Decrease in perceptual suppression correlates with increased heart rate

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INTRODUCTION

Conscious perception is not only shaped by processing of external stimuli but is also influenced by intrinsic signals arriving from the body, such as cardiac signals.[1,2,3,4]

We aimed to investigate the causal relationship between visual perception, cardiac, and neural activity by combining a perceptual suppression task with an autonomic challenge.

Generalized Flash Suppression (GFS): A salient target is presented, and then rendered invisible in a subset of trials following the presentation of random dot motion in the background.[5] Parieto-occipital alpha power prior to motion onset was found to be higher on trials where the target remains visible.[6]

Autonomic challenge: Cycling was used to elicit neural changes by increasing heart rate. A pilot experiment showed that alpha power is lower during / after cycling.

Hypothesis: Cycling should correlate with increased perceptual suppression.

METHODS

- 29 healthy subjects
  - Mean age: 24.1 years; Range: 21-29 years
  - 11 male, 18 female
- Perceptual paradigm: GFS
  - 7 runs of 90 trials: 65 GFS, 15 catch (physical target removal), 10 zero-surround (no RDM onset)
  - Anaglyph glasses for stereoscopy
  - Subjects reported visibility using a button box: button pressed for as long as target was visible

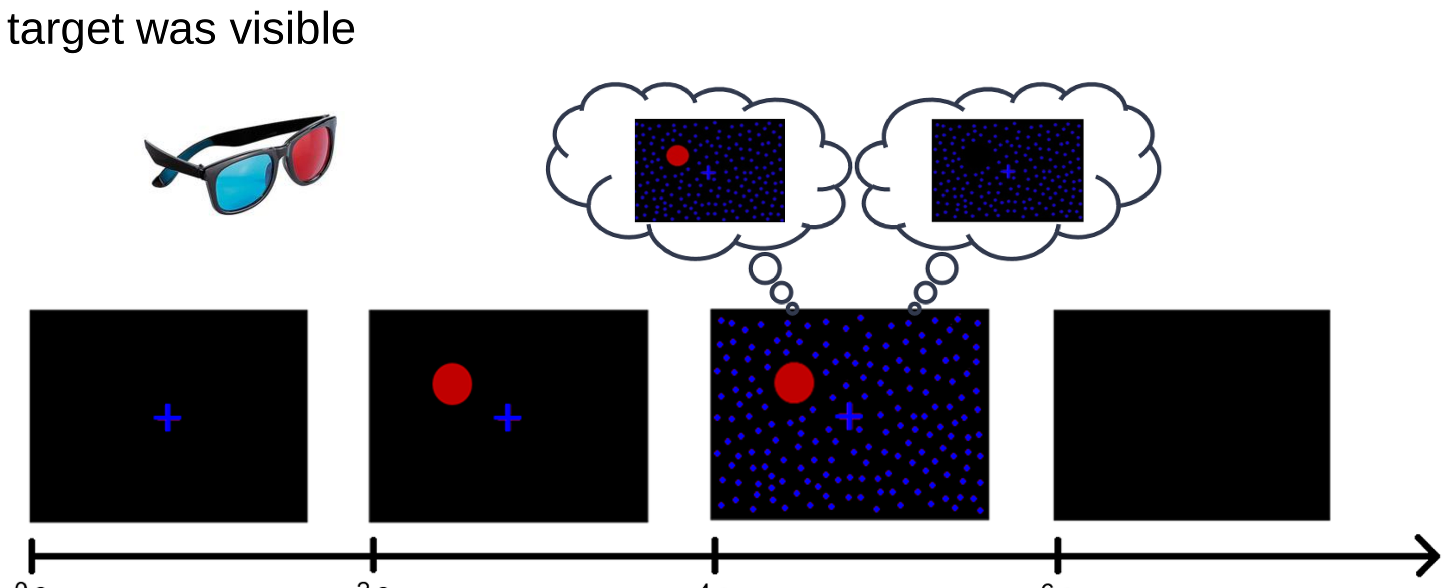
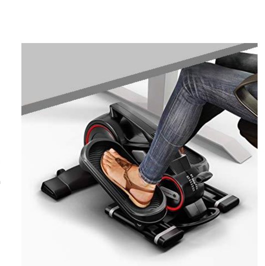


Figure 1: GFS trial structure

- 3 cycling conditions: rest (no cycling), low resistance cycling, high resistance cycling using a desk ergometer
  - Runs at rest and while cycling interleaved
  - Subjects were instructed to maintain a pace of 60 rpm throughout
  - Cycling runs started with a 3 min warm up period



- 8 min baseline recordings with eyes closed before and after the experimental block (blood pressure measurements also taken)

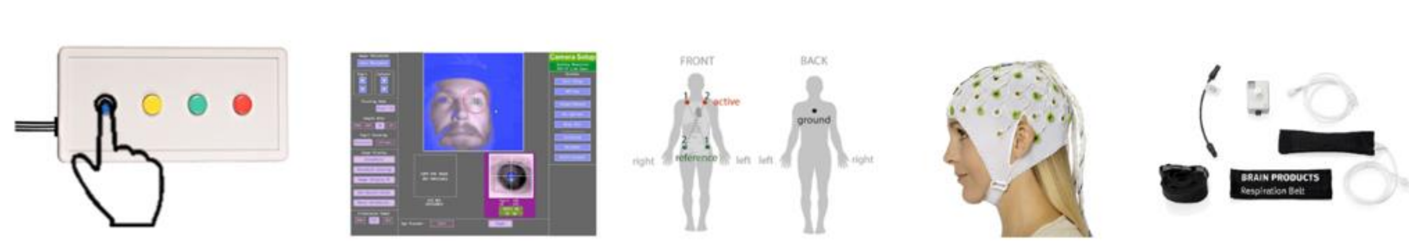


Figure 2: Types of data collected

- Additionally collected the following questionnaires: sociodemographic data, Ishihara colour vision test, Edinburgh handedness inventory, BDI-II, BPQ, MAIA

RESULTS

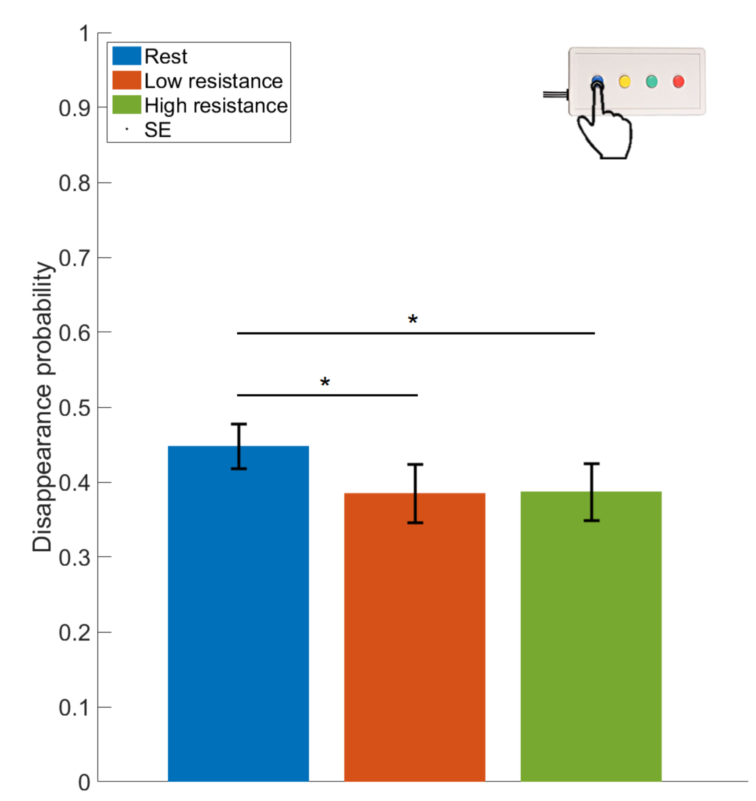


Figure 3: Average GFS disappearance probabilities

Behavioural results

- RM ANOVA with a Greenhouse-Geisser correction showed statistically significant difference in disappearance probability between exercise conditions, $F(2, 56) = 4.46$, $p = 0.018$.
- Post hoc paired *t*-test showed mean value of disappearance probability was significantly different between both low-resistance ($p = 0.012$, 95% C.I. = [0.015, 0.111]) and high-resistance cycling ($p = 0.028$, 95% C.I. = [0.007, 0.115]) compared to rest.
- Disappearance probability during catch trials was close to 1, irrespective of rest/cycling conditions, indicating subjects had understood the task and were performing it accurately (results not pictured here).

ECG results

- Friedman test showed statistically significant difference in heart rate (HR) depending on cycling condition, $\chi^2 = 58.0$, $p < 0.001$.
- Wilcoxon signed-rank test showed that compared to rest, both low-resistance ($Z = -4.70$, $p < 0.001$) and high-resistance ($Z = -4.70$, $p < 0.001$) cycling elicited a statistically significant change in HR, corresponding to a 15.1% and 45.3% increase respectively.

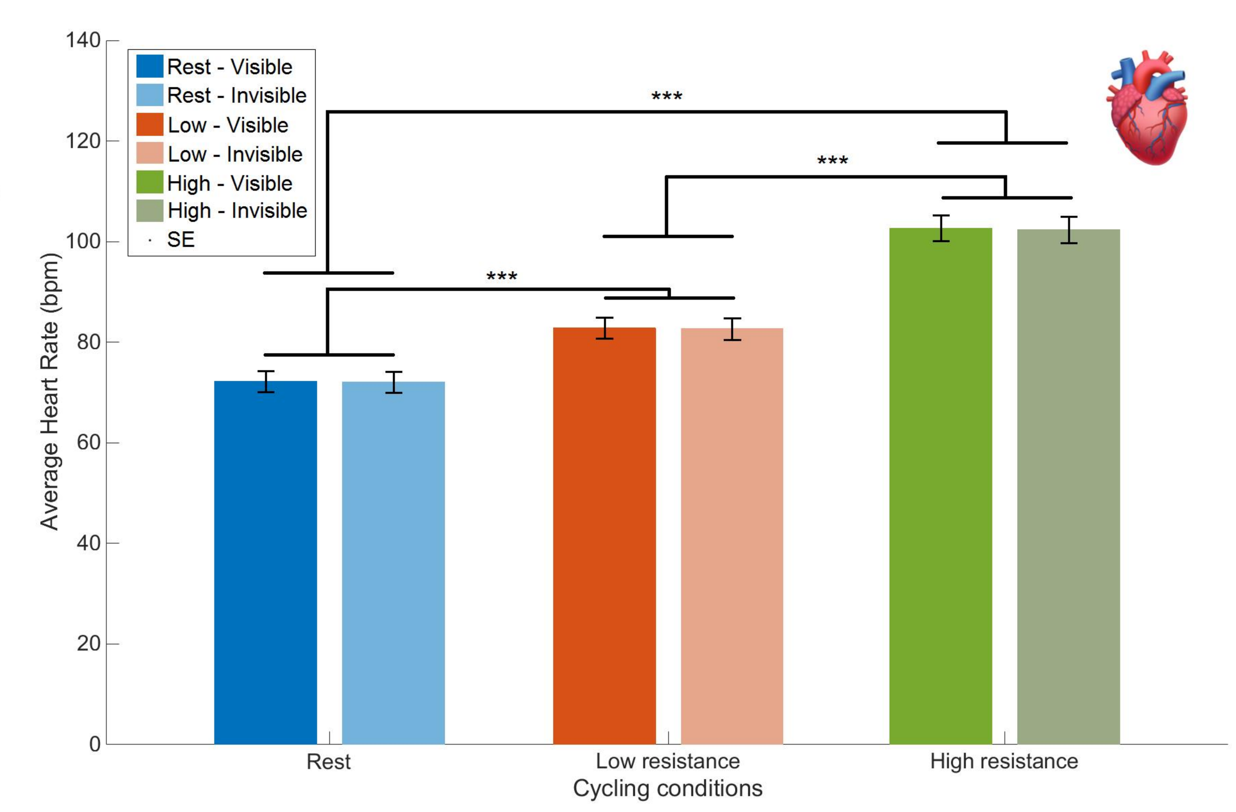


Figure 4: Average heart rates during trials where the target remained visible and where the target became invisible during the rest and cycling conditions

- While this increase in HR correlates with the decrease in perceptual suppression due to cycling, the difference in heart rate between the trials where the target becomes invisible and where it remains visible is not significant for the rest/cycling conditions.

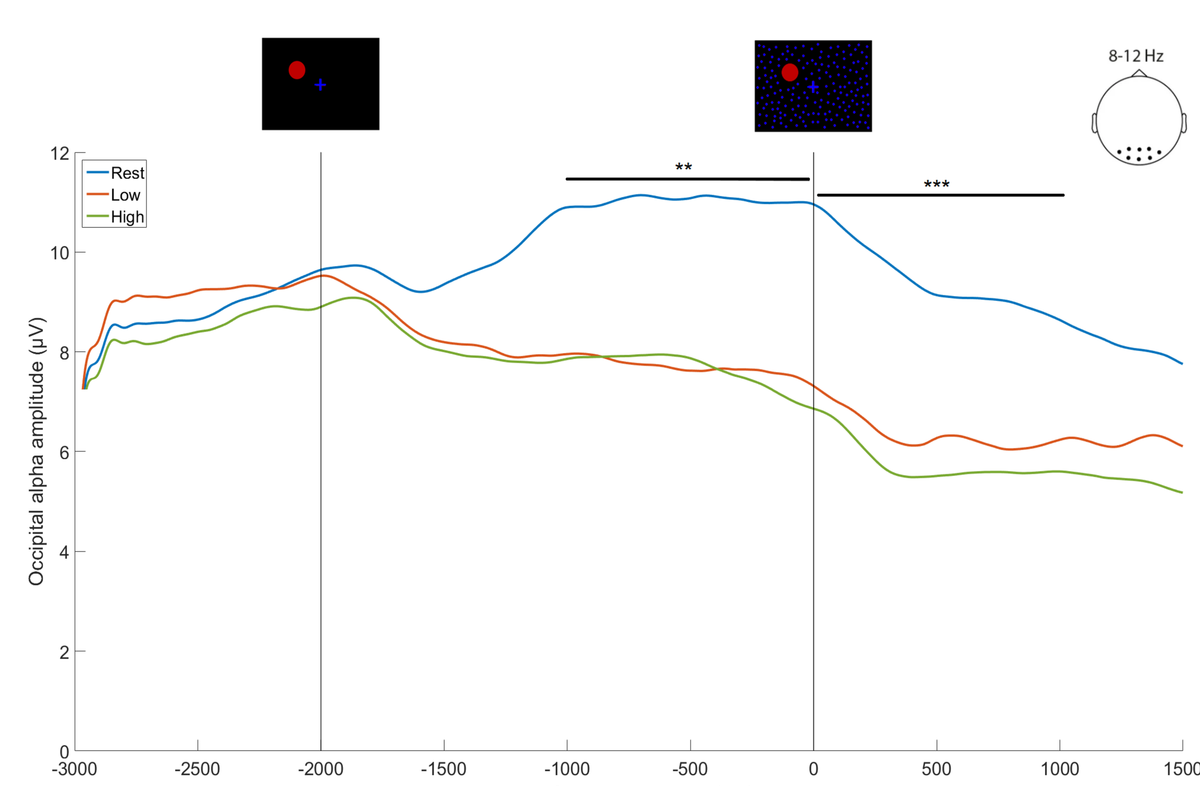


Figure 5: Average time course of alpha band (8-12 Hz) amplitudes computed over all parietal-occipital electrodes for the rest and cycling conditions.

- Alpha amplitude was also lower in the second following RDM, (low: $Z = -3.125$, $p = 0.002$ and high: $Z = -4.098$, $p < 0.001$.).

EEG results

- Friedman test showed statistically significant difference in average parieto-occipital alpha power amplitude depending on cycling condition in the second prior to RDM, $\chi^2 = 13.24$, $p = 0.001$, and in the second following RDM, $\chi^2 = 16.83$, $p < 0.001$.
- Wilcoxon signed-rank test showed that compared to rest, both low-resistance ($Z = -3.081$, $p = 0.002$) and high-resistance ($Z = -3.211$, $p = 0.001$) cycling elicited a statistically significant decrease in alpha amplitude in the second prior to RDM.

DISCUSSION

These findings indicate that cycling results in a decrease in perceptual suppression, which correlates with an increase in heart rate. However, an increase in parieto-occipital alpha amplitudes doesn't appear to be the mechanism behind the decrease in perceptual suppression associated with cycling / increased heart rate. Nor can these autonomic challenge-induced perceptual effects be attributed to a change in task performance.

Perhaps the change in perceptual performance can be attributed to changes in general arousal or can be attributed the neural processing of cardiac signals. Further investigation is necessary to fully understand these results.

REFERENCES

1. Park, H.-D., Correia, S., Ducorps, A., & Tallon-Baudry, C. (2014). Spontaneous fluctuations in neural responses to heartbeats predict visual detection. *Nature Neuroscience*, *17*(4), 612–618. https://doi.org/10.1038/nn.3671
2. 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: The Official Journal of the Society for Neuroscience*, *36*(18), 5115–5127. https://doi.org/10.1523/JNEUROSCI.4262-15.2016
3. Azzalini, D., Rebollo, I., & Tallon-Baudry, C. (2019). Visceral Signals Shape Brain Dynamics and Cognition. *Trends in Cognitive Sciences*. https://www.ncbi.nlm.nih.gov/pubmed/?term=visceral+signals+shape+brain+dynamics+and+cognition
4. Al, E., Iliopoulos, F., Forschack, N., Nierhaus, T., Grund, M., Motyka, P., Gaebler, M., Nikulin, V. V., & Villringer, A. (2020). Heart-brain interactions shape somatosensory perception and evoked potentials. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(19), 10575–10584. https://doi.org/10.1073/pnas.1915629117
5. Wilke, M., Logothetis, N. K., & Leopold, D. A. (2003). Generalized Flash Suppression of Salient Visual Targets. *Neuron*, *39*(6), 1043–1052. https://doi.org/10.1016/j.neuron.2003.08.003
6. Poland, E., Bhonsle, A., Steinmann, I., & Wilke, M. (2021). Reduced alpha amplitudes predict perceptual suppression. *Scientific Reports*, *11*(1), 13040. https://doi.org/10.1038/s41598-021-92404-8

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