Concurrent activation of hierarchical neural representations compensates for neural delays in visual motion perception

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INTRODUCTION

- There is a delay between visual events and neural responses, caused by the time required for transmission and processing[1,2].
- Later representations have larger processing delays than earlier representations due to the accumulation of processing time.
- There is evidence that, in the case of predictably moving objects, neural processing delays can be compensated based on knowledge of the object's previous trajectory[3,4,5].

Aim:
Investigate whether EEG position representations normally activated sequentially will be activated concurrently when processing predictable visual motion.

Hypotheses:
H_0: No compensation; neural representions are activated sequentially -> gradient of 1

H_1: Full compensation; neural representions are activated concurrently -> gradient of 0

METHODS

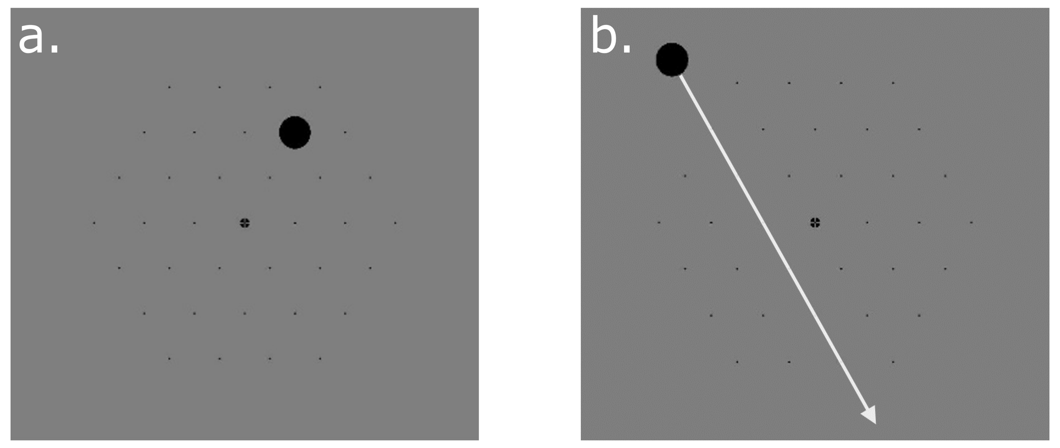

Figure 1. Experimental design
In each trial, the stimulus either (a) flashed for 250ms in one position on a hexagonal grid or (b) moved through the grid at 0.32 pixels/ms. EEG data were recorded from 6 participants. In total, there were 23,976 motion trials and 9,324 flash trials per participant.

- We computed the CAI over multiple training and testing timepoints.
- **Later training timepoints correspond to later representations**, as the information has time to reach a further stage of processing.
- By comparing the timepoints at which different representations are activated in the flash and motion trials, we can determine whether the delays between different representations are compensated.

Classification Anisotropy Index (CAI):
a measure of the amount of evidence in the EEG signal for the stimulus being present at a given location at a given time. This is calculated using LDA classifiers trained on flash trials and tested on flash or motion trials.

RESULTS

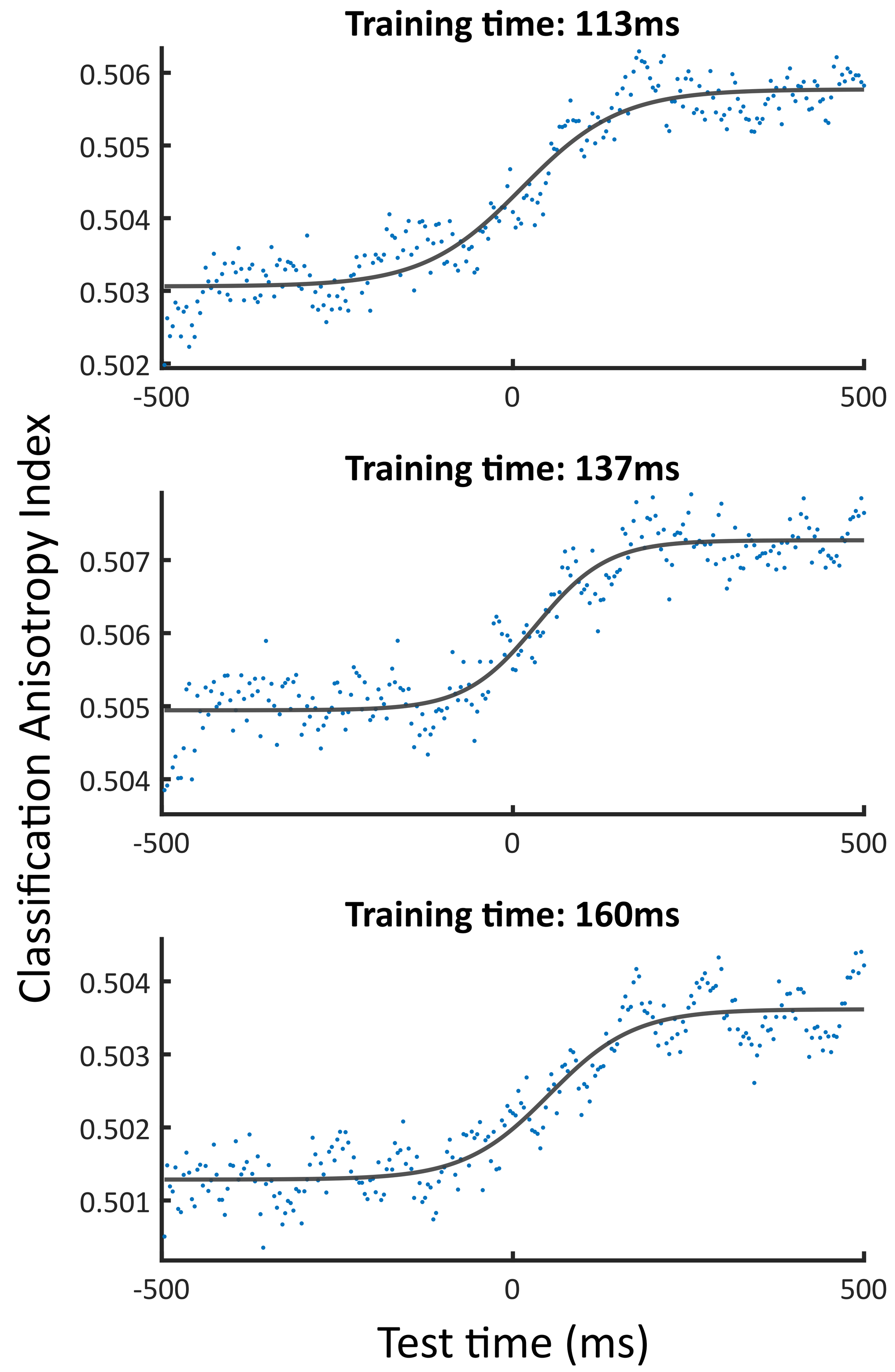

Figure 2. *At every training timepoint between 100 and 200ms (here, 3 examples selected), a sigmoid function was fit through the Classification Anisotropy Index (y-axis) at each test timepoint (x-axis). We calculated the midpoint of each sigmoid, which is plotted on the y-axis of Fig. 3.*

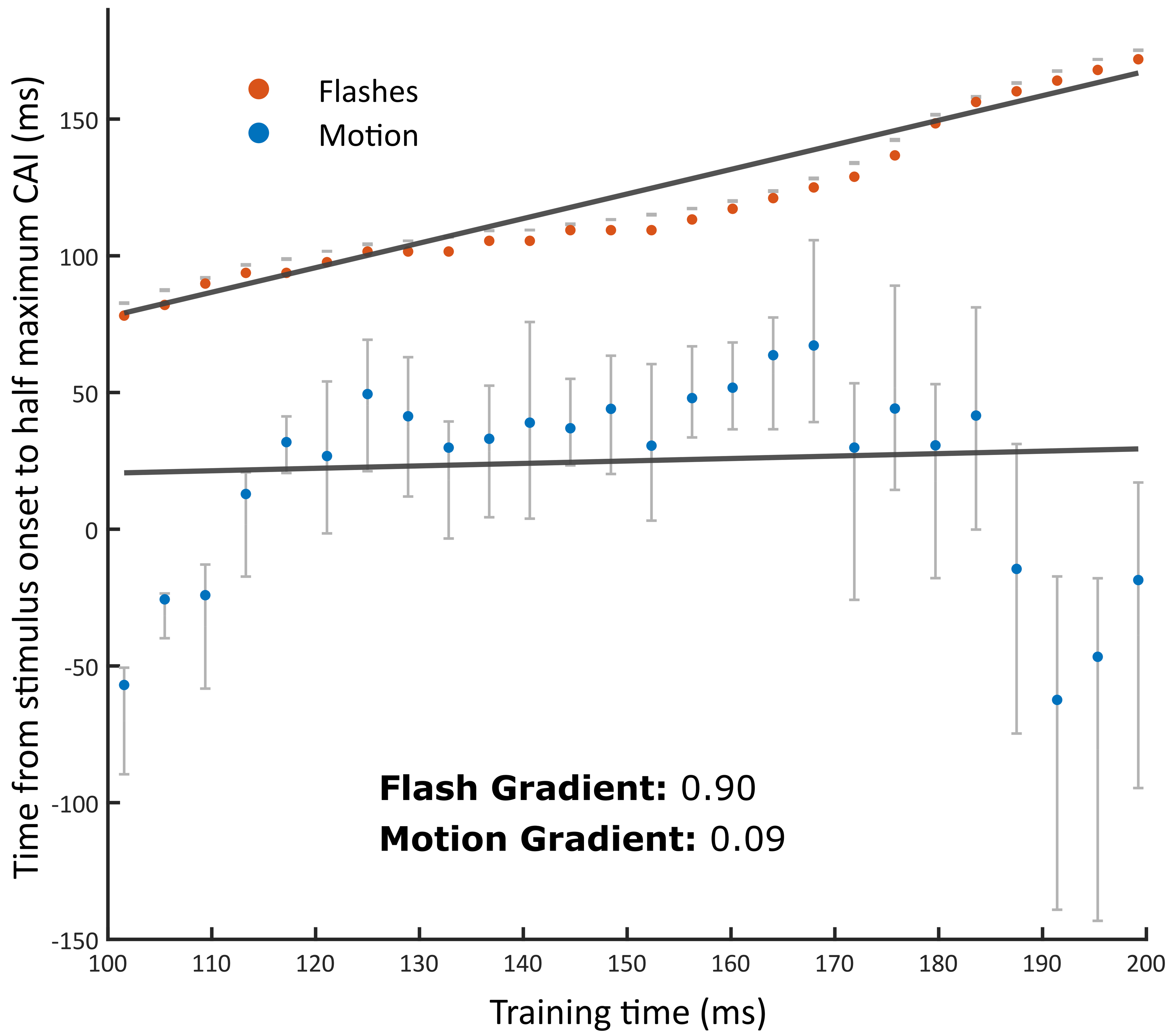

Figure 3. *Timepoint at which half peak CAI is reached, plotted against training time. Errorbars show bootstrapped 95% confidence intervals. A line was fit through these points for the flashes and motion. As expected, for flashes the gradient was 0.90 (close to unity), indicating the later representations were indeed activated at later timepoints. For motion, the gradient was 0.09 (close to zero), indicating full compensation: neural representations at all levels are activated at the same time.*

Bayes Factor comparison between models

BF in favour of gradient 0 compared to gradient 1: 622

This indicates **overwhelming evidence for the full compensation model with gradient 0** (H_1).

BF in favour of gradient 0 compared to fitted line: 3.4

This indicates some evidence for the model with gradient 0 compared to the fitted model.

DISCUSSION

- We provide strong evidence for a gradient of 0, indicating that **the visual system compensates for delays accumulated during motion processing by activating neural position representations concurrently** (Fig. 3).
- These results indicate temporal alignment across hierarchical levels.
- This enables predictably moving objects to be represented closer to their veridical position.

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References: 1. Maunsell, J. H., & Gibson, J. R. (1992). Visual response latencies in striate cortex of the macaque monkey. journal of Neurophysiology, 68(4), 1332-1344. **2.** Schmolesky, M. T., Wang, Y., Hanes, D. P., Thompson, K. G., Leutgeb, S., Schall, J. D., & Leventhal, A. G. (1998). Signal timing across the macaque visual system. Journal of Neurophysiology, 79(6), 3272-3278. **3.** Nijhawan, R. (2008). Predictive perceptions, predictive actions, and beyond. Behavioral and Brain Sciences, 31(2), 222-239. **4.** Hogendoorn, H. & Burkitt, A.N. (2019). Predictive coding with neural transmission delays: a real-time temporal alignment hypothesis. eNeuro 10.1523/ENEURO.0412-18.2019. **5.** Khoei, M. A., Masson, G. S., & Perrinet, L. U. (2017). The flash-lag effect as a motion-based predictive shift. PLoS Computational Biology, 13(1), e1005068. Icons made by https://www.flaticon.com.