School of Biological and Behavioural Sciences

Windscreen Wiper Triggered Neural Responses as Causes and Predictors of Driver Drowsiness

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Motivation

➢ Does the moving pattern/existence of windscreen wiper affect driver drowsiness?

➢ Does windscreen wiper as a form of Steady-state Visual Evoked Potential (SSVEP) induce brain oscillation entrainment effect?

➢ If so, how does the entrainment effect impact the development of driver drowsiness?

➢ And if so, can we quantify driver drowsiness with wiper triggered neural responses?

Contribution

✓ We conducted **a controlled experiment in a simulated driving environment** with different wiper patterns, with Karolinska Drowsiness Test and EEG recordings.

✓ **A significant SNR triggered by wipers with regular and irregular moving patterns** across PO7/PO8 electrodes is observed, which **correlates negatively** to sleepiness.

✓ **Causal Mediation Analysis** for the effect of wiper conditions (treatment) on Karolinska Sleepiness Score (outcome) via EEG Delta band power (mediator) **showed significant indirect effect through mediator** for regular and irregular wiper moving patterns.

Experiment
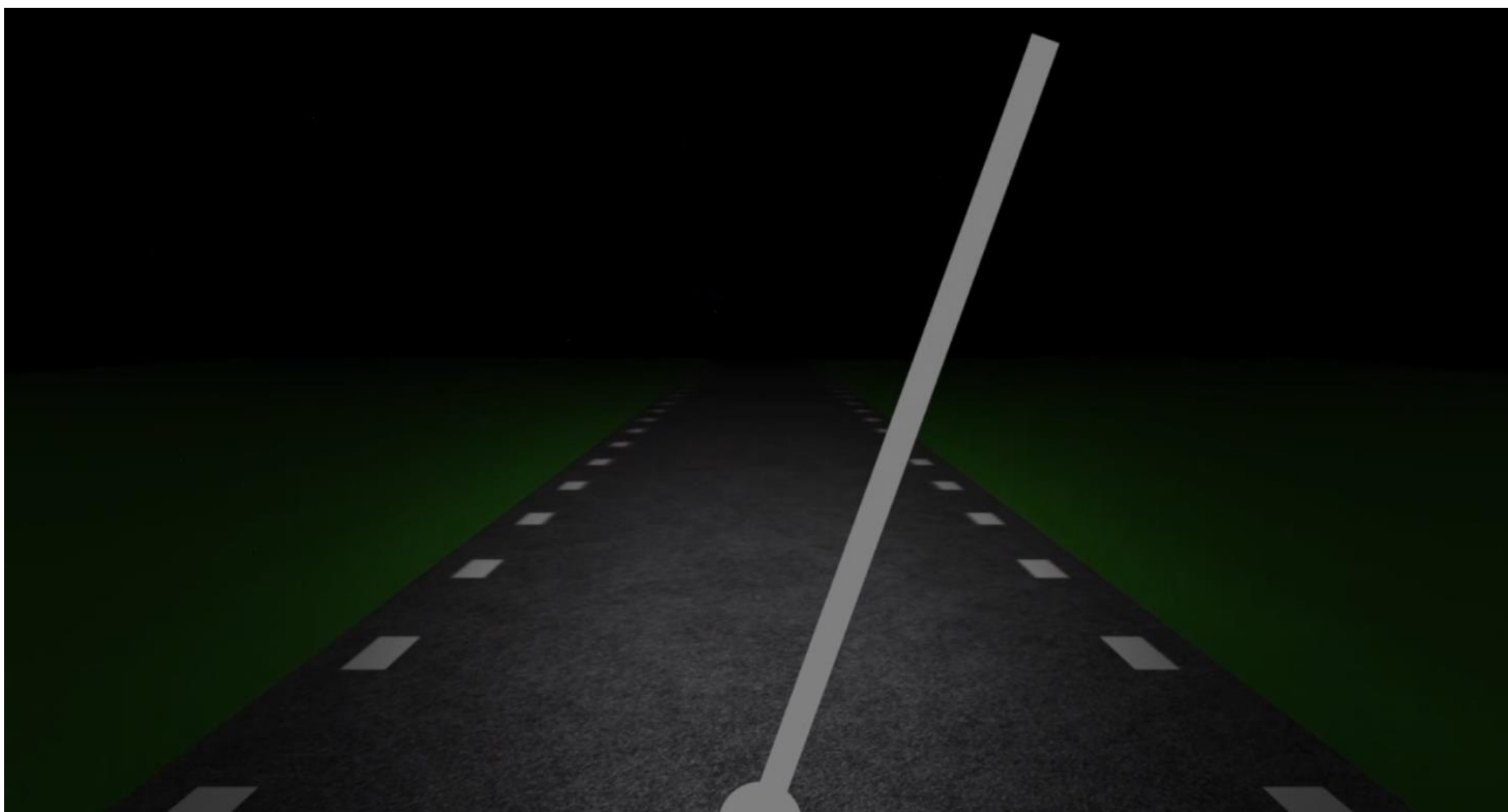
21 Participants, 60-minute Session

Wiper Moving Patterns

❑ Regular Moving Wipers

❑ Irregular Moving Wipers

❑ No Wipers

Karolinska Drowsiness Test every 5-minute

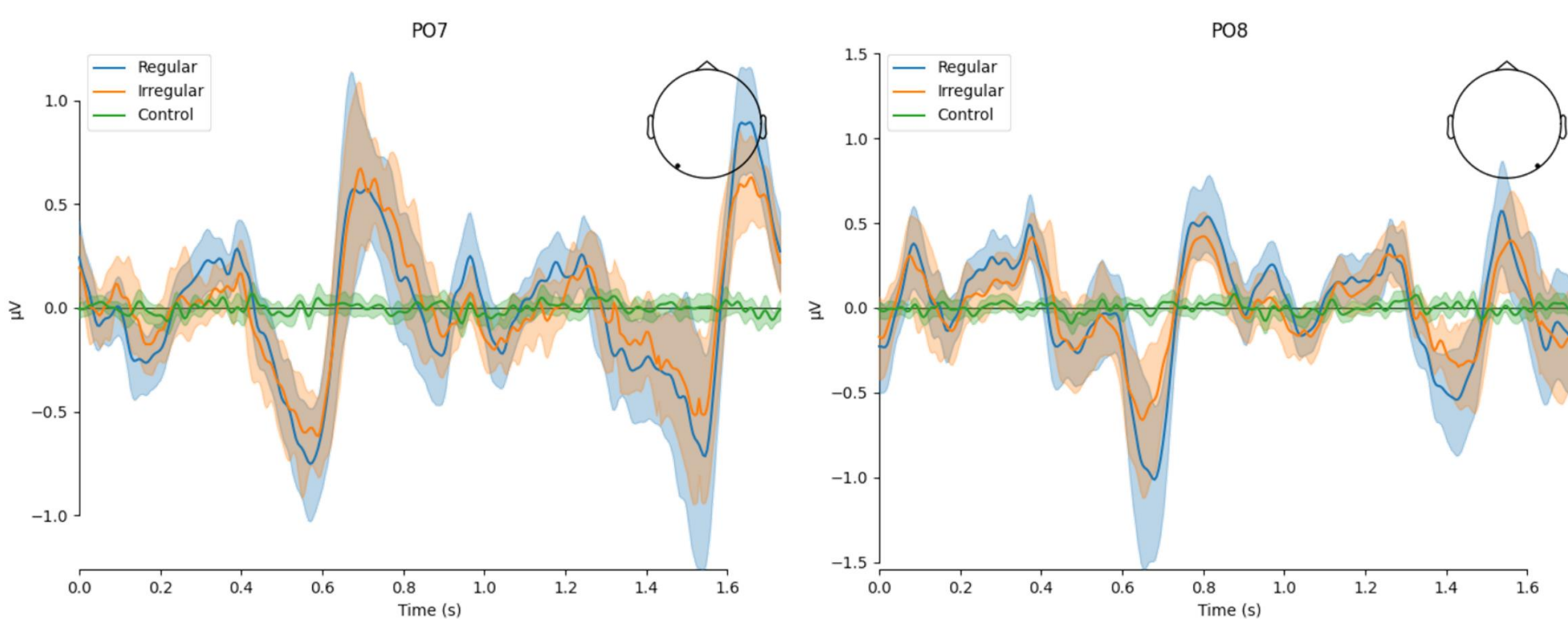## Result: Wiper Triggered Neural Responses as Drowsiness Predictors

Figure 1: Visual evoked potential in PO7 and PO8 channels without/with wipers moving in regular and irregular patterns, with mean (solid line) and variance (shaded area) presented in different colours.
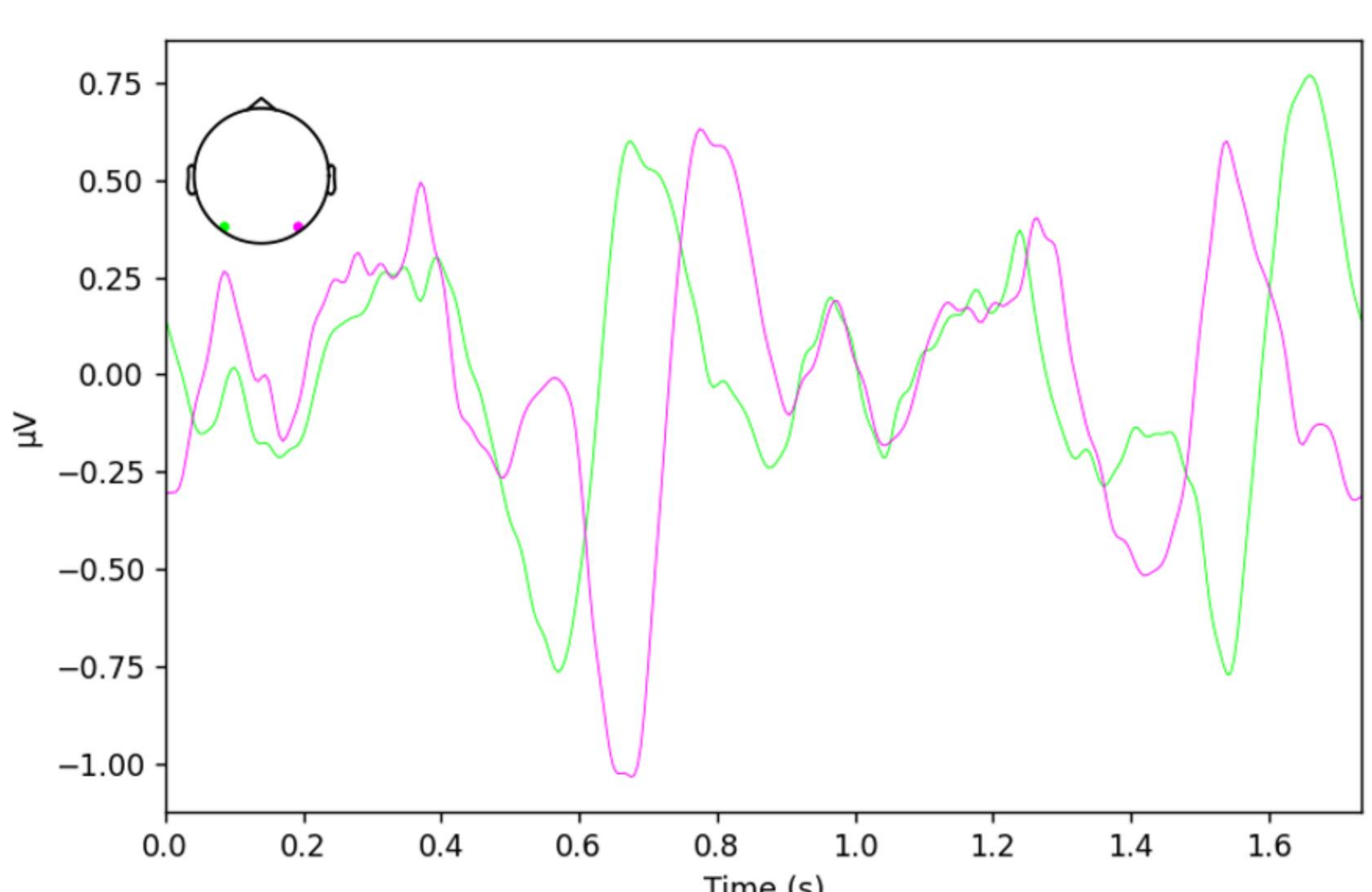
Figure 2: Visual evoked potential in PO7 (green) and PO8 (pink) channels under regular wiper condition.
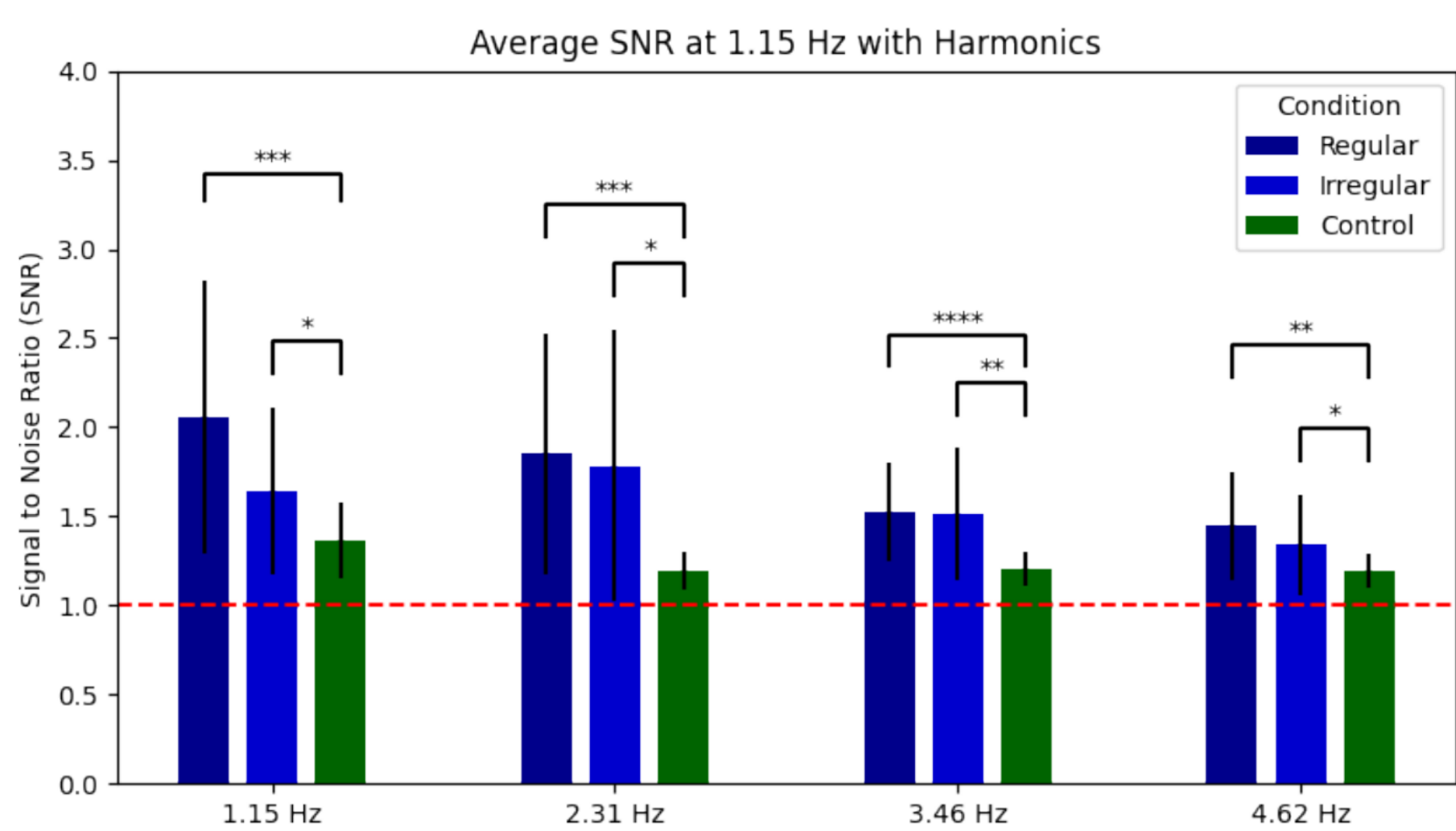

Figure 3: Signal-to-noise (SNR) bar plot under all conditions with significance test by paired T-Test.

(*: p < 0.05, **: p < 0.005, ***: p < 0.0005, ****: p < 0.00005)

Linear Correlation Analysis with Mixed Effect Model

Null Hypothesis: `kss ~ log(snr) + (1 | participant_id)`
Alternative Hypothesis: `kss ~ (1 | participant_id)`

| Predictor	Model	AIC	BIC	Log-likelihood	$p > (\chi^2)$	Estimates	CI	ICC	Marginal/Conditional R^2
SNR [1.15 Hz]	H_0	534.74	545.00	-264.37	-	-	-	-	- / -
	H_1	534.61	548.29	-263.30	0.144	-0.09	-0.22 - 0.03	0.54	0.008 / 0.540
SNR [2.31 Hz]	H_0	534.74	545.00	-264.37	-	-	-	-	- / -
	H_1	532.20	545.89	-262.10	0.033*	-0.12	-0.22 - -0.01	0.54	0.014 / 0.547
SNR [3.46 Hz]	H_0	534.74	545.00	-264.37	-	-	-	-	- / -
	H_1	531.87	545.55	-261.94	0.027*	-0.11	-0.21 - -0.01	0.54	0.011 / 0.548
SNR [4.62 Hz]	H_0	534.74	545.00	-264.37	-	-	-	-	- / -
	H_1	532.92	546.61	-262.46	0.051	-0.10	-0.20 - 0.00	0.53	0.011 / 0.539

Table 1: Likelihood ratio test of slope with Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Log-likelihood, significance of ANOVA, estimates, Confidence Interval (CI), Intraclass Correlation Coefficient (ICC) and coefficient of determination (R^2) for paired correlation analysis between Karolinska Sleepiness Score and SNR from SSVEP at harmonic frequencies for regular wiper condition.

(*: p < 0.05, **: p < 0.005, ***: p < 0.0005, ****: p < 0.00005)

Results: Wiper Triggered Neural Responses as Drowsiness Mediators

Causal Mediation Analysis

Mediator: `log_eeg_band_power ~ block + condition + (1 | participant_id)`
Outcome: `kss ~ log_eeg_band_power + condition + (1 | participant_id)`
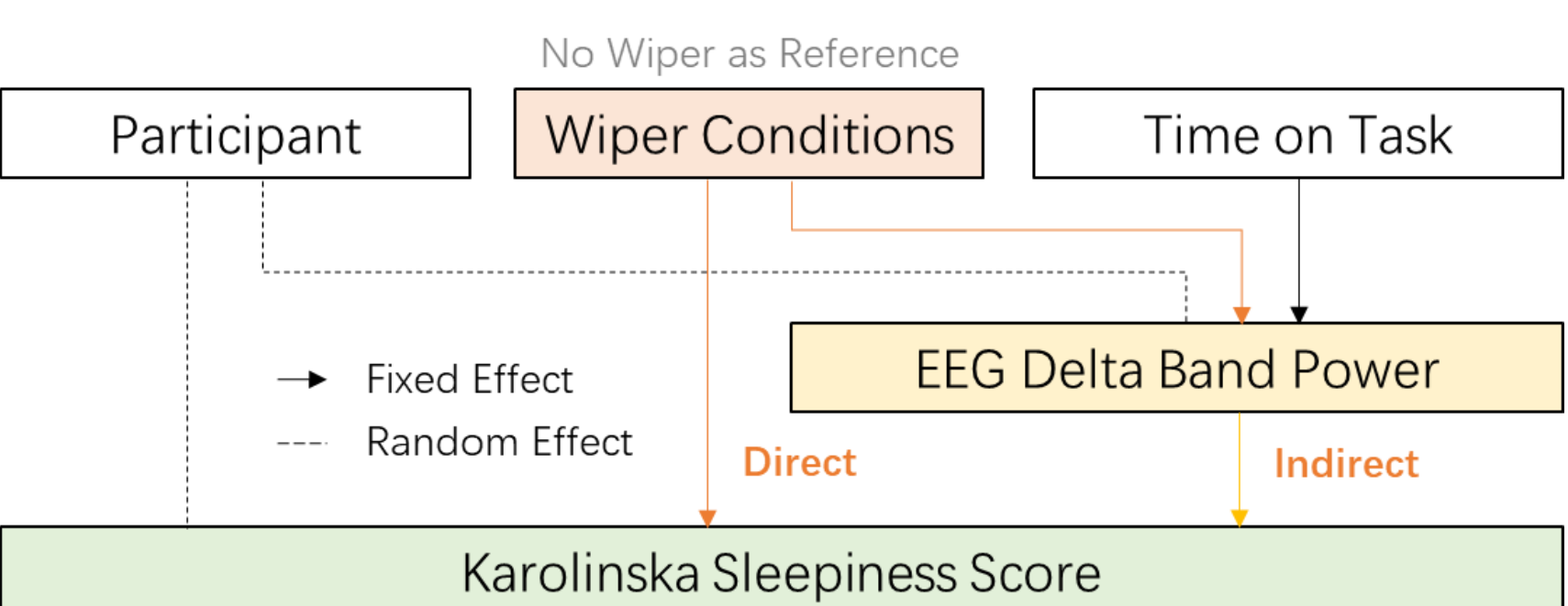
Condition	Measurements	Estimate	95% CI Lower	95% CI Upper	p-value
Regular Wiper ↕ No Wiper	ACME	0.0693	0.0102	0.14	0.012*
	ADE	-0.0364	-0.3622	0.31	0.840
	Total Effect	0.0329	-0.2912	0.39	0.874
	Prop. Mediated	0.1852	-5.6463	4.53	0.866
Irregular Wiper ↕ No Wiper	ACME	0.08208	0.02105	0.16	0.008**
	ADE	0.31672	-0.00543	0.64	0.056.
	Total Effect	0.39880	0.08377	0.71	0.014*
	Prop. Mediated	0.20072	0.03927	0.89	0.022*

Table 2: Causal mediation analysis of wiper moving pattern on drowsiness with Average Causal Mediation Effect (ACME), Average Direct Effect (ADE), Total Effect, Proportion Mediated based on no wiper condition as reference.

(.: p < 0.1, *: p < 0.05, **: p < 0.005, ***: p < 0.0005, ****: p < 0.00005)