Multimodal Physiological States Underlie Infant Visual Attention

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Introduction

Infants who exhibit longer durations of sustained visual attention (SVA) show better self-control [1], attentional skills [2], and language development [3]. SVA has often been defined through corresponding changes in heart rate [4]. However, physiological processes underlying behavioral and cognitive states are also complex, dynamic, and extend beyond heart rate alone [5].

While prior work has primarily focused on corresponding changes in heart rate, less is known about the extended physiological processes of SVA, including respiration and body movement, especially in infancy. Here, we examine how naturally occurring clusters of heart rate, respiration, and body movement relate to gaze velocity, a proxy for visual attention.

Methods

Infants between the age of 9-24 months (N = 9, M = 17.1mo, SD = 5.79) engaged in a naturalistic free-play task for 15 minutes each. Caregivers were instructed to play with their infants as they would at home.

Infants wore a *Pupil Labs Neon* eye tracker and a *Movisens ECGMove 4* wireless cardiorespiratory sensor.

Figure 1. A dyad engaged in a naturalistic free-play task.

Heart rate was calculated using *TonaFlow [6]*, a free and open-source MATLAB application for processing ECG signals. Respiration was extracted from the ECG signal by fitting cubic spline interpolation to R-peak amplitudes. Respiration rate was then calculated by computing the zero-crossings rate of the phase angle of its' Hilbert transform.

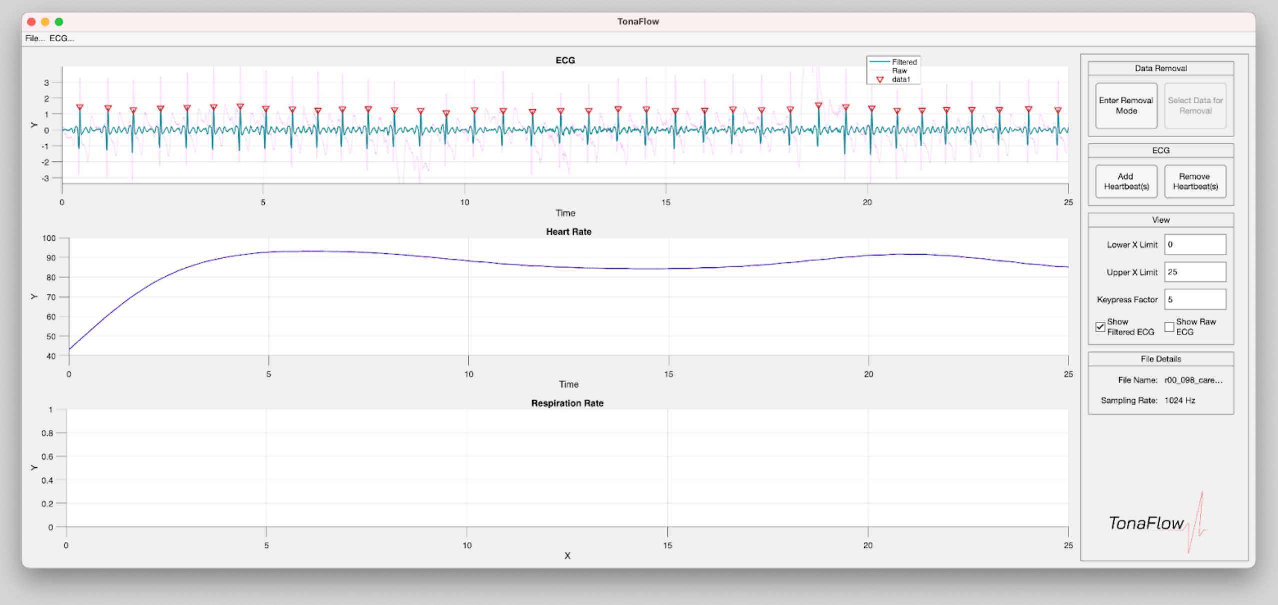

Figure 2. A screenshot of a processed ECG signal in TonaFlow. Red marks indicate detected heartbeats.

Heart rate, respiration rate, body velocity, and gaze velocity were then split into 3 second windows. The average of each were calculated for each window. K-Means clustering was used to identify naturally occurring clusters of physiology. Average gaze velocity was calculated for each corresponding cluster.

Conclusion

Exploratory clustering suggests that high gaze velocity co-occurs with elevated heart rate, body movement, and respiration, while low gaze velocity is marked by reduced heart rate, body movement, and respiration rate. Pair-wise joint probability distributions suggest that during states of low gaze-velocity, lower heart rate co-occurs with reduced body movement. These results are consistent with prior work showing that SVA is accompanied by head stilling [7] and cardiac decelerations [4], but also highlights variability across physiological systems. Rather than a single cardiac marker, SVA may reflect a broader bottom-up physiological profile that includes multiple interacting processes. Ongoing work will test this idea in a larger sample with detailed behavioral coding of gaze to determine whether such a signature can reliably characterize infant attention.

TonaFlow   References

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Results

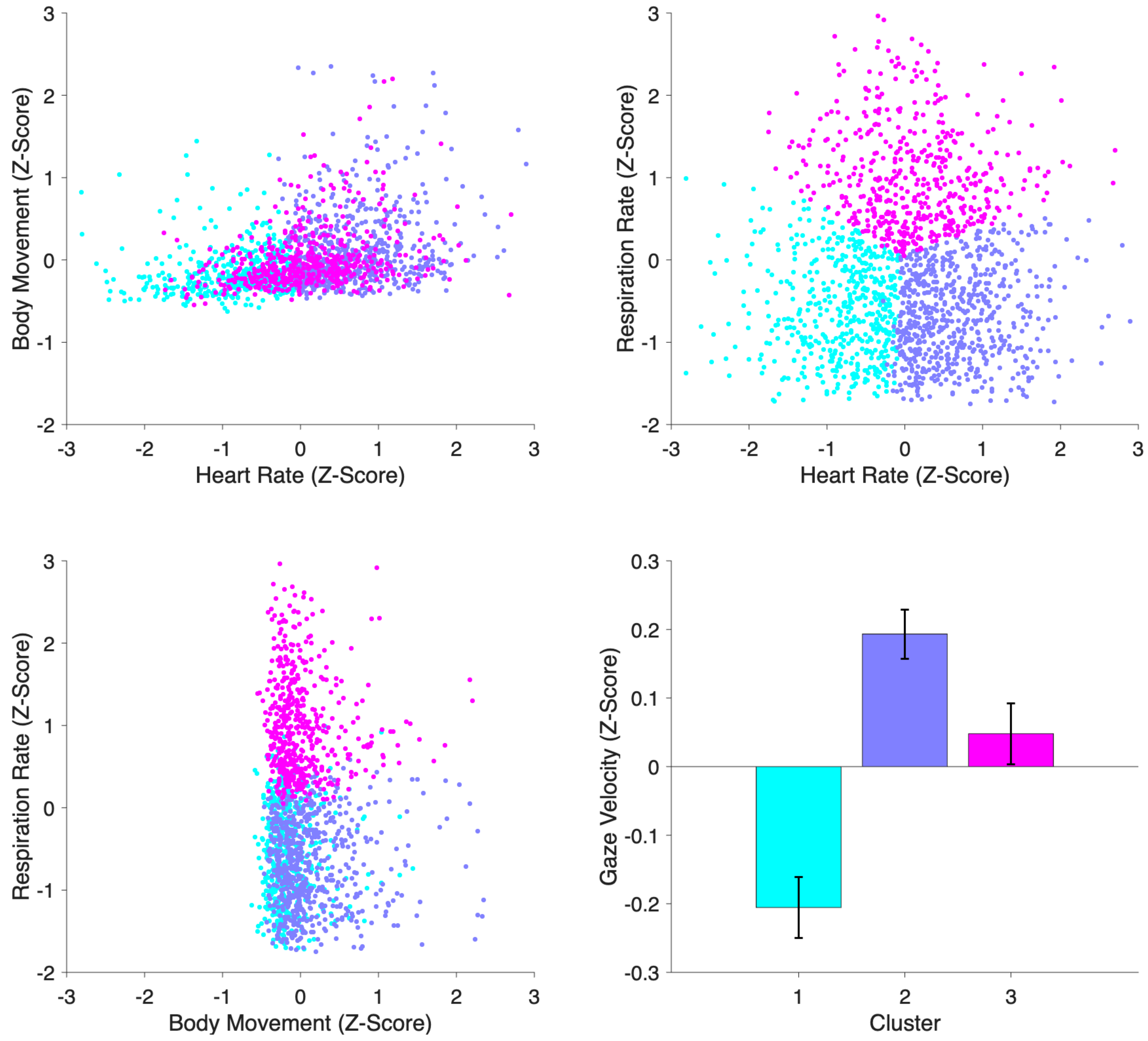

*Figure 1: Multiple clusters of physiology. **Cluster 1 (Teal)**: Lower heart rate (z = -0.87), lower respiration rate (z = -0.60), and lower body movement (z = -0.15). **Cluster 2 (Purple)**: higher heart rate (z = 0.66), lower respiration rate (z = -0.68), and higher body movement (z = 0.12). **Cluster 3 (Pink)**: higher heart rate (z = –0.10), and higher respiration rate (z = 1.05).*

Wilcoxon ranksum tests showed gaze velocity in cluster 1 was lower than cluster 2 (Z = -6.69, p < .001), as well as cluster 3 (Z = -3.49, p < .001). Gaze velocity in cluster 2 was higher than cluster 3 (Z = 2.79, p = 0.005).

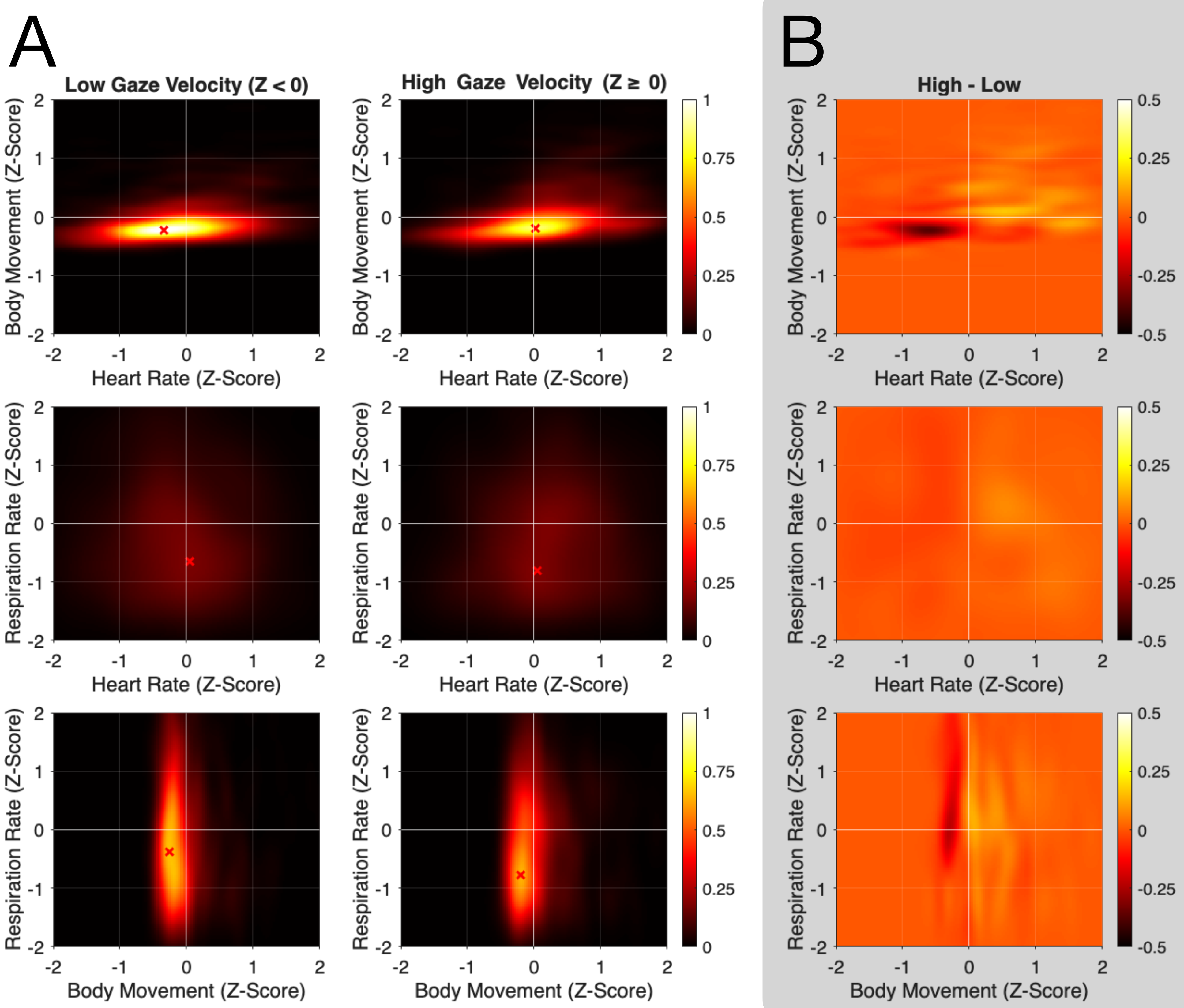

Figure 2 (A): Joint probability density distributions between each pair of physiological measures for low gaze velocity (below the mean) and high gaze velocity (above the mean). Brighter bands represent higher probability density. Red X marks represent the peak of the probability distribution.

(B): Arithmetic difference between high and low gaze velocity groups - darker bands correspond to higher presence in low gaze velocity, while brighter bands correspond to lower presence in low gaze velocity.