

PLOS Science Wednesday: Hi Reddit, we're Roslyn Dakin and Suzanne Amador Kane. We published a study in PLOS ONE assessing the physics behind displays of courtship from male peacocks – Ask Us Anything!

PLOSScienceWednesday ¹ and r/Science AMAs¹

¹Affiliation not available

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Thanks for joining us today! How specific is this phenomena to peacocks? Do you believe that other birds use resonance to attract mates?

[p1percub](#)

Suzanne: Indeed, there are other species of birds related to peacocks that use feather vibrations in a very similar way during mating displays, including the Great Argus and a variety of Peacock Pheasants. Some birds species have feathers that make sounds due to vibrations driven by the passage of air over the feathers during flight, while others drive the vibrations using specially adapted feathers. There is an active area of research investigating such mechanical sounds and their possible roles in various kinds of signaling.

Roz: some hummingbirds have feathers specialized to make mechanical sounds (e.g., Rufous and Allen's hummingbirds, Anna's hummingbirds). Also manakin courtship displays like this one: <https://www.youtube.com/watch?v=7FHSQQMnOko>

Do male peacocks in captivity have larger feathers because they are no longer at risk of becoming prey? It seems like having too large/many feathers would slow the peacock down and make it more vulnerable in nature.

[shiruken](#)

Suzanne: The various studies of peacocks have included wild populations in natural settings, so we are sure the long feathers are not due to domestication and protection from predators. Graham Askew has studied the flight of peacocks and shown that, contrary to expectations, their long feathers do now slow them down. This of course does not contradict your point that having long feathers may in other ways make them more vulnerable to predators. They are quite unaware of humans approaching them from behind their trains during courtships displays, for example. And studies by other scientists have shown they must expend energy growing and maintaining these splendid feathers. Peacocks actually may be well-camouflaged when their long trains are folded up so as to hide their eyespots. The resulting iridescent green and blue coloration blends well into the surrounding vegetation in the settings I have observed them in.

Roz: One study of peafowl at a zoological park in London found that males with shorter trains were actually predated more often: https://www.researchgate.net/profile/Marion_Petrie/publication/232545934_Petrie_M_Peacocks_with_low_mating_success_are_more_likely_586/links/0c96052d50d8fbc03e000000.pdf That's not to say having a longer train doesn't slow a peacock down or have any costs at all; just that a lot of the variation in feather length in a population may be correlated with condition or health (healthier males -> longer trains & better at avoiding predation). The birds in our study population in California do get predated by coyotes, bobcats, and raptors/predatory birds. The chicks have the greatest mortality though - the adults are much better at avoiding predation.

Seems like a natural next step might be to test peahens' reaction to an artificial train perturbed at

various frequencies. Any plans to do this kind of work?

[superhelical](#)

Suzanne: We have not done this, but it is a good idea. One could also use robotic birds to replicate the peacock or peahen behavior. This has been done for some other species of birds (sage grouse, gannets and others) and worked well.

In an earlier study, Roz and Bob Montgomerie found that covering up the peacock feather eyespots with either white or black stickers reduced the mating success of the peacock whose train was treated the way. (Peacocks completely molt and regrow their feathers every year, so he did not have to wait long to get back to normal.) This agrees with their finding that the iridescence of the eyespots is strongly related to male mating success. They did not determine whether this also changed the vibrational frequency of the train. However, when we did a similar manipulation to eyespot feathers of two lengths in the laboratory, applying similar stickers did not change the feather resonant frequency.

Seems like a natural next step might be to test peahens' reaction to an artificial train perturbed at various frequencies. Any plans to do this kind of work?

[superhelical](#)

Roz: that's a great idea, and yes we definitely want to test some of these ideas experimentally! The tricky part is how to evaluate a response. Even with live males, most of the time the peahens just saunter away and don't show any obvious signs of being impressed. But maybe using an artificial display with naive (young) hens could give us more insight into what frequencies are innately more attractive. It would be great if we could manipulate the dynamics of the feather motions on a live male - but not easy!

Hi, Professors Dakin and Kane! Thank you for taking the time to do this AMA. Do peacocks use this for other purposes (i.e. intimidation etc)? And if so, do they vibrate their feathers at a different rate depending on purpose?

[AudiWanKenobi](#)

Roz: I have not seen (adult) peacocks using their train as a threat display. Sometimes two males that are near each other, and both trying to court to females, will get aggressive. One male will turn and "start" at the other, all while their trains are still raised. If it escalates further the trains will come down. But I've never seen an adult peacock raise his train in what looks like the context of a threat display. On the other hand, the females raise and rattle their tails in a similar way and that behaviour does look like a threat display (it's often directed towards other species or other females). So perhaps the peacocks display evolved from behaviours that were originally used as a threat.

Suzanne: Davison (<http://www.sciencedirect.com/science/article/pii/S000334728380098>) has observed males of a related species, the Malaysian Peacock Pheasant, threaten males using displays very similar to the peacock's courtship display.

Serious question. Can peacocks fly and if not if there was one that could would male/female peacocks prefer that individual?

[eastmaven](#)

Suzanne: Yes, peacocks are quite good at flying! See this story about an earlier study by Graham Askew: <http://phys.org/news/2014-09-peacock.html> On a less scientific note, also see this truly amazing video of peacocks flying to get a sense of how well they do this: https://www.youtube.com/watch?v=o_FAR1g41IM

Roz: on the second half of that question, there are birds that use exaggerated flights in their courtship displays. Two of my favourites are the Anna's hummingbird: <https://www.youtube.com/watch?v=yQJkdp9YCpU> and the lance-tailed manakin: <https://www.youtube.com/watch?v=cAwevkUaB2Q> ...so presumably females in these species prefer males that perform better (in some way) when making these flights. I would love to study what females "look for" in these flight displays, and why (i.e., what if any advantage do females gain by preferring certain males).

In what way do the different auditory and visual ranges of peacocks influence the perception of the male courtship rituals compared to how a human would perceive it?

[IceBean](#)

Suzanne: Birds (including peafowl) have four different cones in their eyes -- they can detect colors that humans with normal vision cannot! They have cones similar to those of humans used to detect light in the red, green and blue regions of the human visible spectrum. However, peafowl also can detect ultraviolet light using a fourth type of cone. The central "dark" region of their eyespots reflects ultraviolet light, so this is relevant to how they sense their displays. (Weird fact: some women, including myself, have four cone populations in their eyes due to an effect related to how X chromosomes are expressed during development. However, I don't have ultraviolet vision. Colors just look a bit different in my two eyes!)

Here's a response I wrote to a related question: There are several ways in which one could think about this issue of what's the "perfect" frequency/vibration rate. Our study focused on the biomechanical properties of the peacock's feathers: we found their natural frequencies of vibration were well-matched to those actually used by peacocks rattling their feathers during courtship displays. However, we also found that peacocks with longer tails used higher vibrational rates, even though longer feathers had lower resonant frequencies when we shook them in the lab. This means that, not surprisingly, there are other factors influencing the male's choice of shaking frequency. These could be due to the mechanical properties of the bird's muscles, features of his nervous system or other influences we have not considered yet.

However, you could also ask, which frequencies would be best-matched to the female's vision and hearing, so as to best signal to her during courtship? Indeed, birds have been found to respond to visual signals that change as fast as 100 or more times per second (this depends on species, but it's a good ballpark figure). Thus, we expect that the females (peahens) can resolve the fast flickering motion of the male's train. How about the sound component? We don't know yet whether or how this functions as a signal to the female during mating displays. The rattle the male makes sounds like a true rattle: it has individual percussive notes covering a range of frequencies that are repeated about 25 times per second as the peacock shakes his feathers. These sounds should indeed be quite audible to peahens given our understanding of the range of frequencies birds can hear. There's only been one study of birds (budgies) investigating how fast they can distinguish such repeated rattle-like notes and it showed that those birds could indeed detect a rattle-like signal repeated 25 times a second.

Roz: We would love to study this! I have noticed that when I watch our videos of the vibrating eyespot feathers at different rates (e.g., slowing the display down 5x vs. 10x etc), some rates make the display look more striking to me than others. No idea why - maybe it has to do with the temporal properties of the retina and how they relate to colour and motion perception. Anyway, it does make me wonder whether there is a vibration "sweet spot" for peahen vision.

Have you tried replicating this occurrence synthetically? That is to say, could one build a machine that could attract the peahen with a relatively high success rate?

Does this have any self defense applications? Being brightly colored, peacocks seem like they would be fairly easy prey but it seems like this illusion could potentially be used to temporarily confuse or stupefy predators allowing the peacock to escape.

[Aramillio](#)

Suzanne: We have not done this, but it is a good idea. One could also use robotic birds to replicate the peacock or peahen behavior. This has been done for some other species of birds (sage grouse, gannets and others) and worked well.

In an earlier study, Roz and Bob Montgomerie found that covering up the peacock feather eyespots with either white or black stickers reduced the mating success of the peacock whose train was treated the way. (Peacocks completely molt and regrow their feathers every year, so he did not have to wait long to get back to normal.) This agrees with their finding that the iridescence of the eyespots is strongly related to male mating success. They did not determine whether this also changed the vibrational frequency of the train. However, when we did a similar manipulation to eyespot feathers of two lengths in the laboratory, applying similar stickers did not change the feather resonant frequency. I do not know of any studies showing that peacocks use this display to threaten or confuse predators. However, there have been many studies showing that eye-like patterns can startle and intimidate other animals. For example, some insects and fish have eye-like "eyespot" patterns that have been shown effective at deterring attack by predators.

Roz: I have never seen it being used for self-defense, but it is possible! (& I wonder if that could be the origin of some of these behaviors.) Sun bitterns spread out their patterned feathers in a self-defense context: <https://www.youtube.com/watch?v=8xmsgQkkERM>

A robotic peacock would be a great way to look at a lot of these questions. It will be tricky because there is so much movement during the display - the peahens are often skulking around, and the males

frequently changing position during displays. They are quite sensitive to whether the movements are natural. e.g., they treat stuffed birds that don't walk with a lot of suspicion.

Do you have any ideas on how you would study what the impact of vibration of the display is on courtship? Would it be possible to artificially damp the feathers and see how that effects success of the courtship? Or are there enough other factors at play that determining it would be difficult?

[kerovon](#)

Roz: Yes we would definitely like to do that (damp the feathers). It is definitely possible to add small amounts of weight. Ideally in this experiment we would also increase the vibration amplitude and/or frequency - that would be a lot harder!

Other than courtship rituals how can you see this research applying to fields outside of zoology? Perhaps camouflage or distractions in a battle?

[Mr_Tissues](#)

Suzanne: I'll take this question in the direction the next questioner indicates--implications outside of the study of animal behavior. Feathers have many remarkable physical properties: they are lightweight but can be quite stiff and tough. In addition to supporting flight, feathers provide birds with superior thermal insulation and waterproofing. Many have brilliantly iridescent "structural colors" that are due to interference and reflection of light from their internal nanostructure. In many feathers, the barbs (the smaller projections that run along the stiff quill) zip together into a vane that functions as a single unit. There's considerable interest in feathers as an inspiration for new biomaterials as a result of this interesting interplay between structure and mechanical function. I was particularly interested in how feathers used primarily for courtship displays differed in their structure--and hence their mechanical behavior--from those used for flight. For example, we found that peacock eyespot feathers have a surprising dependence of vibrational resonant frequency on length: one would ordinarily expect longer feathers to have much lower frequencies than those of shorter feathers (just like a bass has a lower pitch than a violin). For our cantilever geometry, we expected feather vibrational resonant frequency to vary as the inverse square of feather length--since the peacock's eyespot feathers vary by a factor of 10 in length, this means that we expected their resonant frequencies would vary by a factor of 100! Instead, the structure of different length eyespot feathers varies such that the resonant frequency depends only weakly on feather length. This is achieved by subtle variations in the taper of the feather, its internal structure and how mass is distributed along the feather's length. This phenomenon helps explain how the entire elaborate peacock train (the fan-like array of feathers with eyespots) can vibrate at a common frequency during these rattling displays. We were also intrigued at how variations in the zipping properties of the feathers enabled the eyespot to remain near-motionless while the rest of the feather vibrates strongly. The eyespots acted like a single mass at the feather's end, rather like a finger pressing down on a violin string to create a node. We also saw more than one resonant frequency being manifested (the train feathers appear to oscillate in both the second and third harmonic) but not the first. Why? It turns out that the peacock's lowly, drab tail feathers strum the train into motion, and the tail's feathers have no resonant frequencies that match the first harmonic of the train.

Roz: I'll chime in too - a bit behind because I'm on Pacific coast time! This project was purely curiosity-driven, but I do think that research on animal signals & visual signals has the potential to inspire certain applications. Understanding how animals capture visual attention via their elaborate displays could help us design better ways to prevent them from colliding with buildings, airplanes etc. It could lead to new ways to ways to attract pollinators, or repel pests. Evolution is cleverer than we are! Another connection (although it's not really outside zoology) is that a lot of courtship displays target basic visual processes in an extreme way. If we want to understand how vision works in other species, these displays might be a good place to start.

Hi, Professors Dakin and Kane! First, thank you so much for taking the time out of your busy lives to do this AMA and answer our questions! Second, I have two questions, if I may:

1. As a scientist fairly far removed from the life sciences and more involved in the physical sciences, what aspect of your research—either this study, specifically, or the broader, overall research you both undertake—do you wish to convey to someone like me or, even, a layman? Said a bit differently, what are the overall, further-reaching conclusions of the research you've done/are doing that you'd like us to know, especially those of us outside of the research realm that focuses on

peacock behavioral studies? (I hope my question makes sense; I intended it to be a bit a wee bit vague, as I'm interested in how you both see your research in the overall, general landscape of science as a whole.)

2. I particularly appreciate the physics "angle"—if you will—that you undertook in this study's methodologies. In other words, your approach employed physics-based methodologies that are not, from my admittedly limited and somewhat ignorant perspective, super common in most animal behavioral studies I come across. (Again, I don't do much life sciences research, so please forgive me if my impression is mistaken and I seem naïve and/or ignorant!) I found myself much more readily capable of interpreting your findings and sharing in your insights than I typically do in research so far afield from my own. In both your opinions, what benefits did this more "by the numbers and mathematical models" approach shall we say afford you? (As opposed to a, say, more abstract, observational approach that would have delved less into the numbers and models and more into the overall impressions and general observations.) Do you feel there were any drawbacks to this approach?

Again, thank you so much, Professors Dakin and Kane, for taking the time to do this AMA and answer my questions! And sorry for fibbing a bit earlier, since technically, I ended up asking more than just two questions. I hope you don't feel too swindled by me!

I wish you both all the best in your future research and all other endeavours you undertake.

EDIT: Added a line break to make things a bit easier on the eyes and more readable. Also changed a few singulars to plurals and cleaned up some confusing sentences.

[sexybeastscotty](#)

Suzanne: I've partly addressed your questions in my response to the question above. More generally, there actually is a large and growing community of researchers applying the same combination of techniques from biology, physics and engineering to problems in animal behavior. While these results are published in a wide variety of venues, including PLOS One, I'd especially recommend the Journal of Experimental Biology for someone just starting to learn about this field. The scientists working in this area come from all different backgrounds and hail from many different departments. The advantages to a combined, collaborative approach extend outside the obvious: opening up new tools for the study of organismal biology and animal behavior, and avoiding oversimplified (or just incorrect) physical approaches to complex biological problems. As we've found, this also leads to new questions and observations that would not occur to any one of us individually. Many of our ideas came from one of us noting an interesting feature or behavior, and then another realizing possible interpretations.

Drawbacks? Researchers face challenges when they must learn to talk across disciplinary boundaries. As a physicist, I've had to learn to read the field biology literature and understand biostatistical methods. There's really no substitute for engaging in this way. Otherwise, you'll reenact the old joke about "consider a spherical cow"!

Roz: Thanks for these questions! I totally agree with Suzanne. I come from an animal behaviour background but am trying to learn *some* of the physics. Regarding the math angle, most of my work is studying visual guidance of flight (i.e., behaviour, not biomechanics). Even in that work, it's useful to model the different visual motions that we expect the birds to have experienced in our experiments, because then we can ask how their behaviours fit different hypotheses about the cues they might be using. So even though it's not strictly biophysics, modelling is part of our approach.

As for your first question, I'm not sure our peacock study has far-reaching conclusions because I think it is just a first step. But it does point to the importance of (visual) change and unusual motions in attention-grabbing displays.

Do you believe there is a perfect level of fan rate and vibration frequency that might exist in this display? Is it possible that this is something we are not looking at in animals across the board? Could a perfect set of circumstances (biomechanical movement, sounds, smells etc) in mating displays be applicable to every animal?

[SmellsofMandom](#)

Suzanne: There are several ways in which one could think about this issue of what's the "perfect" frequency/vibration rate. Our study focused on the biomechanical properties of the peacock's feathers: we found their natural frequencies of vibration were well-matched to those actually used by peacocks rattling their feathers during courtship displays. However, we also found that peacocks with longer tails

used higher vibrational rates, even though longer feathers had lower resonant frequencies when we shook them in the lab. This means that, not surprisingly, there are other factors influencing the male's choice of shaking frequency. These could be due to the mechanical properties of the bird's muscles, features of his nervous system or other influences we have not considered yet.

However, you could also ask, which frequencies would be best-matched to the female's vision and hearing, so as to best signal to her during courtship? Indeed, birds have been found to respond to visual signals that change as fast as 100 or more times per second (this depends on species, but it's a good ballpark figure). Thus, we expect that the females (peahens) can resolve the fast flickering motion of the male's train. How about the sound component? We don't know yet whether or how this functions as a signal to the female during mating displays. The rattle the male makes sounds like a true rattle: it has individual percussive notes covering a range of frequencies that are repeated about 25 times per second as the peacock shakes his feathers. These sounds should indeed be quite audible to peahens given our understanding of the range of frequencies birds can hear. There's only been one study of birds (budgies) investigating how fast they can distinguish such repeated rattle-like notes and it showed that those birds could indeed detect a rattle-like signal repeated 25 times a second.

Roz: I would add that I think we'd be unlikely to find "perfection" across the board, for a couple of reasons. Often there are constraints that limit what animals can do. e.g. Suppose 35 Hz is even more attractive to peahens, but it's not (yet) physically possible for peacock muscles to generate that frequency. A higher frequency might evolve eventually, but it may take a lot more time (here's a nice study on how super-fast muscles have evolved for manakin courtship displays: <https://elifesciences.org/content/5/e13544>). Or there might be other constraints that prevent something like this from ever happening, even with ample evolutionary time (e.g., faster muscles may be too costly in some other regard). Biological designs that are favoured probably work best on average, rather than being perfect at any one thing. Good examples of these trade-offs and imperfections are our large heads as babies & mortality during childbirth, and the blind spot in our eyes.

Whose idea was it to start this study in particular? And is there something about this that you didn't expect to find?

[SKxU](#)

Suzanne: This study came from several threads developed by the different authors. Roz and Bob Montgomerie had already been studying many facets of peacock behavior, including feather iridescence and how it influences male mating success and how the males and female's orient relative to each other and to the sun during displays. Jim Hare and his coauthor Angela Freeman had studied aspects of mechanical sounds emitted by peafowl during displays. I was studying the visual ecology of a different species when I become fascinated by high speed videos Roz had filmed that showed peacock displays. I was initially interested in the patterns the eyespots assumed in the female's visual field, but her videos made it apparent that there were interesting issues in the vibrational patterns. We all got in touch using social media and decided to collaborate! Most surprising to me personally: that the feather's have such similar resonant frequencies when their lengths vary so widely--and that the males with longer trains vibrate at higher frequencies--not lower frequencies as expected from the physics alone.

Roz: I was surprised at how different the display looks when slowed down via high-speed video, as compared to when you see it in real life. I had spent 100s of hours watching peacocks but didn't get a sense that the rattling vibration had such visual impact, until we slowed it down on video. I had no idea that the eyespots got that floating appearance until I saw it on video.

How could this research applying to fields outside of the feather vibrates strongly.

[mandyster](#)

Suzanne: Feathers are intriguing biomaterials that have been adapted into many different uses. In fact, we already use them as biomaterials (think of down comforters and coats!) Engineers are actively exploring how we can use ideas from feathers to design new materials with novel features. For example, the study of the iridescent colors of feathers like those of the peacock have inspired a new way to create vivid colors in artificial materials--and these structural colors are inherently fade resistant and can be readily programmed to create different colors at different angles and so on. Feathers are very lightweight, strong, and tough. They are used in flight and to create structures that can stand upright, vibrate and serve as sensors. All of these uses are providing inspiration for new applications.

How could this research be utilised in a way that benefits humans? Is there any use for this in design perhaps?

[ElectiveAffinities](#)

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Roz: Courtship displays also involve motions, colours, and sounds that are evolutionarily tuned to be attention-grabbing. This can be useful for applications where we want to modify the behaviour of animals (e.g., preventing collisions, attracting or repelling certain species, or providing enrichment to animals in captivity).