

Seeing the Forrest through the trees: Oculomotor metrics are linked to heart rate

Alex J. Hoogerbrugge¹, Christoph Strauch¹, Zoril A. Oláh¹, Edwin S. Dalmaijer², Tanja C.W. Nijboer¹, Stefan Van der Stigchel¹

¹ Department of Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, The Netherlands. ² School of Psychological Science, University of Bristol, United Kingdom

✉ a.j.hoogerbrugge@uu.nl
 a.j.hoogerbrugge



Introduction

- **Fluctuations in arousal modulate brain states and have a profound effect on task performance**^{1,2}
- Extensive evidence for links between oculomotor metrics and cognitive aspects via arousal; e.g., mental effort^{3,4}, motivation⁵
- Mental effort also covaries with derivatives of heart rate measures⁶
- **We investigate how strongly eye movements and heart rate are linked via arousal and which features show this link**

Data

- The **studyforrest** dataset⁷ ($N = 14$)
 - 1 kHz eye tracking
 - 100 Hz pulse oximetry (heart rate)
- Participants watched 2-hour *Forrest Gump*
- Data split into 240 chunks of 30 seconds per participant
 - ~3360 chunks in total

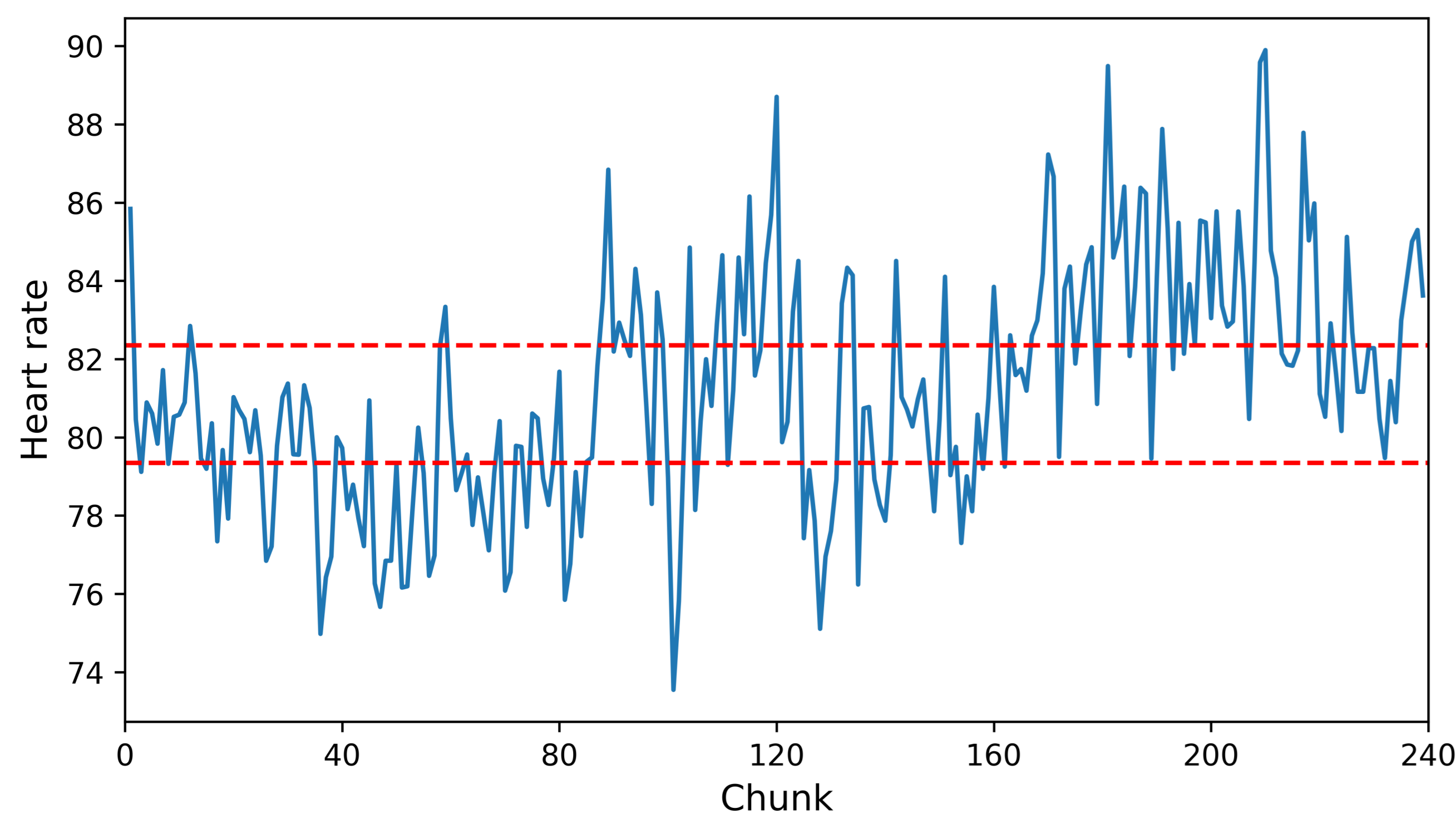


Figure 1. Example of heart rate over time (one participant; 240 chunks). Red dashed lines indicate $mean \pm 0.5 SD$.

Regression

- Linear and polynomial **regressions are limited in prediction of heart rate** as a continuous variable ($R^2 \leq .20$), but are indicative of a link between the two

Random Forest classifiers

- We create a binary split of *high* and *low* heart rates
 - $mean \pm 0.5 SD$
 - ~1100 chunks remaining
- Random Forests trained with hyperparameter tuning and run 50 times to compensate for random initialization

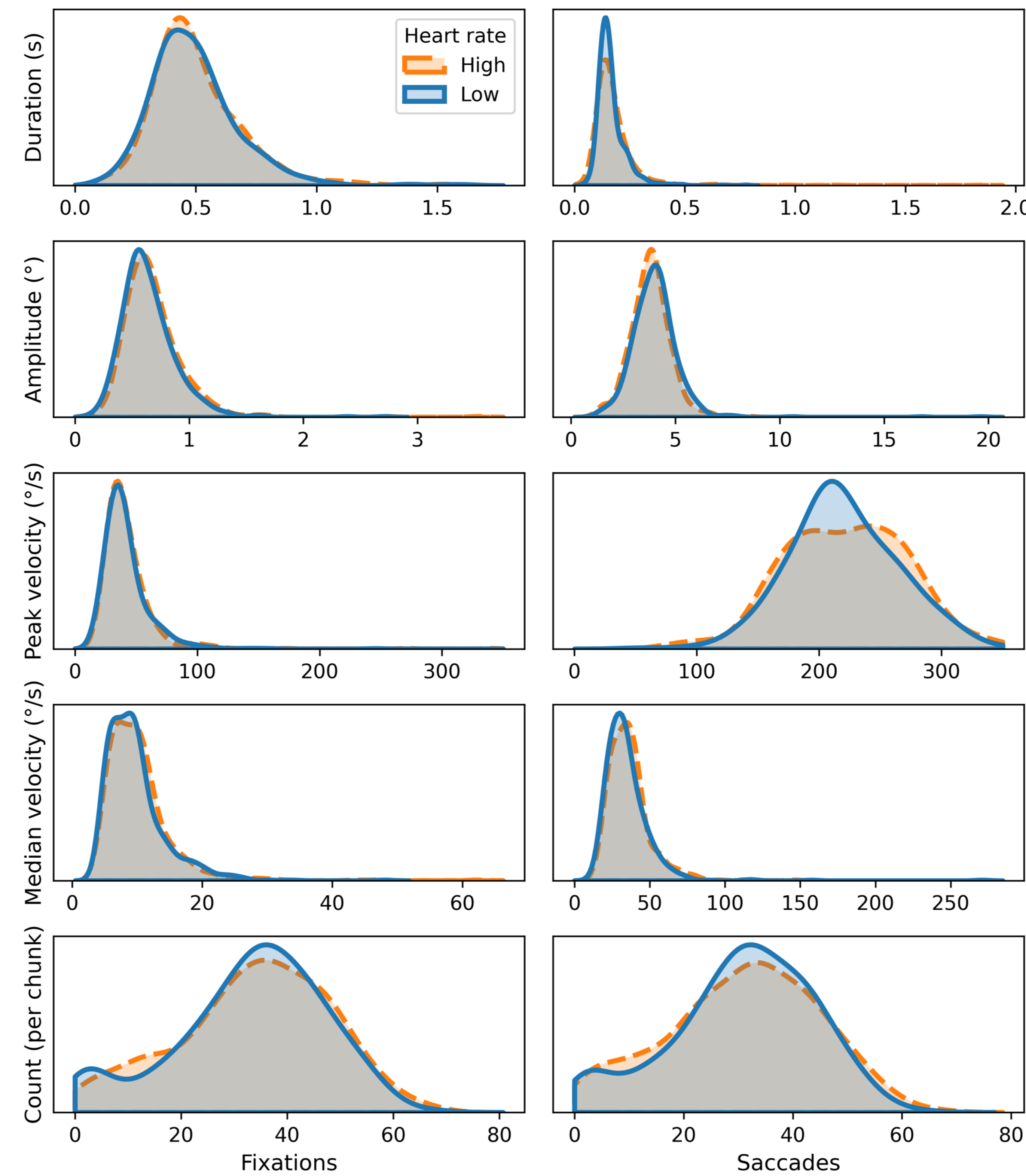


Figure 2. Kernel density estimations for each of the ten input features, split by high- and low heart rate.

Classifier results

- Random Forests predict heart rate consistently at above chance (0.5) level; $AUC = .63$ ($SD = .03$)
- **Most informative features relate to degree of movement, less to duration**

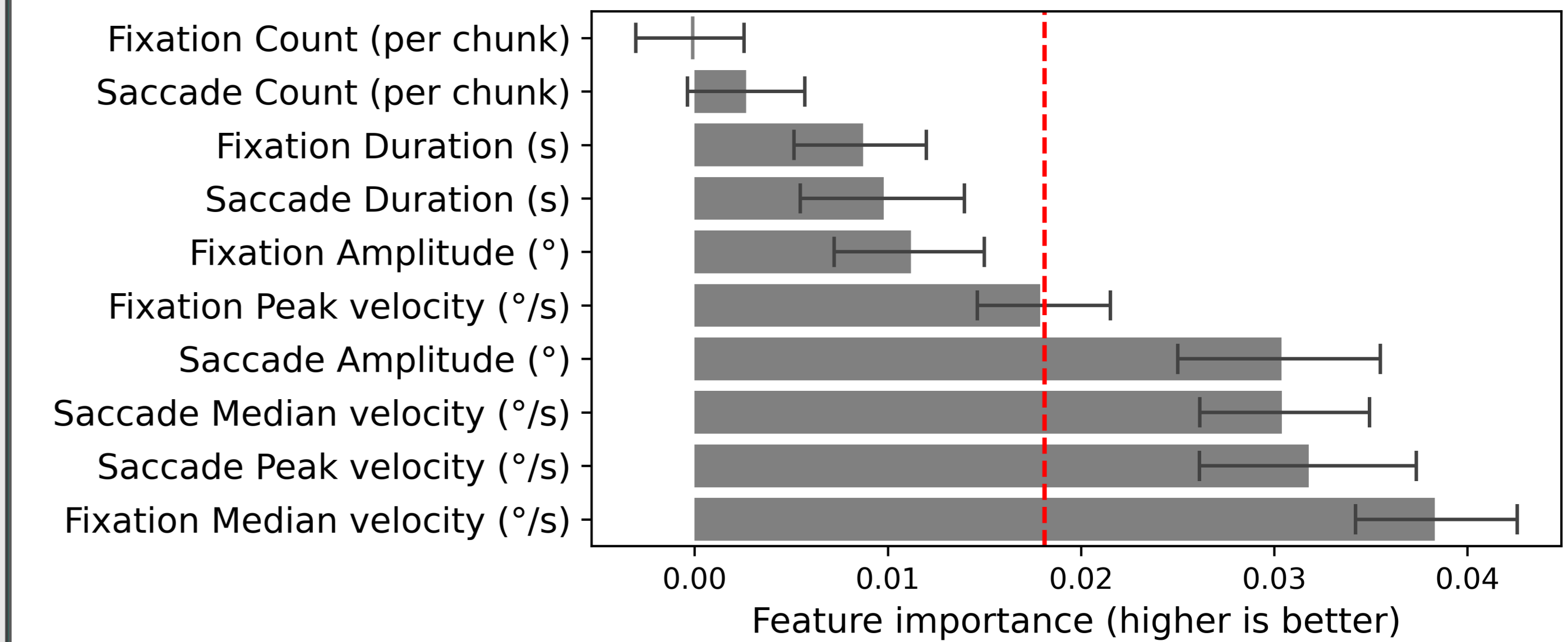


Figure 3. Feature importances ($\pm 95\% CI$) from 50 Random Forest runs. Red vertical line indicates mean importance.

Discussion

- **Consistent classification indicates a link between eye movements and heart rate, modulated via arousal**
- Velocity of oculomotor movement (saccades, microsaccades⁸) most strongly show this link
- Possibly a result of physiological changes during the heartbeat cycle
- Provides new avenues for investigating the link between oculomotor metrics and various aspects of arousal

References

1. Yerkes, & Dodson (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*
2. Teigen (1994). Yerkes-Dodson: A Law for all Seasons. *Theory & Psychology*
3. Beatty (1982). Task-evoked pupillary responses, processing load, and the structure of processing resources. *Psychological Bulletin*
4. Dj Stasi, et al. (2013). Saccadic velocity as an arousal index in naturalistic tasks. *Neuroscience and Biobehavioral Reviews*
5. Muhammed, et al. (2020). Voluntary modulation of saccadic peak velocity associated with individual differences in motivation. *Cortex*
6. Charles & Nixon (2019). Measuring mental workload using physiological measures: A systematic review. *Applied Ergonomics*
7. Hanke, et al. (2016). A studyforrest extension, simultaneous fMRI and eye gaze recordings during prolonged natural stimulation. *Scientific Data*
8. Ohl, et al. (2016). Microsaccades are coupled to heartbeat. *Journal of Neuroscience*

This work was supported by ERC [ERC-CoG-863732], awarded to Svds
 Code and outcomes: <https://osf.io/skcd8/>