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00:49 SC: Welcome to The Science Podcast for September 21, 2018. I'm Sarah Crespi. In this week's show, we're all about making science more scientific. It may sound convoluted, but researchers are turning science back on itself to better understand the enterprise as a whole. We are gonna hear first from freelance science journalist Jop de Vrieze about his story on meta-analysis. Why are there so many of these studies? And why are there so many conflicting ones? And we're also gonna hear from three researchers about their battles with big scientific myths. For example, can you make a big contribution to science after the age of 30? Einstein said no. The evidence says yes.

01:35 SC: First up in our special on the science of making science better, we're gonna focus on meta-analysis. This is when you round up all the information about a scientific question, crunch the numbers, and come out with an answer, possibly a definitive one. Jop de Vrieze, a freelance science journalist based in the Netherlands, is here to talk about a feature story he wrote on the problems with meta studies and what can be done about them. Hi, Jop.

02:00 Jop De Vrieze: Hi there.

02:00 SC: The meta-analysis, these types of studies are intended to incorporate many experimental studies and let you come away with strong conclusions. They're supposed to be an objective way to mediate different areas of research when the studies are in conflict. But instead, they seem to be causing a lot of conflict. Some research groups are fighting meta-analysis wars. Can you describe how these wars unfold? Let's talk about, for example, violence in video games.

02:26 JV: That controversy has been going on for decades now. Every time when there's a school shooting, these debates starts again. And there were all these different studies with different results, and then they think, "Okay, let's do a meta-analysis and see what the body of evidence says. The two meta-analysis I focus on in my article are one from 2009, Christopher Ferguson and Kilburn. They came up with a meta-analysis concluding that when you take all the evidence together and correct for certain things like studies that were not published, then you end up with no effect.

03:06 SC: No linkage between video games and violence.

03:09 JV: It's insignificant, nothing. But then another team, Brad Bushman and Craig Anderson and some others, Bushman and Anderson had been in that field for over 20 years, they came up with a counter meta-analysis and they did find an effect. And then there's a whole debate.

03:25 SC: What was the difference between these two studies? Were they looking at the same body of research?

03:29 JV: First it was you collect all the studies, but you have to sort of predefine criteria for which studies you'll regard relevant and good enough. So one is based on search terms and another is based on certain quality criteria. And then there are these corrections like, you assume that there are certain studies missing and you have statistical methods to correct for that, which are never perfect but usually better than nothing. Or you try to collect all these unpublished studies, and that's one of the main differences between these two. The first team, they tried to find and correct for this publication bias, and the other team said, "Now we'll go and look for all the studies that were not published like PhD thesis, other studies from other groups." They said, "Well, if we include all those, we don't have to correct anymore." And then they started debating, like the one team said, "Well, you're only regarding your own studies and the studies that favor your conclusion as good quality." And the other said, "Well, you did statistical analysis, that's not correct." And that's... In this case, it's often... You can see where the debate comes from. They have their own work and they have their own ideas.

04:40 SC: Other examples that you include that highlight this meta-analysis fight include positive parenting, anti-depressants and so many other things, and these topics are often important to public health and important to policy decisions. What are some solutions to these problems? How can we stop these fights and get clarity on fields where there's been a lot of conflict?

05:03 JV: There are a lot of what they call a researcher degrees of freedom, so even if you try to make it as objective as possible, depending on what your real question is, what your criteria are, you get to different answers. Instead of making it more objective, you'll have to make it more transparent and showing, "I'm making these decisions, these judgment calls and I take this analysis instead of that type of analysis because of this and this and this." And then you can really sort of show to your readers to your colleagues why this is the relevant answer.

05:33 SC: And on the same idea about transparency, another thing that people are trying is registering experiments. How would that help?

05:40 JV: If you don't do that, it's very easy to manipulate. What's even better is... Because another problem is when you try to combine all these studies, they're all different and it seems very straightforward, but it's very difficult to combine all those very different studies. So if you already plan to do a meta-analysis and you already adjust your experimental studies so that you can easily combine them, that also makes your meta-analysis stronger.

06:05 SC: One of the problems you mentioned earlier was that the missing studies, the studies with negative results that probably never get published. Is that something that'll be helped with this trial register, this experimental registration is you get all those Nulls?

06:20 JV: Yeah, yeah, that's indeed... If all those studies are pre-registered and you have an oversight of what's there and you don't have to do all these weird, statistical tricks to correct.

06:31 SC: In one of these studies that you mentioned in your story, researchers said, "Let's stop fighting... " And this is amazing. "And let's do studies, all work together, and combine them into a meta-analysis." How did that work out and what was the area that they were researching?

06:47 JV: That was in the debate on ego depletion, so it's about whether your self-control can be depleted just like a muscle can be depleted. It was a very popular ideas, a lot of articles in the popular press about, and even a whole book by one of those researchers, Roy Baumeister. But then people started trying to replicate and they didn't replicate a lot of those findings. Instead of trying to replicate all these single studies, we start all over again. So we set up a lot of more or less similar experiments together, adjust them so that they can be easily combined and then draw this conclusion based on this meta-analysis. And they couldn't find the effects. You can never say it's not there. It's never a total debate ender.

07:34 SC: An intermediate option between these two that we've already talked about, registering your trial and all working together to redo the research, is to agree on the terms of a meta-analysis, so have everybody come together and actually just agree before instead of doing competing ones.

07:52 JV: They call it an adversary collaboration. It can really be a solution, although based on some of the examples that I mentioned, you could also imagine that there would still then be debate on what would be the real relevant question and what should be the right criteria. But at least then you have agreed upon that upfront and then afterwards, it will be no longer up for debate.

08:14 SC: That would be nice.

08:15 JV: Of course there will always be different ideas on certain topics, but it's good to know, to realize that it is a human endeavor. It's also good for us as journalists, so that we don't just think, "Oh, I found one meta-analysis, so now I know this is the real, this is it, this is the truth."

08:31 SC: So there's a really nice graphic with your feature and it shows this exploding growth in the number of meta-studies. So two questions about that: Is this adding to the problem, is having more and more of these making more arguments? And then also, why are we seeing so many more meta-analysis come out?

08:51 JV: Yeah, it's a combination of factors. Sometimes it's just pharmaceutical industries is paying a lot for meta-analysis. Another reason is for just an academic scientist it's also very attractive, because it's relatively cheap. You don't need a lab, you just need a computer and some handbooks. And it's relatively well cited, those papers. John Ioannidis, a famous meta-researcher that I've talked to also for this article, has been looking at it and he said the great majority of all these extra that have come out over the years, they are redundant, they are of very poor quality, no added value.

09:30 SC: Yeah. You caution me not to get jaded and just assume all these conflicts are personal wars. Every part of science is human, and we all have to make decisions, and if we're transparent about it, that legitimizes it, often. But sometimes when I see these arguments, I just think, "Oh, well this person just has an axe to grind," or, "That person is cherry picking." So what's the argument for doing this? Why shouldn't we just throw out all of these meta-analysis?

09:58 JV: Well, I think that then you would have to do that for science as a whole.

[laughter]

10:03 JV: I think, and that's what Edward Miguel... He said, "Yeah, okay, I could see that people, they would say, 'Oh, you are already in this field and you're proving your own point,' but you have to look at the science." And not that I will just look at my science, but what question are they trying to answer? So if you as a bystander, or as a policy maker, or as a doctor are interested in the solution, don't just look at, "Oh, this is the meta-analysis on this topic," but what question were they trying to address? Then it still has value and I think it has more value than single studies, if they are performed well.

10:37 SC: What are some things to look out for if you're reading a meta-analysis? Either if you're a journalist or a researcher trying to get the lay of the land.

10:45 JV: Before I started with this project, I had no idea, though I have a background in epidemiology. So, one of the things is, are they trying to solve the problem of publication bias, either by applying several methods to correct or to look out for more studies? Did they predetermine their criteria? Is their question really clear? Does it sound indeed relevant and not just a basic, general question without any...

11:13 SC: Does it work?

11:14 JV: Utility. Yeah. The number of studies they've included serve an indicator, but it doesn't say everything.

11:19 SC: Right. What kind of problems do meta-analysis solve? Is it when there's no way to do an experiment, you kind of have a bunch of correlations? What are good times when this is kind of a useful tool?

11:32 JV: Sometimes it's just you have a lot of different studies with comparable design but not exactly the same.

11:39 SC: Yeah.

11:39 JV: And then you get higher precision, because you have combined data, so you get a more accurate answer than one single study would do. And sometimes it's trying to see whether all these different studies that are looking at slightly different things in different population, looking at the same drug or a younger or older people and then trying to combine, okay whether the drug in

general has an effect. And then sometimes when you have a lot of small studies, then it can help to have stronger... And if it's just like a fuzz and you say, "Okay, now we need some kind of method to... "

[laughter]

12:15 SC: Well, now that you've been through the wars yourself, do you feel like this is something that's gonna be resolved? Are journals and societies and funders trying to tamp down on some of this?

12:25 JV: I think not just after reading my article. I think that's one small step. But I think that we are starting to realize that we should look at meta-analysis in a different way without turning into a certain post-modern fatalism and thinking it's just an opinion, because it's not like that, it's just... If you do it well, it's more than an opinion.

12:48 SC: Yeah. Okay. Jop, thank you so much.

12:51 JV: Thank you.

12:52 SC: Jop de Vrieze is a science journalist based in the Netherlands. You can find a link to his story and the rest of the Science of Science package at sciencemag.org/podcasts. Stay tuned for a quick spin through the rest of the meta-meta-research package in this week's issue. Next up, I talk with three scientists that have worked to debunk some of the oldest myths about science, uttered by the likes of Newton, Planck, and Einstein.

[music]

13:20 SC: This week's issue is all about science as an endeavor and enterprise. How studies are done, how they are communicated, and how they are received. And researchers are using the tools of science to pick apart these processes and overturn some old wisdom about how these things work. I spoke to a few researchers who have looked into these long-standing ideas. They questioned Isaac Newton. Do we stand on the shoulders of giants? They questioned Max Planck. Does truth win out because its opponents die? And Albert Einstein. Can scientists make great contributions after the age of 30? The answer, according to the research: Climb atop the shoulders of giants and wait for the funerals. I know that's a riddle, we're gonna unpack it. First we have Ben Jones, he's the Gund Professor of Entrepreneurship at the Kellogg School of Management. Hi, Ben.

14:17 Ben Jones: Hi, Sarah.

14:18 SC: So, Einstein said, "A person who has not made his great contribution to science before the age of 30, will never do so." What do we empirically know about scientific productivity after the age of 30?

14:32 BJ: We've learned that this is one of the rare cases where Einstein appears to have been wrong.

14:37 SC: What does productivity look like after 30 in science?

14:40 BJ: We see that productivity tends to peak in middle age. If you look at the main part of the distribution, it tends to be in late 30s, early 40s.

14:51 SC: And these are people who have made groundbreaking insights and Nobel Prize winners, so they have kind of a documented status.

15:00 BJ: Right, so you could look at great achievements, you could look at the age at which people did the thing for which they will win the Nobel Prize, you could look at the great technological inventions of the 20th century, say the MRI machine or the light bulb, and you could look more generally at particular fields and look at great scholars, national academies members.

15:18 SC: But this has changed over time. This number is skewing a little bit older. Does this reflect differences in career paths for sciences?

15:28 BJ: In fact, the average age, for example, at which people did Nobel Prize winning work went up by about 6-8 years over the course of the 20th century. It looks like what's really happening is that people are increasingly delayed in the start of their innovative career, they spend much more of their 20s in the education phase and less in the post-education innovative phase.

15:51 SC: Why do this, besides to debunk a little bit of Einstein's legacy?

15:57 BJ: It matters a lot for how we fund researchers, who we fund.

16:01 SC: Yeah.

16:01 BJ: This belief that people are at their best when they're very young can divert resources in that direction. We certainly see that in entrepreneurship, for example. Beyond whether funders or research institutions support people at different ages, I think it's a question of perspective on oneself. If you believe that your best days are behind you, psychologically, you might not try as hard, you might not think you're as capable and you might make different choices. But if you understand that in fact you're peaking later, that gives people, I think, more incentive to keep going and to keep trying.

[music]

16:36 SC: Next on the chopping block, Max Planck. Planck wrote, "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die." Pierre Azoulay is a Professor of Management at the Sloan School of Management at MIT. Pierre is here to talk about a ghoulish experiment that looked at the deaths of superstars and the impact of it on their fields. What made you decide to look into the death of researchers and the impact of that on the field?

17:10 Pierre Azoulay: My coauthor Joshua Graff Zivin and I, we were very interested in the role of superstars in the progress of science. Our sort of prior was that superstars make the people around them better, they would be missed if they disappeared in some sense. But I vividly remember a senior scientist telling us, "The problem with superstars is that they tend to suck out all the oxygen in the room."

17:36 SC: Yeah.

17:36 PA: When we began and we looked only at the effect of superstars dying on the collaborators of those superstars, once the superstar goes away, the fount of ideas in some sense dries up, collaborators suffer, and we found that. But it turns out that that person was correct, it's just that the scope of the superstars sucking all the oxygen out of the room doesn't apply to collaborators, it applies to non-collaborators.

18:05 SC: So it's people who wouldn't enter the field because the superstar was there.

18:08 PA: Exactly.

18:09 SC: What do these new people do to the field?

18:11 PA: Well, it turns out that they bring new and important ideas into those domains. They tend to use different keywords, they tend to reference different types of research more likely to be from outside the field. But also, those papers themselves in the future will go on to be disproportionately highly cited. So this matter is in the aggregate.

18:32 SC: Yeah. So this sounds like superstars might not be all they're cracked up to be.

18:36 PA: What you wanna conclude here is not that we should start offing superstars...

[laughter]

18:40 PA: To make place for new people.

18:42 SC: Yeah.

18:42 PA: I think that would be the wrong conclusion. Our paper provides sort of a basis for creating policies that try to level the playing field a little bit, like preserving space for young investigators in grant competition. You also have to recognize that science is a tournament and there are lots of things you do that might be very positive to get to the top of the mountain. The fact that once you're at top of the mountain not everything you do necessarily has beneficial aspects doesn't mean that we should be weary of people trying to compete extremely hard to try to exert an influence. There are a lot of good things you do in the process of trying to be in a situation to actually control the intellectual direction of your field.

[music]

19:34 SC: Now let's hear from Isaac Newton. Here's a slightly paraphrased quote from him saying, "If I have seen farther than others, it is by standing on the shoulders of giants." Heidi Williams, an associate professor in MIT's Department of Economics, is here to help us with this one. Hi, Heidi.

19:52 Heidi Williams: Hi, Sarah.

19:53 SC: So this seems intuitively true. Yeah, giants aren't real, but it is true, science seems to build on itself. But the issue here is quantifying it. How important is it to have that access to past research to move ahead? Heidi, you talk about two experiments in your piece and how they tackled this problem. What approaches did they take to quantifying the value of access to past research?

20:17 HW: One of the two papers, which was some of my own work, looked at human genes that were sequenced during the so-called race to sequence the human genome. Genes are curated very carefully by the scientific community in a way that they actually have a gene equivalent of a social security number. PubMed, which is an index of biomedical publications, uses those ID numbers to curate which scientific publications are related to those genes, and then you can also look at those ID numbers in catalogs of medical diagnostic tests.

20:44 SC: Where does access come into this? How is it possible to block the use of a gene in research?

20:49 HW: In that experiment, basically we were comparing two different regimes. One was the publicly funded Human Genome Project. All of the genes that were sequenced under the Human Genome Project went into the public domain within 24 hours. In contrast, the private firm that was simultaneously working on sequencing the genome, Celera, they held the sequence genetic data with a form of essentially copyright. There were some restrictions on the use of the data. By any objective standard, it was actually a very light set of restrictions, so scientists were free to use the data for scientific research free of charge, but if you wanted to use the data in commercial research, you needed to negotiate a licensing agreement with Celera.

21:27 SC: And when you compare those two sources of genetic sequences, what did you see? What were the differences like?

21:34 HW: What you find is that there was about 30 percent less scientific research and product development that came out of the genes that were sequenced by Celera relative to otherwise similar genes that were sequenced at the same time by the Human Genome Project.

21:48 SC: Let's also talk about the other study you mentioned in your piece, this one on access to biomaterials.

21:54 HW: Yeah, so the other study was done by one of my colleagues at MIT Sloan as well as a colleague from Boston University, and what they were looking at is what are called biological resource centers. So these are essentially institutions who have an objective of certifying and disseminating knowledge. There are biomaterials that are accessed to these institutions and they're

then sort of curated in a way that is meant to provide easier access to other scientists to reuse those materials.

22:20 SC: What kind of access restrictions do they have or not have on those materials?

22:24 HW: What they did is that they... There's a paper essentially documenting the discovery that was submitted to the center, and then they looked at how citations to the papers changed when the materials, like the cell lines, got submitted to one of these centers. The results of that analysis suggest that when new materials get accessed to the biological resource centers, you get a big increase in citations to the papers that are linked to the discoveries. And so it suggests that basically scientists making discoveries in their labs is of course very useful, but is less socially useful than if we can sort of have the access to those discoveries be set up through an institution like these biological resource centers which have a goal of making it less costly for other people to access those discoveries.

[music]

23:08 SC: Pierre Azoulay, Heidi Williams and Ben Jones write about making science more scientific in a special section this week. Also in the section, we have stories on how to identify a research hotspots ripe for breakthroughs, how to deal with congestion on the frontiers of science, and tracing the ripple effects of retractions.

23:31 SC: And that concludes this edition of the Science Podcast. If you have any comments or suggestions for the show, write to us at sciencepodcast@aaas.org. You can subscribe to the show anywhere you get your podcasts or you can listen on the Science website, sciencemag.org/podcasts. There you'll also find links to the research and news stories discussed in the episode. To place an ad on the science podcast, contact midroll.com. The show was produced by Sarah Crespi and edited by Podigy. Jeffrey Cook composed the show music. Additional music provided by Wen Wen. A special thanks to Brad Wyble for editing the package on science myths. On behalf of Science Magazine and it's publisher, AAAS, thanks for joining us.