

Vascular Dynamics in Active Perception

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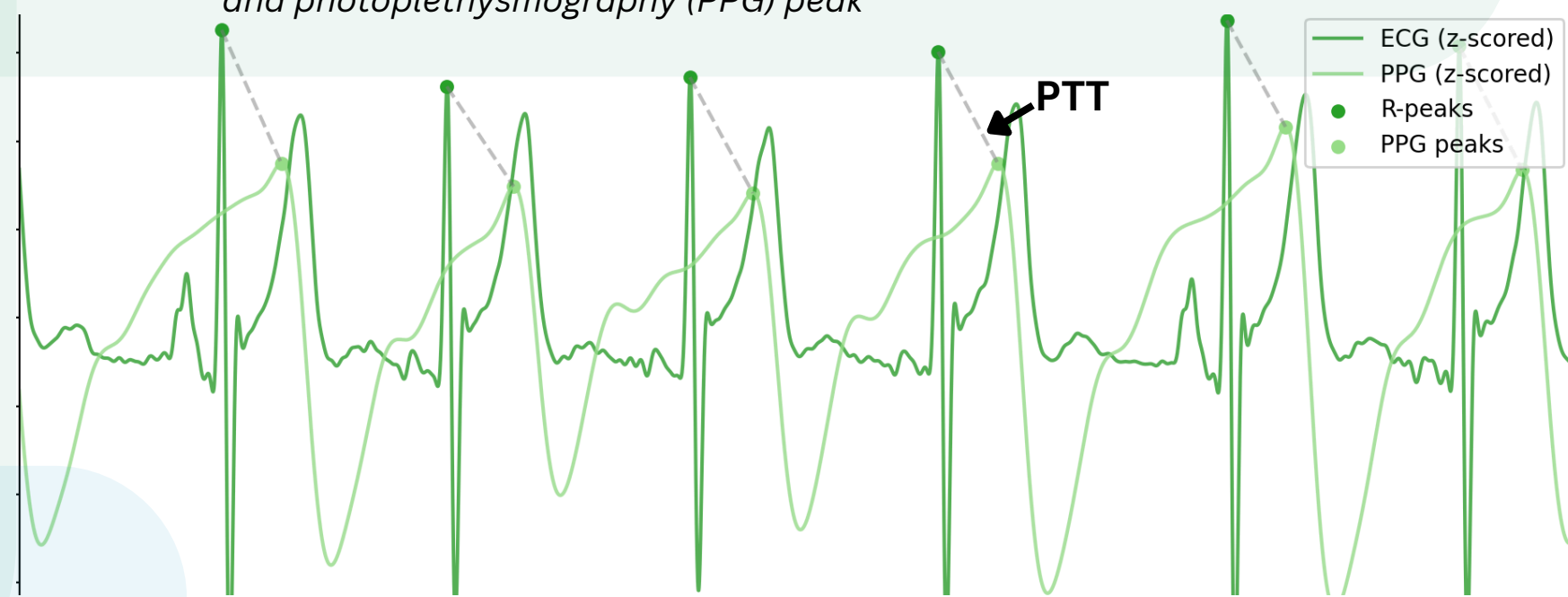
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Background

- Perceptual accuracy varies across cardiac and respiratory phases, but it is unclear whether this reflects adaptive optimization or passive physiological constraints.
- Blood pressure adds a complementary interoceptive signal closely linked to autonomic regulation, baroreflex control, and brain-body communication.
- Combining ECG and PPG allows estimation of pulse transit time (PTT), a non-invasive proxy for beat-to-beat BP changes, to probe vascular contributions to active perception.

Pulse Transit Time

Pulse Transit Time (PTT) = delay between electrocardiography (ECG) peak and photoplethysmography (PPG) peak



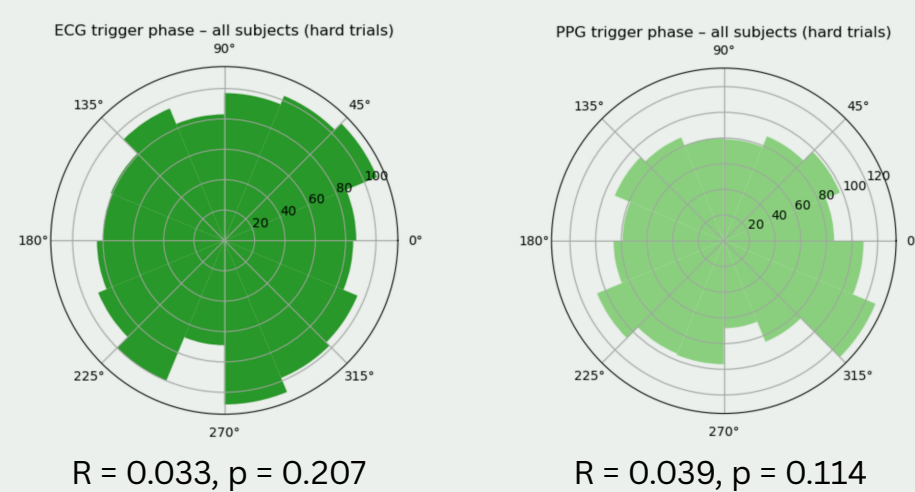
Exploratory Questions

- Do self-initiated sampling responses preferentially occur at specific cardiac or pulse phases?
- Do inter-individual differences in mean PTT modulate perceptual performance (accuracy) especially when perceptual demands are high?
- Does trial-by-trial PTT variability relate to perceptual performance (accuracy) especially when perceptual demands are high?

Preliminary Results

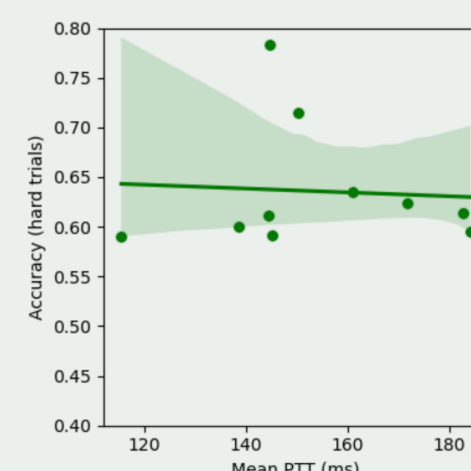
With data from N = 10 participants, for 2000 hard trials

1. ECG (left) and PPG (right) phase of self-initiated triggers



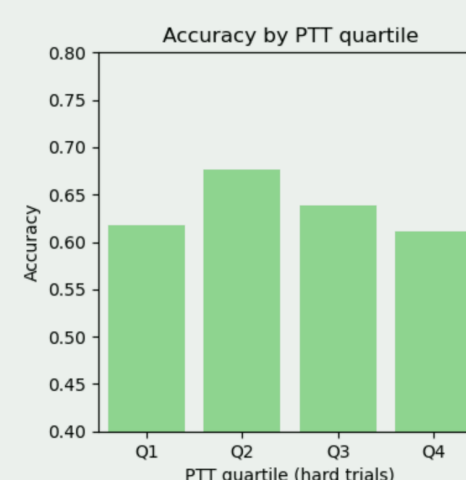
Phase distributions during hard trials do not deviate significantly from uniformity (Rayleigh tests ns), suggesting no robust preferred cardiac or pulse phase for sampling in this preliminary subset.

2. Inter-individual differences in PTT and accuracy



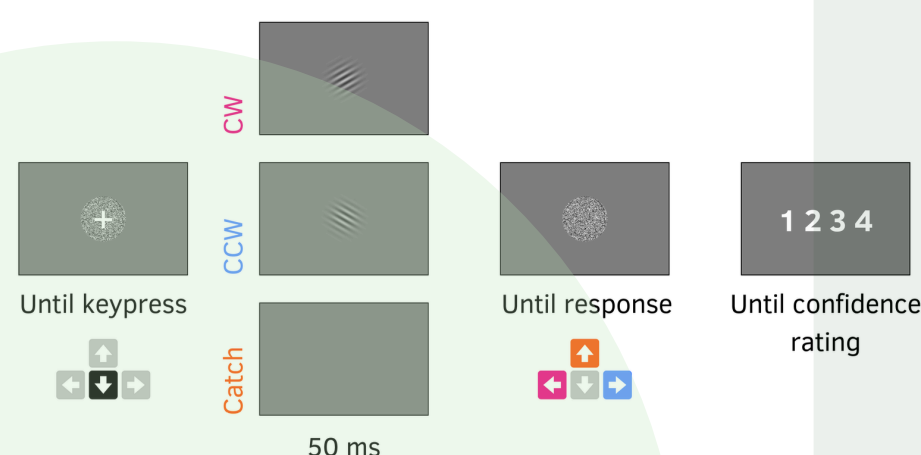
Mean PTT per subject was 153ms (SD=20ms) and ranged from 139ms (SD=6.2ms) to 182ms (SD=13.7ms). Neither the Mixed Effects GLMs, nor the Standard Logistic Regression Models showed any significant modulation of accuracy by subject-level PTT differences.

3. Trial-by-trial PTT variability and accuracy



Mean PTT per trial was 151ms (SD = 22ms). Neither the Mixed Effects GLMs, nor the Standard Logistic Regression Models showed any significant modulation of accuracy by trial-level PTT differences.

Methods



- N = 45, 500 trials
- orientation discrimination of a self-initiated stimulus (Gabor patch)
- adaptive adjustment of the contrast due to performance of the participant
- Conditions:
 - Easy (90% accuracy)
 - Hard (60% accuracy)
- Measures:
 - Behavioral (accuracy, response time, confidence)
 - Physiological (ECG, respiration, ePPG)

Outlook

The analyses will be extended to the full sample, incorporate respiratory phase, and test more explicit active inference models of how interoceptive predictions and vascular dynamics shape self-initiated perception.

References:

- Galvez-Pol, A., McConnell, R., & Kilner, J. M. (2020). Active sampling in visual search is coupled to the cardiac cycle. *Cognition*, 196, 104149. <https://doi.org/10.1016/j.cognition.2019.104149>
- Kunzendorf, S., Klotzsche, F., Akbal, M., Villringer, A., Ohl, S., & Gaebler, M. (2019). Active information sampling varies across the cardiac cycle. *Psychophysiology*, 56(5), e13322. <https://doi.org/10.1111/psyp.13322>
- Mukkamala, R., Hahn, J.-O., Inan, O. T., Mestha, L. K., Kim, C.-S., Toreyin, H., & Kyal, S. (2015). Toward Ubiquitous Blood Pressure Monitoring via Pulse Transit Time: Theory and Practice. *IEEE Transactions on Biomedical Engineering*, 62(8), 1879–1901. <https://doi.org/10.1109/TBME.2015.2441951>