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How stories and narrative move the heart—literally

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Researchers are finding that the heart offers insights into when and how people respond to a story. Applications might some day include monitoring the engagement of an entire audience during a talk, or even ascertaining whether a loved one will regain consciousness. Image credit: Dave Cutler (artist).

In June 2019, at the University of Birmingham in England, psychologist Damian Cruse invited 27 young adults to come to the lab, on separate occasions, and listen to the same clips from an audiobook of Jules Verne's *20,000 Leagues Under the Sea*. Sitting alone, each donned headphones and electrocardiogram (EKG) equipment while a voice with a British accent recounted tales of a mysterious monster taking down ships. When researchers later compared volunteers' heart rates, a curious phenomenon emerged: The heart rates of nearly two-thirds of the participants rose and fell together as the story progressed (1).

"It's not that the beats align synchronously, but rather the heart rate fluctuations go up and down in unison," explains Lucas Parra, a biomedical engineer at City College of New York, and co-senior author on the study.

Research has already shown that brain activity can synchronize when listeners pay attention to the same video or story (2). Now, Parra and others are finding that the heart, too, offers insight into who is really paying attention to a story. Potential applications are myriad. With heart rate recordings from smart watches, a webinar host may one day learn whether the audience is engaged, or a doctor could offer a family insight into whether a loved one will recover consciousness.

But the technology is new and researchers are still grappling with how to harness heart rate data responsibly, even as they continue to explore why stories move hearts in synchrony in the first place.

Hearts and Stories in Step

Neuroscientists have been studying how stories and movies affect brain activity for about two decades, notes neurobiologist Christopher Comer, professor

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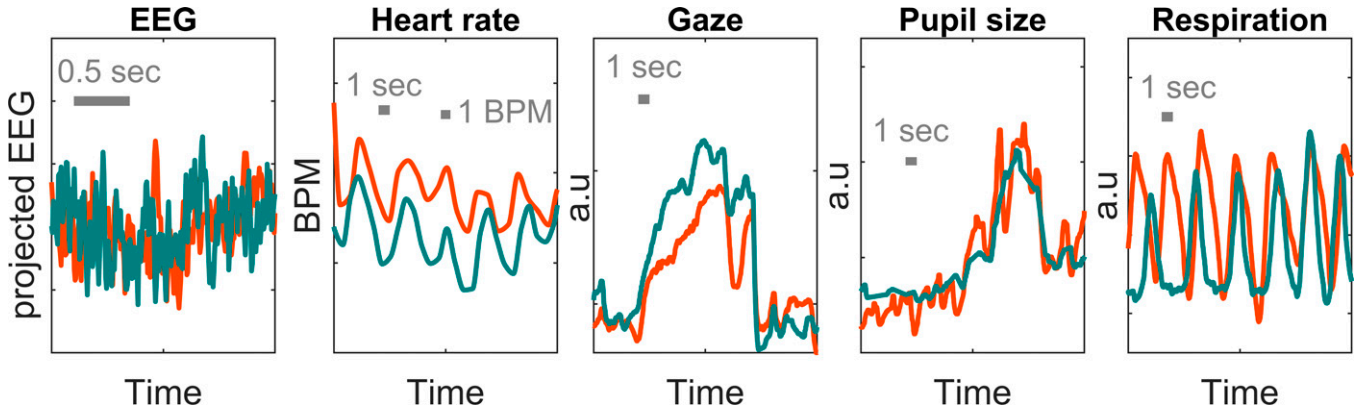

Researchers are exploring how heart rate—as well as other neural, physiological, and behavioral metrics—synchronize across listeners paying attention to the same story. Here, two volunteers show similar responses to the same educational video. Reprinted with permission from Reference 9.

emeritus at the University of Montana in Missoula and coauthor of the 2021 book *Brain, Mind, and the Narrative Imagination* (3). "There are amazing things that powerful literature can do to grab our attention."

Researchers can track this attention by following brain activity using tools such as electroencephalography (EEG) or functional magnetic resonance imaging (fMRI). fMRI studies in particular can show not only that brains are active but also that "a specific region of the brain is sort of clicking along in the same way in two people or three people or four people," says Comer.

In 2004, for example, Princeton University neurobiologist Uri Hasson, then at the Weizmann Institute of Science in Rehovot, Israel, and colleagues reported that brain activity, tracked via fMRI, synchronized across viewers watching a portion of the film *The Good, the Bad, and the Ugly*, and this synchrony seemed to correspond to particular moments in the movie, such as plot twists and gun shots (2). But monitoring brain activity requires specialized equipment, so researchers are looking for more accessible windows into engagement.

Physicist and psychiatrist Jacobo Sitt of the Paris Brain Institute, France, reasoned that if a stimulus can impact brain activity, and the brain controls organs, then there could be some downstream effect on those organs. Sitt and colleagues presented patients experiencing disorders of consciousness with patterns of tones followed by tones that didn't follow the pattern (4). In 2017, the team reported that these latter, unexpected tones caused the heart beats of patients in minimally conscious states to shift slightly but didn't affect unresponsive patients. Sitt then joined Parra and others to explore whether attention to stories could similarly move the heart.

In addition to their *20,000 Leagues Under the Sea* study, Sitt, Parra, and colleagues showed healthy volunteers a series of five educational videos (1). Nearly all participants' heart rates moved in synchrony during the videos. But when these same volunteers watched the videos again—this time with the distraction of counting backwards silently by sevens—attention dropped and synchrony diminished. In another study, volunteers whose heart rates more closely synchronized with others' while listening to children's stories were also better at recounting details such as character names.

If you are paying attention to a story, your heart rate will move up and down along with others paying attention to the same story, explains Parra. "If [your heart rate's] not similar to an attentive group, it means you're not really paying attention. And if you are not paying attention, you won't remember what was said in the story."

Other researchers have found that heart rate synchrony strongly indicates attention, although not necessarily as accurately as synchronous brain activity (5). Experimental psychologist Anne-Marie Brouwer, of The Netherlands Organisation for Applied Scientific Research, and colleagues asked volunteers to individually listen to an audiobook of the Dutch thriller *Zure koekjes*, which they expected would interest a wide audience and be neither boring nor too intense. The researchers asked half of the volunteers to focus on the story and the other half on additional sounds such as beeps or a baby crying. Based on heart rate data, a statistical analysis accurately identified whether a volunteer had focused on the story or the extraneous sounds 73 percent of the time, compared with 96 percent with EEG. "It was quite surprising," says Brouwer, noting that they didn't expect heart rate to be as predictive of attention as it was.

But heart rate fluctuations can also vary even among attentive listeners, says neuropsychologist Hennric Jokeit at the Swiss Epilepsy Centre in Zurich. Perhaps one moviegoer foresees disaster while another is unaware. "Probably the majority of us see different movies, although we watch the same," says Jokeit. He and his colleagues recorded heart rates as 40 volunteers watched *The Impossible*, a film based on the true story of a family caught in a tsunami (6). Only four people's heart rates synched together across the film as a whole. But when the team focused on heart rate responses within six highly emotive moments, they discovered that for each scene, most participants fell into one of three or more groups of at least four individuals who had similar responses. "We found clusters," explains Jokeit. "Different subjects may be more similar than others regarding the roller coaster of heart rate responses to this disaster movie."

What Moves the Heart?

Although stories can move the heart, exactly why isn't clear. Many researchers believe emotional scenes are important—a theory supported by research suggesting that emotions drive heart rates up or down (7). In 2020, researchers at the University of Parma in Italy reported that heart rate synchrony was greatest within audiences

made up of people sharing similar self-reported emotional responses to a theatrical performance (8).

Yet emotions are not necessarily a prerequisite for heart rate synchrony, says Martina Ardizzi, a neuroscientist and author on the study, but "rather a useful medium to elicit this spontaneous phenomenon." Simply paying attention to the same stimulus, whatever the emotional content, may also be enough for heart rates to synchronize, Ardizzi says. Parra's team, for example, found heart rate synchrony among viewers of educational videos, even though the videos did not contain obvious emotional content (1).

Small details of shared experiences may also matter. In Ardizzi's experiment, 12 different audiences of four people listened to the same two monologues. But each audience experienced the show performed at a different time by a different actor. Heart rates synched most closely within audience groups, as opposed to across all groups as a whole, even though everyone heard the same series of words (8).

Keen to find the mechanism responsible for the narrative's heartfelt effects, Parra hypothesizes that the brain follows the narrative and sends signals to the heart to ready the body for action. In one study (9), his team tracked a suite of neural, physiological, and behavioral metrics while 92 people watched educational videos. Only metrics that correlated with brain activity, such as heart rate and eye movements, synchronized within an attentive group. Respiration and head movements did not correlate with brain activity or synchronize across participants.

Still, Parra isn't ruling out the possibility that the heart also affects the brain. In another study, not yet published, Parra found that people listening to the same audiobook showed synchrony in brain activity, heart rate, and pupil dilation—another metric of attention. But heart rate fluctuations occurred before pupil changes. The simplest explanation is that the brain drives the heart faster than the eye, says Parra. "But it is also possible that the heart has an effect on the brain that then has an effect on the pupil."

"Brain science sometimes is criticized if we focus too much on the brain without respect to the rest of the body," says Comer. He expects that future research into how hearts follow narratives will reveal more about the mind–body connection. "Is the brain interacting with the heart and that's why they are correlated?" he asks. "Or is the heart interacting with the brain? Or more likely there is two-way traffic of information between them."

Clinics and Classrooms

Whatever the cause, if researchers can demonstrate that heart rate synchrony is indeed a reliable signal of attention in specific environments, heart rate data could become invaluable in any arena where it helps to know whether someone's paying attention. And unlike expensive brain monitoring equipment, heart rate data can be collected by simple wearables. "We have all of [these] data in our smart watches," says Jokeit.

Accessibility is a goal for Sitt. His lab develops tools for assessing consciousness in patients who have experienced brain injury. Not every hospital has fMRI or EEG equipment, or trained personnel to perform and analyze these studies, he says. As a proof of concept, his team played a children's story for 19 patients with disorders of consciousness, including those in comas. The degree that patients' heart rates synched with healthy listeners correlated with a measure of brain health known as the fractional anisotropy (FA) index (1). This index, which gauges how well the brain's white matter fibers remain intact, has been linked with recovery of consciousness (10). "Our measure serves as a good proxy—something that everybody can apply," says Sitt. He's now testing these findings in a larger, multi-center study.

Jokeit too envisions heart rate synchrony as a diagnostic tool. He conducted his disaster film experiment to capture a baseline variability in heart rate responses among healthy adults. Ultimately, he'd like to explore how people experiencing neurological disorders that disturb social cognition respond to this same film.

Beyond the clinic, applications range from entertaining to practical. Moviegoer heart rate data could potentially help film producers create trailers that capture the most engaging scenes. In one study by cognitive neuroscientist Hakwan Lau, then at the University of Hong Kong, researchers used heart rate data from volunteers to pinpoint interesting scenes from movies and commercials and then confirmed these selections by asking separate groups of volunteers to choose the most engaging scenes (11). Lau, now at the RIKEN Center for Brain Science in Wako, Japan, imagines public speakers or teachers receiving real-time input on audience engagement. "I would love to have some information like this as I'm giving a talk," he says. "I want to know if people are getting it or people are just yawning and playing on their phones."

Not for the Faint of Heart

Whether in the classroom or the boardroom, heart rate data come with ethical considerations. Do consumers want marketers to know what storylines move them? Do students want teachers to know whether they're paying attention?

It's not enough, for example, for students to give teachers consent to track their heart rates, says University of Pennsylvania bioethicist Jonathan Moreno. "They also need to know how their data is being stored, how private it is, who's got access to it."

"Even though it is just heart rate, you might not think it is a big deal," says Lau. "But it could be." He notes that audience members at a political event, for example, might not want others to know how they're reacting.

But there are ways to minimize risk. Rather than sharing individual heart rates, a speaker could instead receive data only on the level of synchrony of the group as a whole. People would still transmit personal data, but it could be encrypted, says Lau.

For prerecorded online educational videos, Parra suggests that rather than transmitting heart rate data to an instructor, heart rate data from a previously recorded attentive group could be sent to students. Software on students' own computers could compare their individual heart rates with the group.

Of course, a key first step in using heart rate data ethically is asking permission. Some may want to keep their hearts to themselves. "You cannot do this without consent of the audience," says Brouwer. "That's maybe still open—whether people want this."

1. P. Pérez *et al.*, Conscious processing of narrative stimuli synchronizes heart rate between individuals. *Cell Rep.* **36**, 109692 (2021).
2. U. Hasson, Y. Nir, I. Levy, G. Fuhrmann, R. Malach, Intersubject synchronization of cortical activity during natural vision. *Science* **303**, 1634–1640 (2004).
3. C. Comer, A. Taggart, *Brain, Mind, and the Narrative Imagination* (Bloomsbury Academic, 2021).
4. F. Raimondo *et al.*, Brain-heart interactions reveal consciousness in noncommunicating patients. *Ann. Neurol.* **82**, 578–591 (2017).
5. I. V. Stuldreher, N. Thammasan, J. B. F. van Erp, A. M. Brouwer, Physiological synchrony in EEG, electrodermal activity and heart rate reflects shared selective auditory attention. *J. Neural Eng.* **17**, 046028 (2020).
6. B. K. Steiger, L. C. Kegel, E. Spirig, H. Jokeit, Dynamics and diversity of heart rate responses to a disaster motion picture. *Int. J. Psychophysiol.* **143**, 64–79 (2019).
7. S. D. Kreibig, Autonomic nervous system activity in emotion: A review. *Biol. Psychol.* **84**, 394–421 (2010).
8. M. Ardizzi, M. Calbi, S. Tavaglione, M. A. Umiltà, V. Gallese, Audience spontaneous entrainment during the collective enjoyment of live performances: Physiological and behavioral measurements. *Sci. Rep.* **10**, 3813 (2020).
9. J. Madsen *et al.*, Cognitive processing of a common stimulus synchronizes brains, hearts, and eyes. *PNAS Nexus* **1**, pgac020 (2022).
10. L. Velly *et al.*; MRI-COMA Investigators, Use of brain diffusion tensor imaging for the prediction of long-term neurological outcomes in patients after cardiac arrest: A multicentre, international, prospective, observational, cohort study. *Lancet Neurol.* **17**, 317–326 (2018).
11. T. Y. So, M. Y. E. Li, H. Lau, Between-subject correlation of heart rate variability predicts movie preferences. *PLoS One* **16**, e0247625 (2021).