, rerunning the experiment, running the analysis exactly as specified in the original, and reporting that result. So that's replication. Reproducibility is a similar version, and typically that is used: If I take your data, can I generate your results? Basically, if I run your data through the algorithm that you said I should. Do I generate the result? oh, I can I build, basically build the same model from the same sort of building.

N1: This is an important distinction to make. Replication is different than reproducibility. Replication is like trying to recreate a chef's signature dish from a recipe on your own. It involves conducting the same experiment using the same methods and conditions but on a whole new set of subjects. You are following the same recipe, but you are sourcing your own ingredients.

On the other side of the coin, we have reproducibility. So let’s say you are not able to replicate the same flavor in your own kitchen. You are kinda mad and you run straight into the chef’s kitchen to see if you can capture the same flavor there. Reproducibility means obtaining consistent results using the same methods and input data. So here, you are using the same ingredients and kitchenware as the chef, instead of sourcing your own.

N2: Ok so if something is not reproducible or replicable, that definitely raises some red flags but does that mean all non-reproducible or replicable research is fraud?

Elizabeth:

I don't think that all science that is not replicable is necessarily fraud. It might just be, you know, the original author not sharing enough details, or just making use of a machine that is slightly different than another, and just not knowing which particular technique or circumstances are important to be able to replicate the results. As an example, I've heard, there's something on your glove, some powder that comes off and ruins your hybridization. And so little things like that might make a huge difference. And you can try to write down exactly how you did it, but another person is going to grab another pair of gloves not thinking that it might make a huge difference, or how do you shake it? Do you shake it like, you know, back and forth or in a circle? That could sometimes also make a difference. So sometimes, the trouble with replications are tiny details like that where it will work in one lab, but not in another, and you have no idea why.

N1: Like Dr. Bik said, experiments especially in biology are so sensitive to environmental conditions. Sometimes results are non-replicable not because the authors maliciously faked the results, but because of all the environmental variables that we could not account for.

N2: You know how people are obsessed with New York bagels and they keep saying that it is the water in New York that gives it that unique taste and texture? Different hands mean different experimental outcomes. The water used in one lab could have different mineral compositions than the water used in another lab across the world. In the same experiment, you could be using a different brand of reagents that come from a different supplier. There are just so many things to account for.

N1: Although we like to believe the results published in journals are true in every sense, the truth is sometimes these findings do not represent the general reality. This is why findings from one lab need to be validated by one or more independent labs before being accepted as fact in the field.

[music]

N1: Hey Camila. Have you ever wondered? With all the brilliant minds in our scientific community, if someone commits fraud, wouldn't someone else notice?

N2: Yeah I imagine a lot of people must have noticed something went awry before a fraudulent paper went out. Nowadays, a typical paper has more than ten authors which means more than ten people have at least looked at the paper and vouched for its validity. Surely, if someone is doing something fishy in the lab, people would notice and report it.

N1: Well… it is not as straightforward as it seems. Dr. Bik has a great example of why it is so hard to whistleblow in academia.

Elizabeth:

Let's say a graduate student is being asked to Photoshop something and their professor tells them, "oh, this is how we all do it and this is how it should have been". And I think if you're young and you're still not fully formed in terms of your professional career, you might actually be influenced by that. You might believe that that is true.

And you might also be, as a young researcher, you're very dependent on the senior person, the person who in whose lab you work. But sometimes these people will blow the whistle. They will contact, another professor whom they trust or a research integrity officer at their university. And sometimes an inquiry or an investigation will follow. But unfortunately, these young folks usually are, these whistleblowers are being retaliated upon, so they're seen as troublemakers. Unfortunately, this is not how it should be, obviously.

That is very hard if you are in the middle of such a misconduct case. And I think that emotion that people bring to the table, which is completely understandable,that makes them being seen as troublemakers. And, it is very hard if a respected researcher at a university is being accused of being a fraud without any evidence, then you can sort of see that a junior person might have to leave eventually. If they're not being fired, but then suddenly their key card doesn't work or their email address is locked and, suddenly, their life becomes very hard, unfortunately, and I've heard too many of these cases.

Academia is set up with this dependency and this hierarchy, it is set up for young, honest people to fail and for the cheaters to succeed. And very often the senior researchers are the ones who are successful. That's why they become professors in the first place. And these are probably people who are good at getting grants. And if you think of a university as a business, which most universities are actually, are not run anymore as educational or research institutions, they're seen as businesses. They're companies basically. And so they care about money, they care about athletes, money, sports, and they care about research grants coming in. And so, the senior professors who bring in all the grant money, they see them as the rainmakers.

N1: The way our funding system is set up is that a professor leading a research lab applies to a funding agency, usually the National Institution of Health. If the lab gets one million dollars in funding, up to 60% of that will go to the university the professor is based at as indirect costs. These indirect costs do not support the research project in the lab directly, but they help support everyday operations at the University including equipment and administrative expenses.

N2: As you can imagine, universities want professors to get as much funding as possible, so they can benefit through these indirect costs. As a result, professors live in the world of "publish or perish". If you want to keep your faculty job, you better publish groundbreaking science that generates headlines and reels in money.

Elizabeth:

And so if you think of it that way, if, you know, a young researcher yells, oh, there's misconduct, the university doesn't really care, the money comes in, so why should they worry? And so if you see it from that point, you see where the big problem is. In academia, most universities don't seem to care much about their science, the quality of their science. They care about money, and they also care about their reputation. And so they are very hesitant to admit that there was misconduct in their walls. It's much easier to push out a young graduate student, but yeah, where do they go? They need a letter of recommendation. If their boss is now angry with them, it's very hard to find another position in a similar lab in a similar field. And so a lot of these young folks who have been whistleblowers are actually leaving academia and they end up in all kinds of other careers, but it's such a waste of talent, and it's all because these people were trying to do the right thing.

N1: The right thing to do is to still whistleblow and report the misconduct… But that comes at a tremendous cost for the trainees. Do you have any advice for people who find themselves in this situation?

Elizabeth:

It's a super tough situation to be in. I think I can only recommend trying to see if there's coworkers, maybe postdocs who are in a slightly less, but not that much less vulnerable position and see, like carefully ask around if you can find an ally, another person who has exactly the same feelings and exactly the same hesitancy to ring the bell and blow the whistle because they are also in a vulnerable position. But there is power in numbers. If a bunch of grad students and postdocs would go to their research integrity officer all with the same story and with proof, then you have a much stronger point than if you're just by yourself.

[music]

N1: Phew, that was a lot. Scientific fraud is a complex issue with roots deeply embedded in both the systems that govern research and human psychology. It is not going to disappear anytime soon and is an ongoing challenge that we have to combat.

N2: Ultimately, to combat scientific fraud, we need a push from all fronts. Funding agencies should be implementing open science policies to increase transparency on how research is conducted. Journals and reviewers should be held more accountable for the rigor of the manuscripts they publish and review. Lawmakers and institutions should increase their efforts in enforcing harsher punishments for research misconduct. And for us scientists and general readers, we should be more critical of the papers we read and not take everything as it is.

N1: We kinda ended things on a depressing note but it is important to remember all the amazing things we have achieved! Science is working as intended - we have made so much progress over the years and honestly, fraud is a rare occurrence compared to many breakthroughs and innovations we have.

N2: There is much to do and much to improve.

N1: Well I guess that's it. Now, if you will excuse me, I need to get back to the bench and do some real science.

N2: Be sure not to commit fraud! I will be keeping a watchful eye on you.

[music]

N1: This episode is produced by Isaac Chang, along with Marilyn Steyert, Camila Benitez, and Cindy Liu. Many thanks to Dr Elizabeth Bik, Dr. Leonid Schneider, and Dr. Leif Nelson for their time and insightful input.

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See yall later!