The Mind-blowing Science of PIEZO2

Mechanosensory Interoception meets HRV Biofeedback

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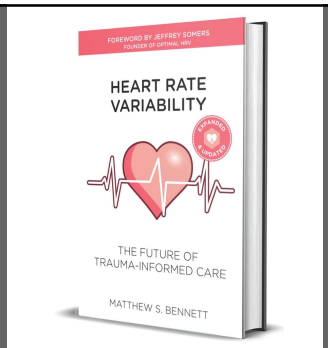
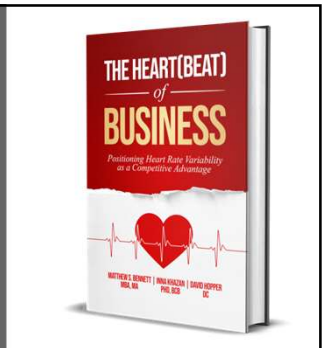
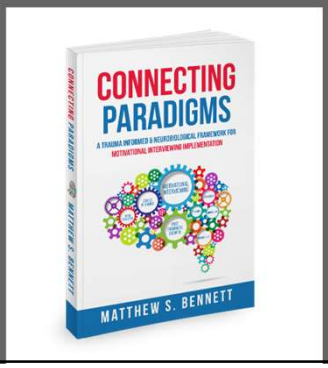
- Free books
- Heart Rate Variability Podcast

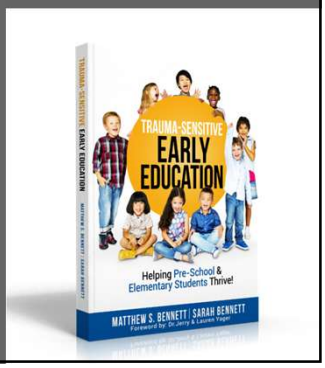
I have the following disclosures:

- Co-Founder of Optimal, LLC
- Company behind Optimal HRV App









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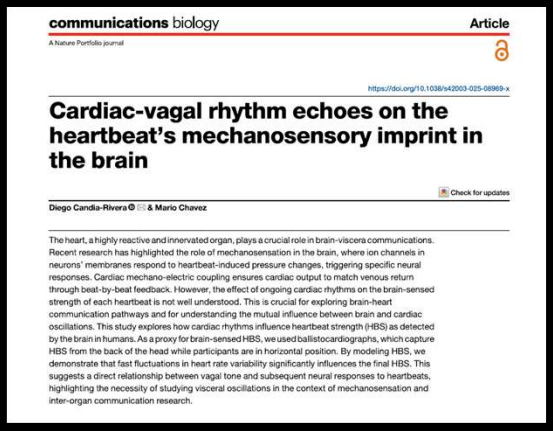
My journey and questionable decisions!

- Another morning of reviewing HRV research
- What in the world is PIEZO2?
- I must be the only one that has not heard of this amazing mechanosensor (and what is a mechanosensor!)
- Okay, people smarter than me have not heard about it either
- AAPB request for workshop proposals
- For better or worse…here I am!!



communications biology

A Nature Portfolio journal

Article

https://doi.org/10.1038/s42003-025-08969-x

Cardiac-vagal rhythm echoes on the heartbeat's mechanosensory imprint in the brain

Check for updates

Diego Candia-Rivera & Mario Chavez

The heart, a highly reactive and innervated organ, plays a crucial role in brain-viscera communications. Recent research has highlighted the role of mechanosensation in the brain, where ion channels in neurons' membranes respond to heartbeat-induced pressure changes, triggering specific neural responses. Cardiac mechano-electric coupling ensures cardiac output to match venous return through beat-by-beat feedback. However, the effect of ongoing cardiac rhythms on the brain-sensed strength of each heartbeat is not well understood. This is crucial for exploring brain-heart communication pathways and for understanding the mutual influence between brain and cardiac oscillations. This study explores how cardiac rhythms influence heartbeat strength (HBS) as detected by the brain in humans. As a proxy for brain-sensed HBS, we used ballistocardiographs, which capture HBS from the back of the head while participants are in horizontal position. By modeling HBS, we demonstrate that fast fluctuations in heart rate variability significantly influences the final HBS. This suggests a direct relationship between vagal tone and subsequent neural responses to heartbeats, highlighting the necessity of studying visceral oscillations in the context of mechanosensation and inter-organ communication research.

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Road Map to the "Force Sensor"

- First, explain what PIEZO2 is in simple terms.
- Next, show how it helps the body sense touch, movement, and internal mechanical changes.
- Then, we will connect PIEZO2 to the vagus nerve, HRV, and interoception.
- Finally, informed speculation: how PIEZO2 might help explain some of the effects of HRV biofeedback.

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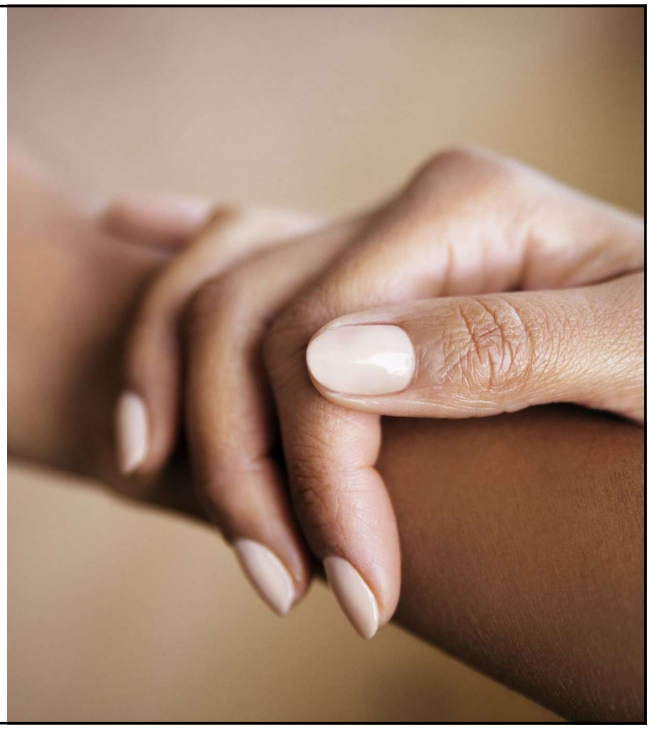
What does PIEZO2 help us feel?

- Light touch
- Body position and movement (proprioception)
- Some internal mechanical signals from the body
- PIEZO2 is not just about skin sensation; it also contributes to sensing what is happening inside us.



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PIEZO2: A Short History

2010: PIEZO channels were identified as a new class of proteins that help cells detect physical force.

2014: PIEZO2 was shown to play a major role in gentle touch.

2015: PIEZO2 was shown to be essential for proprioception, meaning the sense of body position and movement.

2017–2018: Research expanded from skin sensation to breathing, blood pressure sensing, and internal organ function.

2021: Ardem Patapoutian shared the Nobel Prize in Physiology or Medicine for discoveries related to receptors for touch.

Recent work: PIEZO2 is now being studied in the heart, vagus nerve, and internal body sensing.

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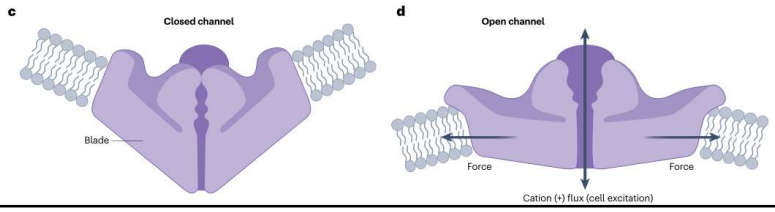
How does PIEZO2 work?

- PIEZO2 sits in the membrane of sensory nerve endings.
- When that membrane is bent, stretched, or deformed, the channel opens.
- Positively charged ions flow into the cell.
- That ion flow helps trigger an action potential.
- It is mechanically linked to the cell's internal scaffolding
- Result: the brain receives information that "something mechanical just happened."



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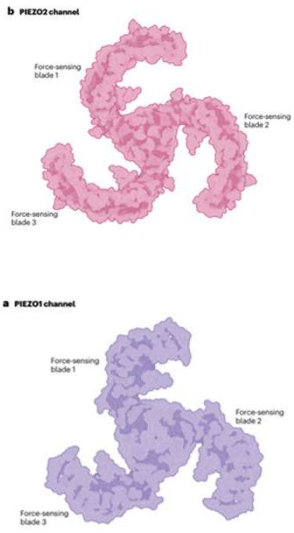
Is there a Piezo1?

- The name "piezo" comes from the Greek word *piezein* (πιέζειν), meaning "to squeeze" or "to press."
- PIEZO2 is closely related to PIEZO1, but they do not behave the same way.
- PIEZO1 is more responsive when the cell's outer surface gets pulled tight, expanded, or stretched outward, often because of pressure, swelling, or force across the whole cell.
- PIEZO2 is more tuned to localized indentation or "soft touch"-type forces.
- That makes PIEZO2 especially well suited for fine touch and other low-threshold mechanical sensing.



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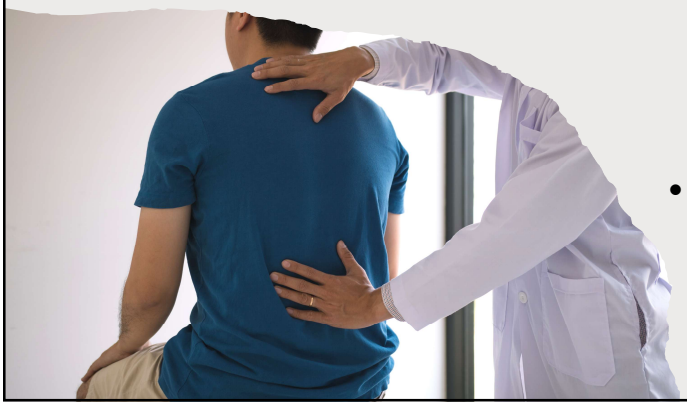
PIEZO2 and Bodily Sensations



- "Mechanosensation" means sensing pressure, stretch, movement, or force.
- Internal examples may include pulses, lung inflation, heartbeat-related forces, and organ stretch.
- Put simply: mechanics -> sensory signaling -> autonomic adjustment -> felt bodily state.

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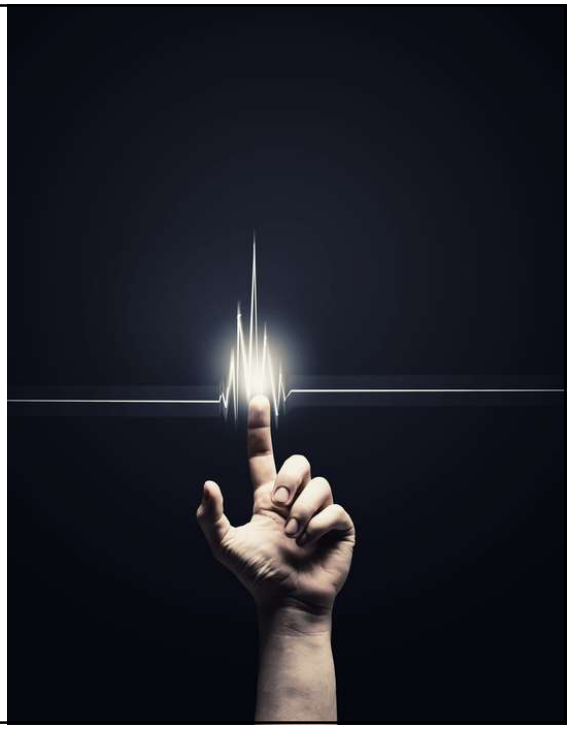
PIEZO2 and Interoception

- Interoception is the sensing of what is happening inside the body.
- It includes awareness of signals such as heartbeat, breath, fullness, tension, and internal rhythm.
- Some interoceptive signals are conscious.
- Others help regulate the body without us noticing them directly.
- PIEZO2 turns internal mechanical events into interoceptive information.



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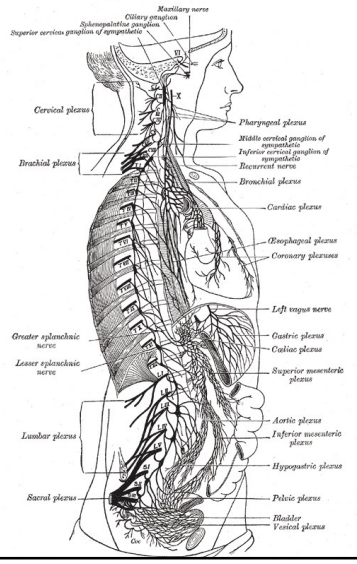
Bridge to Regulation: Our friend the Vagus Nerve!



- The vagus nerve carries signals between the body and the brain.
- Many of its fibers are afferent, meaning they carry information from the body to the brain.
- Those signals include information related to breathing, blood pressure, and cardiac filling.
- The brain then uses that information to adjust output back to the body.
- The vagus helps connect sensation and regulation

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PIEZO2 and Cardiovascular Mechanics

- Research in mice discovered vagal PIEZO2 neurons form distinctive endings in the heart.
- These neurons fire in relation to the cardiac cycle, meaning the repeating pattern of each heartbeat.
- Their activity changes with blood volume and cardiac filling.
- When PIEZO2 is disrupted, the body becomes worse at compensating for posture change and blood loss.
- That suggests PIEZO2 contributes to real-time cardiovascular sensing.

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Another Old Friend: Baroreflex

- The baroreflex is the body's fast blood-pressure control system.
- When blood pressure rises or falls, sensors send that information to the brainstem.
- The brainstem then adjusts heart rate and blood vessel tone to stabilize circulation.
- PIEZO channels appear to be part of the sensor system involved in this process.
- This matters because the baroreflex is highly relevant to HRV and paced breathing.

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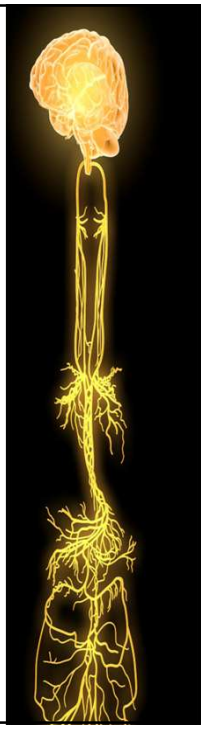
Cardiac-vagal rhythm changes how strongly the brain senses the heartbeat

- A recent human paper adds an important bridge.
- It found that fast changes in HRV were linked to changes in the brain-sensed strength of each heartbeat.
- In plain language: how the vagal system is functioning may influence how strongly the brain detects heartbeat-related mechanical signals.
- Raises the likely possibility that cardio-vagal rhythm and mechanosensory interoception are linked.



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Connecting the Dots

- PIEZO2 helps turn mechanical events into neural signals.
- HRV reflects beat-to-beat changes in autonomic regulation, especially vagal influence on the heart.
- Biofeedback changes breathing, pressure, timing, and rhythm in the cardio-respiratory system.
- Interoception is how those internal signals are sensed and used.
- In simple terms: mechanics -> sensing -> regulation -> felt bodily state

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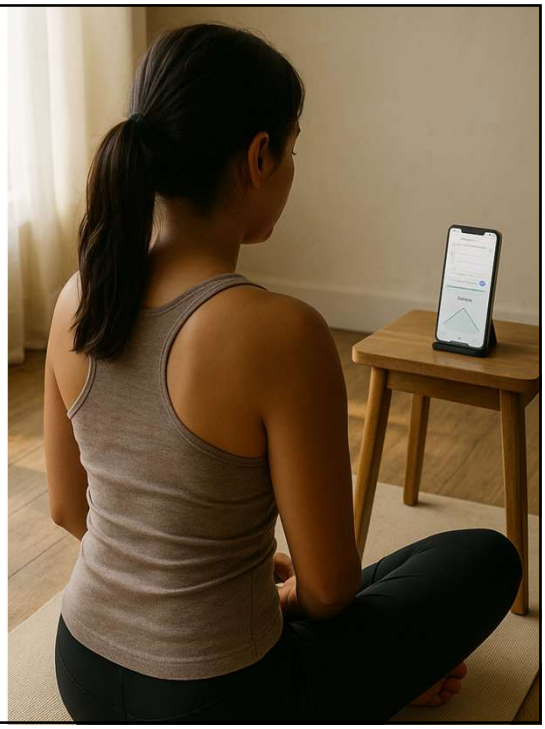
What Resonance Frequency (RF) Breathing **may be** doing in the body

- RF breathing creates the strongest, smoothest rhythm between breathing, heart rate, and blood pressure.
- That can increase mechanical signals related to pressure, stretch, vessel filling, and cardiac filling.
- Those signals may increase sensory input from the lungs, blood vessels, and heart to the brain.
- In simple terms, RF breathing may help the body practice and strengthen a mechanosensory-autonomic feedback loop.



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A Model to Drive Thinking and Future Research

Mechanical event: breath, pulse wave, vessel stretch, cardiac filling

Sensor: PIEZO2-linked mechanosensory signaling

Afferent pathway: signals travel toward the brain through vagal and related pathways

Central integration: the brainstem updates autonomic output

Observable outcome: HRV changes

Subjective outcome: changes in heartbeat awareness, body awareness, and self-regulation

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What we know & What I want to know!

- We do have evidence that PIEZO2 contributes to internal cardiovascular and vagal mechanosensation in animal models.
- We do have human evidence that cardio-vagal rhythm influences brain-sensed heartbeat mechanics.
- We do not yet have direct evidence that a specific HRV biofeedback protocol changes PIEZO2 activity in humans.
- So the strongest safe claim is this: HRV biofeedback likely trains reflex loops that mechanosensors feed into.
- That is different from claiming that HRV biofeedback has been proven to directly "train PIEZO2."

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Takeaways

- PIEZO2 is a force sensor that helps the body detect mechanical events.
- It is relevant not only to touch and movement, but also to internal body sensing.PIEZO2 may help us think differently about interoception, especially mechanosensory interoception.
- HRV reflects how autonomic circuits respond to bodily rhythms and mechanical changes.
- HRV biofeedback may work, in part, by repeatedly exercising mechanosensory-autonomic feedback loops.
- Even where the evidence is still emerging, PIEZO2 offers a useful new lens for thinking about HRV, biofeedback, and self-regulation

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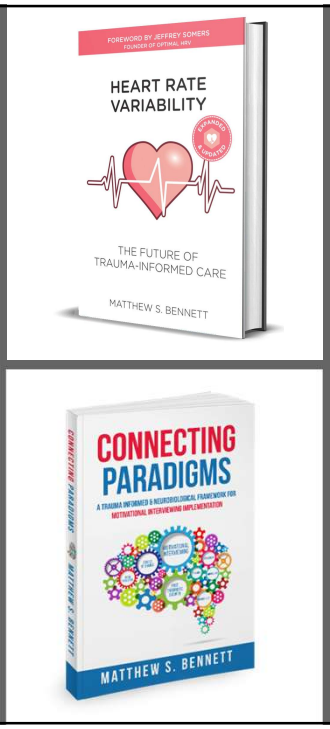
Thank you for joining me and all the work you do!



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