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Cardiac Influences on Bistable Perception in the  
Auditory System

By

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## Abstract

Auditory perception has traditionally been understood as the passive encoding of acoustic energy from the external environment. However, recent research suggests that internal bodily signals, particularly cardiac signals, may also influence how external auditory information is organized in the brain. The present study examined whether the cardiac cycle has a role in modulating auditory stream segregation, a bistable auditory phenomenon. Twenty participants listened to sequences of tones (ABA- triplet), with the timing of the B tone synchronized to either cardiac systole or diastole. Results from the mixed-effects logistic regression showed that stimuli presented during cardiac systole were more likely to be perceived as two separate streams. Notably, this effect did not depend on whether participants could consciously perceive their own heartbeat, suggesting that interoceptive signals are unconscious when modulating the auditory percept. This finding challenges the traditional baroreceptor view that baroreceptors would inhibit sensory processing during cardiac systole. It supports that interoceptive signals dynamically shape perceptual processes. The evidence that cardiac signals influence perception extends from the visual to the auditory domain, suggesting a broad role for interoceptive signals in multisensory information processing.

## **Cardiac influences on bistable perception in the auditory system**

We experience our bodies as distinct from the external environment. While this perceived boundary between internal bodily states and external sensory input is often taken for granted, it is the product of an active cognitive process. The ongoing nature of this cognitive process has been made apparent in well-known experimental paradigms such as the Rubber Hand Illusion (Ramakonar et al., 2011), which demonstrates that bodily self-perception is not received passively but is actively constructed by the brain through the integration of information from multiple senses (Bergman, 1990).

If our internal-external inferences can be so easily tricked in an experimental setting, how is it that we seem to make this distinction so effortlessly and robustly in everyday life? It has been proposed that the way interoceptive signals ascending from our bodies' visceral organs (e.g., the heart) impinge upon the processing of exteroceptive stimuli (e.g., sound) plays a pivotal role in differentiating sensory stimuli that originate from ourselves versus those from the external world (Park & Tallon-Baudry, 2014). This study investigates whether, and in what forms, cardiac signals influence auditory perception, specifically testing whether these signals facilitate or interfere with auditory processing. By examining how cardiac signals affect auditory processing, the present study contributes to a better understanding of interoceptive–exteroceptive interactions in the auditory system, a topic that has not yet been fully explored.

### **Bridging the External and the Internal**

Perception is a complex integration process involving a sophisticated interplay between the brain and the body. Traditionally, research on perception has focused on exteroceptive processes involving external stimuli such as light, sound, and other environmental factors.

However, relatively little attention has been given to interoceptive signals (Critchley & Harrison, 2013). These signals, which convey information from visceral organs such as heartbeat, respiration, and gastrointestinal activity, represent more than simple physiological phenomena; they may modulate how external sensory input is processed.

Park and Tallon-Baudry (2014) argue that interoceptive signals are essential components of perception and self-awareness because they help form a constantly updated internal reference, called the neural subject frame, which supports our first-person perspective in experiencing the world. Importantly, this framework does not depend on us being aware of signals like our heartbeat. Even though we usually do not consciously hear or feel our heartbeat, the brain still automatically processes these bodily signals, which can influence how external stimuli are interpreted (Critchley & Harrison, 2013). The study by Veillette and his colleagues (2024) showed that in a binocular rivalry task, visual stimuli presented during systole dominated perceptual awareness for longer durations than stimuli presented during diastole. Unexpectedly, this effect was present even in participants who were at chance in distinguishing cardiac phases, suggesting that heartbeat signals are still automatically processed by the brain and influence our perception of external stimuli (Salomon et al., 2018).

There is indeed a wealth of evidence that the processing of exteroceptive (e.g., visual, auditory) stimuli differs according to the phase of interoceptive rhythms such as the heartbeat (Critchley & Harrison, 2013). Since some exteroceptive stimuli that originated from our bodies (e.g., the sound of the heart beating) are likely to be synchronized to interoceptive signals (e.g., input from the baroreceptors in major arteries following each heartbeat), these self-related stimuli would be systematically processed at a particular phase of interoceptive rhythms, distinguishing

them from non-self-stimuli. This distinction is thought to be a plausible mechanism for generating experiences of embodiment. In support of this, previous research has shown that a virtual arm that pulses in synchrony with aortic baroreceptors is more likely to be experienced as part of one's own body (Suzuki et al., 2013, though see Moffatt et al. 2024 for alternative findings). Although most previous studies have examined visual perception, auditory perception may be more sensitive to heartbeat-driven modulations, because of its inherently high temporal resolution. Auditory perception provides a uniquely suited context to test whether interoceptive signals influence exteroceptive sensory organization.

### **The Baroreceptor Hypothesis**

Cardiac signals, as typical representatives of interoceptive signals, have received widespread attention. The early Baroreceptor Hypothesis suggested that afferent input from aortic baroreceptors, a type of pressure receptor in the arterial wall, could reduce interference between interoceptive and exteroceptive inputs. This would stabilize perception by inhibiting central nervous system activity during cardiac systole, the period of high blood pressure immediately following contractions of the heart (Lacey & Lacey, 1978). Notably, this account of cardiac effects as having a strictly suppressive/inhibitory effect on exteroceptive perception would seem to clash with the above view in which cardiac inputs to the brain determine whether something is perceived as part of the self.

Originally, the Baroreceptor Hypothesis suggested that afferent input from aortic baroreceptors would inhibit sensory processing during cardiac systole (Lacey & Lacey, 1978), but recent research challenges this simplistic view. This inhibition was thought to stabilize perception by reducing interference from exteroceptive signals. However, recent studies have

shown that this view is too simplistic. For instance, Salomon et al. (2016, 2018) demonstrated that cardiac signaling is phasic, meaning that while systole may impair perception of visual stimuli, diastole activates more complex perceptual mechanisms that counteract this suppression. In a visual attention task, stimuli presented during cardiac systole are found to reduce the effect of distractors. This suggests that baroreceptor inputs can facilitate selection efficiency rather than simply inhibit external perception (Pramme et al., 2016). Additionally, Veillette et al. (2024) found in binocular rivalry experiments that cardiac signaling does not merely passively inhibit perception but, in some cases, can determine how the brain resolves between two possible perceptual interpretations of the same sensory stimuli. These findings suggest that the role of cardiac signaling is far more complex than described by the earlier Baroreceptor Hypothesis.

Importantly, the ability to consciously perceive one's heartbeat is not a prerequisite for such cardiac effects to occur. Even when individuals are not explicitly aware of the cardiac cycle, baroreceptor inputs can still modulate neural processing (Salomon et al., 2016; Park & Tallon-Baudry, 2014). These findings raise important questions about whether perceptual effects produced by cardiac signaling are necessarily mediated by interoceptive awareness, or whether such effects can occur unconsciously.

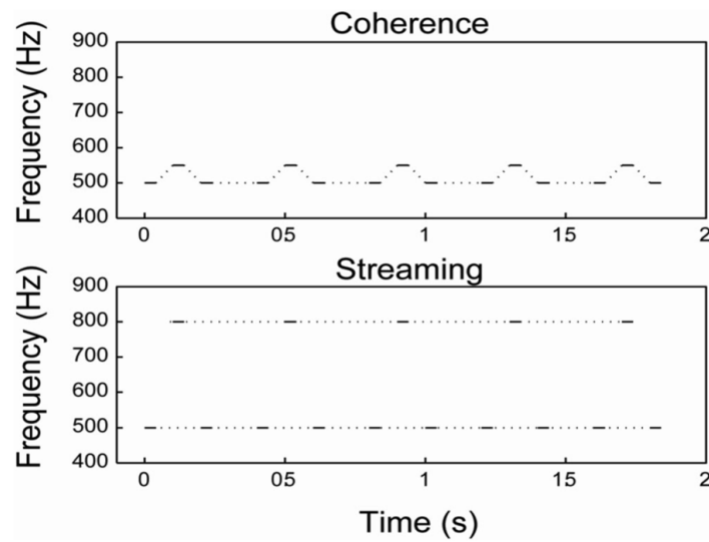
Additionally, beyond the direct afferent input from baroreceptors, there may be an indirect biological mechanism through which cardiac systole influences perception. Specifically, systole produces phase-locked fluctuations in cranial blood pressure that may affect neural excitability. Prior studies suggest that these blood flow pulses can alter neuronal firing thresholds and metabolic input (Golanov et al., 1994; Zanatta et al., 2013; Karavaev et al., 2018). However, this vascular mechanism does not change the main hypothesis of our study and could serve as a

contributing biological mechanism that helps explain the perceptual biases associated with heartbeat timing that we observed in the study.

### **Auditory Stream Segregation**

Research on the role of cardiac signaling in auditory perception is still scarcer than in visual perception. Because the auditory system itself is extremely sensitive to temporal structure, it may be more susceptible than other senses to internal timing signals such as the heartbeat. Thus, auditory becomes an ideal modality in experiments to investigate how interoceptive signals alter perceptual organization unconsciously, especially in ambiguous perceptual contexts like bistable auditory streaming (Van Elk et al., 2014; Seth, 2013).

The complexity of auditory perception lies not only in the need to integrate ambiguous inputs but also in the challenge of separating relevant information from background noise, as in the well-known “cocktail party problem”. Auditory stream segregation is a frequently studied bistable phenomenon centered on the perception of high-frequency (A) and low-frequency (B) tones that may be present in both the "single stream" and the "separated streams" (Carlyon, 2004; Denham & Winkler, 2006). "Stream" in this context refers to the organization of sound sequences into coherent perceptual units by the auditory system. When hearing an ABA-sequence, where the hyphen (“-”) marks a brief silence or pause between triplets, listeners may report perceiving it as a single stream (ABA-ABA) or as separated into two streams (A-A-A and -B-B-), as illustrated in Figure 1 (Pressnitzer & Hupé, 2005). In simpler terms, if tones A and B are perceived as coming from the same source, they are integrated into one coherent sequence. However, if there is a significant difference in frequency between the B and A tones, they are more likely to be heard as coming from different sources, resulting in two “parallel” streams.



*Figure 1.* Schematic depiction of auditory biostability. The same sequence of tones can be perceived either as a single coherent stream or as two segregated streams. Adapted from Snyder and Alain (2007).

Auditory stream segregation is an attractive framework for probing how sensory stimuli are or are not parsed into distinct streams or inferred sources, and the neural underpinnings that produce stereotyped behavior in auditory streaming paradigms are relatively well characterized (Rankin et al., 2015). In this vein, we can use the bistable auditory streaming paradigm as a launching point to test whether a potential stream (specifically, the B's within the ABA-sequence) is more likely to be heard as separate when synchronized to the heartbeat. Unlike explicit heartbeat discrimination tasks, the bistable streaming paradigm allows us to examine whether cardiac signals affect perception even when participants are not explicitly attending to their heartbeats. This can provide insight into the non-conscious interoceptive influences on auditory processing.

## Current Study

While there have been prior studies demonstrating that cardiac signals can influence perception, particularly in the visual domain (e.g., Veillette et al., 2024), current research on how cardiac signals influence auditory perception is still limited. The auditory system's sensitivity to temporal resolution may be more susceptible to interoceptive signals such as the heartbeat than other senses.

Building on this, the present study investigates whether the cardiac cycle (diastole and systole) modulates auditory stream segregation. We hypothesize that synchronizing the B tones to the heartbeat will increase the likelihood of perceiving two separate streams. This prediction is based on established models of auditory stream segregation (e.g., Rankin et al., 2015). It suggests that bistability between streaming and coherence in auditory stream segregation is caused by competition (via lateral inhibition) between the cell populations responding separately to A and B notes and a cell population responding to both types of notes. Inhibiting the response to the B tone would disadvantage the B-tone-responsive population (favoring coherence) but would also, in principle, reduce the spatial spread of the B tone's response in tonotopically-organized auditory cortex, reducing the number of cells responding to both tones (favoring streaming). Given our previous findings in the visual domain (Veillette et al., 2024), in which the systole-synchronized stimulus was dominated in bistable perception in contrast to the traditional baroreceptor hypothesis, we suspect the latter mechanism will matter more, favoring streaming overall. To further explore whether individual differences in interoceptive awareness modulate this effect, we included the heartbeat discrimination task in the study that directly examines this factor.

## Methods

### Participants

We recruited 22 undergraduate psychology students from the University of Chicago through the Sona system, an online platform commonly used in academic psychology research to connect students with research opportunities. Participants earned course credit for their participation. Two participants were excluded from the analysis due to impedance exceeding the acceptable threshold ( $\sim 10\text{ k}\Omega$ ), resulting in a final sample of 20 participants. All participants had self-reported normal hearing (i.e. no prior clinical diagnosis of hearing loss) and no history of cardiovascular or neurological disease.

### Study Design

Stimuli consisted of sine tones with 5 ms Hanning window onsets and offsets, a signal processing technique that softens the tone's edges to avoid clicking sounds or abrupt transitions. This method helped smooth the amplitude envelope of each tone, producing a more natural auditory perception. The amplitude ranged between 65 and 70 dB.

Each trial lasted 10 seconds and presented A-B-A triplets binaurally through insert earphones. The B tones were fixed at 500 Hz, while A tones varied from 510 Hz to 5000 Hz. On each trial, the A tone frequency was adaptively selected using the Quest+ algorithm (Watson, 2017) to target each participant's perceptual threshold. This approach was necessary because we did not know a priori at what frequency difference perception would be bistable (i.e., a 50/50 response distribution for one vs. two streams) for each participant, so we included a range to reliably induce bistable perception.

Meanwhile, tone presentation was synchronized with the participant's heartbeat. Each tone's duration was set to  $1/8$  of the R-R interval. In the systole condition, the B tone was presented  $1/6$  of the R-R interval after each R-peak; that is, it was presented in the middle of cardiac systole. In the diastole condition, the B tone was presented  $2/3$  of the R-R interval after the R-peak (i.e.,  $2/3$  of the way through the heartbeat, in cardiac diastole). The surrounding A tones of the ABA- sequence, in both conditions, were presented  $1/4$  of the R-R interval before and after the B tone, such that the three tones (A, B, and A) and the rest (-) were evenly spaced throughout the cardiac cycle.

## **Procedure**

Prior to the start of the experiment, participants were asked to sign an informed consent form and fill out a brief demographic questionnaire, including age, gender, and dominant hand. Two ECG electrodes were then attached to the participant's right collarbone and left rib cage. ECG data were processed in real time and bandpass filtered between 5–15 Hz. R-peaks were detected using the Pan–Tompkins algorithm (Pan & Tompkins, 1985). The median interbeat interval (IBI) over the last ten heartbeats was used to synchronize tone presentation to the cardiac cycle (quantified here in radians). The participant wore noise-canceling headphones while completing two tasks.

The first task was an auditory streaming task. In each trial, participants listened to a 10-second sequence of A-B-A triplets and then used the keyboard to indicate whether they perceived “one coherent stream” or “two separated streams.” Each participant completed 100 of these trials.

The second task, the heartbeat discrimination task, was designed to assess participants' level of awareness of interoceptive signals (interoceptive accuracy). Each trial consisted of a short tone sequence just like task 1, after which participants made a single yes/no judgment indicating whether the tones were played in sync (systole) or out of sync (diastole) with their heartbeat. Participants completed 100 trials in total. Importantly, participants were informed in advance that the task involved detecting synchrony. They knew to listen for synchrony during the tone sequence. The task was designed to assess whether the perceptual effects in task 1 were modulated by individuals' awareness of their heartbeat. At the end of the experiment, participants were debriefed about the purpose of the study.

### **Data analysis**

To test the main hypothesis of whether the cardiac cycle modulates auditory perception, we used mixed-effects logistic regression. The binary dependent variable was the participants' responses on each trial (1 = two streams, 0 = one stream). Fixed effects included cardiac condition (systole = 1, diastole = 0) and frequency differences between A and B tones. A random intercept was included for each participant to account for individual variability in baseline response tendencies. We predicted positive regression coefficients for systole condition, suggesting that stimuli were more likely to be perceived as separate streams of two tones when presented in systole.

To further explore whether individual differences in interoceptive accuracy explained the effect of cardiac cycle on auditory perception, we computed the correlation between the two tasks: the accuracy scores in heartbeat discrimination task (Task 2) and the perceptual difference scores (changes in the proportion of 'two-stream' responses between systole and diastole

conditions) from auditory streaming task (Task 1). A positive correlation would suggest that greater interoceptive awareness is associated with a stronger perceptual effect of the cardiac cycle.

## Results

### Auditory Streaming

We used a generalized linear mixed-effects model to analyze whether cardiac phase and tone frequency affected the way auditory perception was organized (Table 1). We found a significant main effect of the systole condition ( $\beta = 0.19$ ,  $SE = 0.09$ ,  $p = .042$ ). Participants were more likely to report hearing two tone streams rather than one during systole than diastole. This result supported our hypothesis that cardiac timing modulated stream segregation. We also found a significant effect of frequency difference ( $\beta = -0.31$ ,  $SE = 0.13$ ,  $p = .014$ ). Larger frequency differences between A tones and B tones increased the likelihood of perceiving them as two separate streams.

**Table 1**

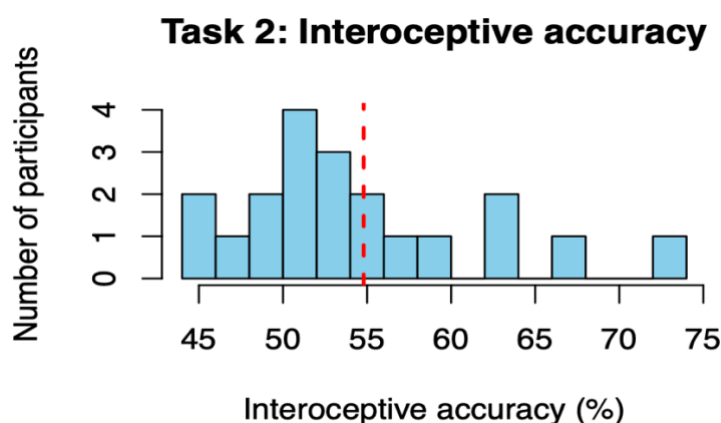
*Fixed Effects from the GLMM Predicting Auditory Streaming Responses*

Term	Estimate ( $\beta$ )	SE	z-value	p-value	95% CI Lower	95% CI Upper
Intercept	-0.31*	0.13	-2.46	.014	-0.56	-0.06
Systole	0.19*	0.09	2.034	.042	0.01	0.37

\*Note:  $p < 0.05$

## Heartbeat Discrimination

Participants' average accuracy on the Heartbeat Discrimination Task was 54.8%, with scores ranging from 45% to 73% (Figure 2). To explore whether individual interoceptive accuracy, a measure of the degree to which one can consciously perceive their own heartbeat, was related to the effect of the cardiac cycle on perception, we calculated Pearson correlation coefficients between the two tasks: participants' heartbeat discrimination accuracy scores in task 2 and the difference in the proportion of “streaming” reports between systole and diastole conditions in task 1. There was no significant correlation between interoceptive accuracy and the cardiac modulation of auditory perception ( $r = .07$ ,  $SE = 0.22$   $p = .77$ ). This result indicated that participants did not need to be aware of their heartbeat for the perceptual effects we had observed in task 1 to occur. In other words, the effect of cardiac entrainment on auditory stream segregation was unlikely to be mediated by consciously directed attention or demand characteristics, as participants who were more likely to consciously perceive the heartbeat entrainment manipulation were no more likely to show the effect.



*Figure 2.* Interoceptive accuracy was calculated as the percentage of correct judgment in the heartbeat discrimination task. The red line represents the average scores (54.8%).

## Discussion

The present study examined whether the cardiac cycle modulates the perception of auditory stream segregation, and the results provide supportive evidence that systole affects perceptual organization. From the results, participants were more likely to perceive the tones as two separate streams when the B tone was synchronized with systole compared to diastole. This finding supports the idea that cardiac signals, especially during systole, play a role in resolving perceptual ambiguity. In addition, we found a robust frequency separation effect consistent with previous studies on auditory streaming (e.g., Rankin et al., 2015). As the frequency difference between tones A and B tones was large, participants were more likely to hear them as two separate streams.

These findings challenge the traditional Baroreceptor Hypothesis, which suggests that input from the baroreceptor during cardiac systole inhibits sensory processing (Lacey & Lacey, 1978). The results of the present study indicate that the interoceptive signals are not passive background signals but active modulators of perceptual organization. Systole does not block sensory input entirely, but biases perception toward segregation, especially under ambiguity. This supports the view that baroreceptor input acts as a context-sensitive perceptual filter, not a uniform suppressor. One possible explanation is that the cardiac systole acts as a temporal cue and thus helps the brain align attention with external events. This rhythmic synchronization may help resolve perceptual uncertainty. Just as previous research (Park & Tallon-Baudry, 2014) has suggested that interoceptive signals (heartbeats) can enhance sensory processing, even when participants were not consciously aware.

One alternative explanation for our findings is that B tones were perceived as quieter, leading participants to interpret them as originating from a separate stream. However, this explanation seems unlikely. First, a similar effect of cardiac timing on perception has been observed in the visual domain using a binocular rivalry paradigm (Veillette et al., 2024), where loudness differences were not a factor. Second, the results of our experiments showed that the perceptual bias persisted, even though participants could not consciously distinguish whether the auditory tones were synchronized with heartbeats or not. Of course, future research could further explain this possibility with more rigorous controls.

This study also has some limitations. To begin with, the sample was drawn from a convenience sample with a WEIRD (Western, Educated, Industrialized, Rich, and Democratic) background, primarily college students. First, individuals from WEIRD societies are more inclined to adopt an analytic perceptual strategy, i.e., focusing on specific details, while individuals from non-WEIRD cultures more often adopt a holistic processing approach (Henrich et al., 2010; Andrews & Monsó, 2025). This difference in the way information is processed may affect whether they hear sounds as coherent or as separated into two streams. Thus, the tendency for sounds to be “integrated” or “separated” may vary across cultures. Second, the theoretical frameworks underlying this study, including the Baroreceptor Hypothesis and the idea that interoceptive signals modulate perceptual ambiguity, are largely based on findings from WEIRD samples. Therefore, the generalizability of the experimental results still needs to be verified.

Additionally, this study used a simple auditory tone stimulus. The cardiac effects we observed with tone stimuli (500 Hz B tones and varied A tones) may not generalize to more complex or naturalistic sounds, such as speech or environmental noise. Compared to the

controlled pure tones used in a lab setting, these naturalistic sounds contain more variation in pitch, rhythm, and meaning, and often are processed differently in the brain (Aydelott et al., 2010). It is possible that cardiac effects affect the simple tones more strongly than it does for real-world sounds, which are more context-dependent and involve higher levels of cognitive processing.

Beyond the experimental findings, this study highlights that interoceptive signals are not passive background noise, but active factors that influence perceptual decisions when dealing with uncertainty. This view has broader theoretical implications that fit with the theory of embodied cognition: perception is not merely a passive response to external stimuli but is continuously and dynamically modulated by the internal state of the body (Critchley & Harrison, 2013). Understanding this relationship may help us to explain individual differences in sensory sensitivity or distractibility and provide new ideas for future research in emotional neuroscience, attentional mechanisms, and sensory processing disorders.

In conclusion, this study found that the cardiac cycle affects how the brain organizes auditory information. Stimuli were more likely to be perceived as two separate streams when presented during the cardiac systole. This effect did not depend on participants' conscious perception of their own heartbeats, suggesting that interoceptive signaling (heartbeats) modulates perception unconsciously. At the same time, this modulation exists not only in the visual domain but also applies to auditory perception, highlighting the broader role of internal bodily signals in shaping multisensory information processing.

## References

- Andrews, K., & Monsó, S. (2025). Does comparative cognition have a WEIRD problem? *Journal of Comparative Psychology*. Advance online publication. <https://doi.org/10.1037/com0000423>
- Aydelott, J., Leech, R., & Crinion, J. (2010). Normal adult aging and the contextual influences affecting speech and meaningful sound perception. *Trends in amplification*, 14(4), 218-232. <https://doi.org/10.1177/1084713810393751>
- Carlyon, R. P. (2004). How the brain separates sounds. *Trends in Cognitive Sciences*, 8(10), 465–471. <https://doi.org/10.1016/j.tics.2004.08.008>
- Critchley, H. D., & Harrison, N. A. (2013). Visceral Influences on Brain and Behavior. *Neuron*, 77(4), 624–638. <https://doi.org/10.1016/j.neuron.2013.02.008>
- Denham, S. L., & Winkler, I. (2006). The role of predictive models in the formation of auditory streams. *Journal of Physiology-Paris*, 100(1–3), 154–170. <https://doi.org/10.1016/j.jphysparis.2006.09.012>
- Golanov, E. V., Yamamoto, S. E. I. J. I., & Reis, D. J. (1994). Spontaneous waves of cerebral blood flow associated with a pattern of electrocortical activity. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 266(1), R204-R214.
- Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world?. *Behavioral and brain sciences*, 33(2-3), 61-83.

- Karavaev, A. S., Kiselev, A. R., Runnova, A. E., Zhuravlev, M. O., Borovkova, E. I., Prokhorov, M. D., ... & Hramov, A. E. (2018). Synchronization of infra-slow oscillations of brain potentials with respiration. *Chaos: An Interdisciplinary Journal of Nonlinear Science*, 28(8).
- Lacey, B. C., & Lacey, J. I. (1978). Two-way communication between the heart and the brain: Significance of time within the cardiac cycle. *American Psychologist*, 33(2), 99–113.  
<https://doi.org/10.1037/0003-066X.33.2.99>
- Moffatt, J., Finotti, G., & Tsakiris, M. (2024). With hand on heart: A cardiac Rubber Hand Illusion. *Biological Psychology*, 186, 108756.  
<https://doi.org/10.1016/j.biopsycho.2024.108756>
- Park, H.-D., & Tallon-Baudry, C. (2014). The neural subjective frame: From bodily signals to perceptual consciousness. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 369(1641), 20130208. <https://doi.org/10.1098/rstb.2013.0208>
- Pressnitzer, D., & Hupé, J. M. (2005). Is auditory streaming a bistable percept. In *Forum Acusticum, Budapest* (pp. 1557-1561).  
<http://www.conforg.fr/acoustics2008/cdrom/data/fa2005-budapest/paper/846-0.pdf>
- Pan, J., & Tompkins, W. J. (1985). A real-time QRS detection algorithm. *IEEE transactions on biomedical engineering*, (3), 230-236. <https://doi.org/10.1109/TBME.1985.325532>
- Ramakonar, H., Franz, E. A., & Lind, C. R. P. (2011). The rubber hand illusion and its application to clinical neuroscience. *Journal of Clinical Neuroscience*, 18(12), 1596–

1601. <https://doi.org/10.1016/j.jocn.2011.05.008>

Rankin, J., Sussman, E., & Rinzel, J. (2015). Neuromechanistic Model of Auditory Bistability.

*PLOS Computational Biology*, *11*(11), e1004555.

<https://doi.org/10.1371/journal.pcbi.1004555>

Salomon, R., Ronchi, R., Dönz, J., Bello-Ruiz, J., Herbelin, B., Faivre, N., Schaller, K., &

Blanke, O. (2018). Insula mediates heartbeat related effects on visual consciousness.

*Cortex*, *101*, 87–95. <https://doi.org/10.1016/j.cortex.2018.01.005>

Salomon, R., Ronchi, R., Dönz, J., Bello-Ruiz, J., Herbelin, B., Martet, R., Faivre, N., Schaller,

K., & Blanke, O. (2016). The Insula Mediates Access to Awareness of Visual Stimuli

Presented Synchronously to the Heartbeat. *The Journal of Neuroscience*, *36*(18), 5115–

5127. <https://doi.org/10.1523/JNEUROSCI.4262-15.2016>

Suzuki, K., Garfinkel, S. N., Critchley, H. D., & Seth, A. K. (2013). Multisensory integration

across exteroceptive and interoceptive domains modulates self-experience in the rubberhand illusion. *Neuropsychologia*, *51*(13), 2909–2917.

<https://doi.org/10.1016/j.neuropsychologia.2013.08.014>

Seth, A. K. (2013). Interoceptive inference, emotion, and the embodied self. *Trends in cognitive sciences*, *17*(11), 565-573.

- Snyder, J. S., & Alain, C. (2007). Toward a neurophysiological theory of auditory stream segregation. *Psychological bulletin*, 133(5), 780
- Veillette, J. P., Gao, F., & Nusbaum, H. C. (2024). Cardiac afferent signals can facilitate visual dominance in binocular rivalry. *eLife*, 13, RP95599. <https://doi.org/10.7554/eLife.95599>
- Van Elk, M., Lenggenhager, B., Heydrich, L., & Blanke, O. (2014). Suppression of the auditory N1-component for heartbeat-related sounds reflects interoceptive predictive coding. *Biological psychology*, 99, 172-182.
- Watson, A. B. (2017). QUEST+: A general multidimensional Bayesian adaptive psychometric method. *Journal of Vision*, 17(3), 10-10.
- Zanatta, P., Toffolo, G. M., Sartori, E., Bet, A., Baldanzi, F., Agarwal, N., & Golanov, E. (2013). The human brain pacemaker: Synchronized infra-slow neurovascular coupling in patients undergoing non-pulsatile cardiopulmonary bypass. *Neuroimage*, 72, 10-19.