Supplementary Material for

Decoding subjective emotional arousal from EEG during an immersive Virtual Reality experience

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Supplementary Methods

Details of the rollercoasters

The "Space" rollercoaster did not feature outstanding events during the ride besides two vertical spins starting around 47 s and 73 s after the onset of the experience. Virtual collisions of asteroids floating through the scenery led to explosions of the celestial bodies involved, accompanied by an explosive sound. Apart from this, there were little sound effects during the space experience.

The "Andes" rollercoaster included a steep drop (24 s after onset), two jumps with steep landings (31 s and 67 s after onset), two passages through fires under the tracks (20 and 55 s after onset) and a looping (60 s after onset). Sound effects mimicked the sound of the waggon on the tracks, the fire, and the airflow. In the background a jingling melody was played.

Simulator sickness questions

The wording and items to assess simulator sickness, were:

Please rate on a scale from 1 to 7 how much each symptom below is affecting you right now:

   (A) General discomfort

   (B) Nausea

   (C) Dizziness

   (D) Headache

   (E) Blurred vision

   (F) Difficulty concentrating
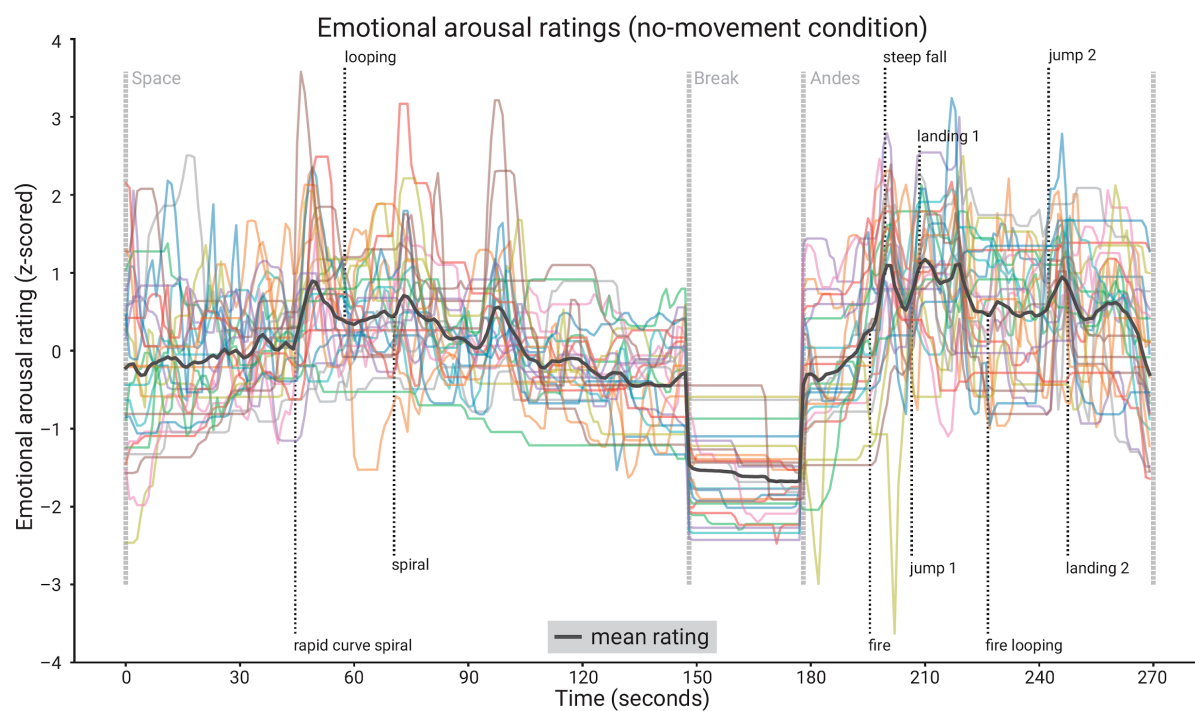
Supplementary Figures

Figure 5 – figure supplement 1. Subjective emotional arousal ratings (no-movement condition). Emotional arousal ratings of the experience (without head movement). Coloured lines: individual participants; black line: mean across participants; vertical lines (light grey): beginning of the three phases (Space Coaster, Break, Andes Coaster); vertical lines (dark grey): manually labelled salient events (for illustration).
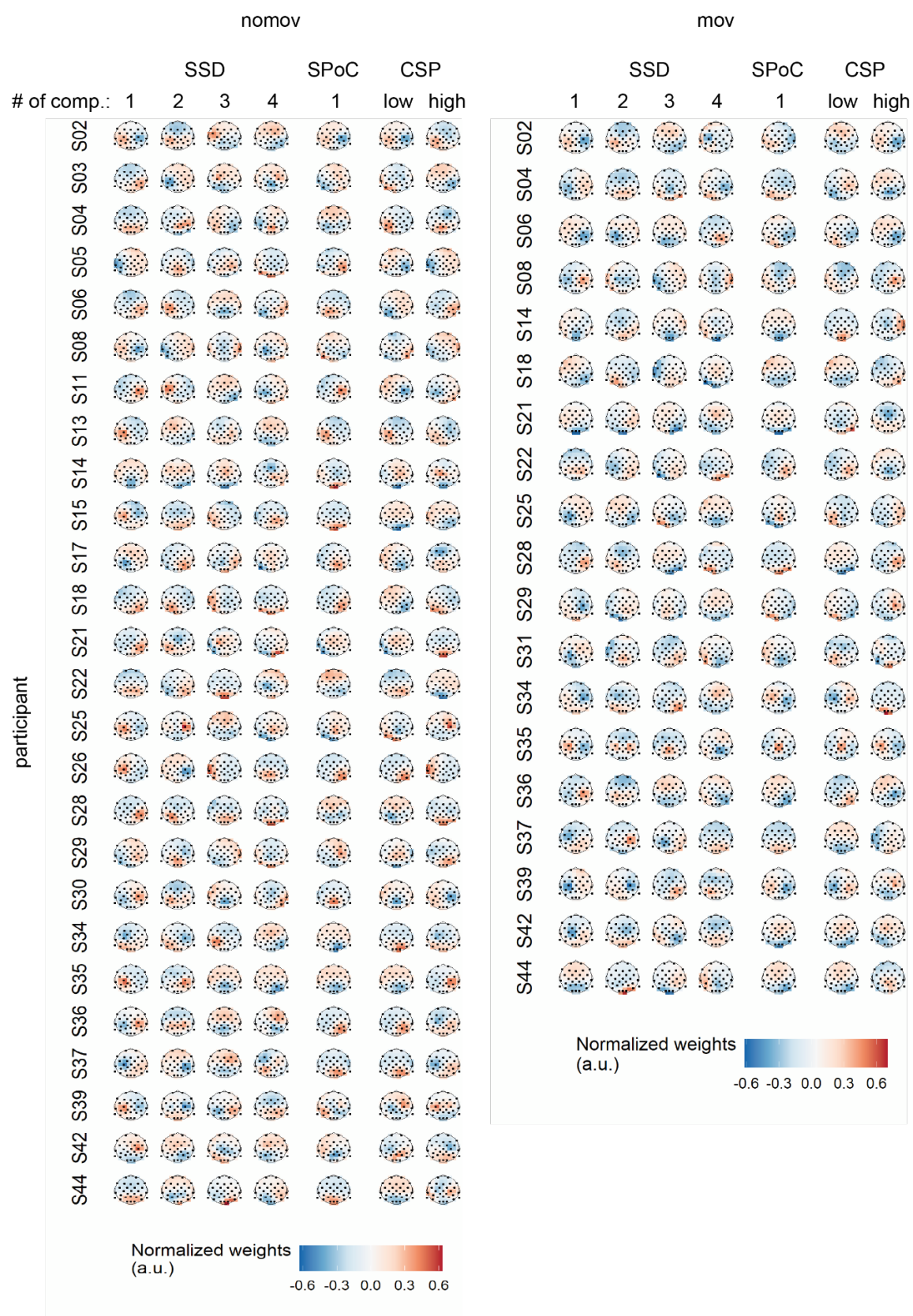
Figure 6 – figure supplement 1. Spatial patterns per single subject and movement condition yielded by the different spatial signal decompositions. For SSD the four patterns corresponding to the four highest eigenvalues among the accepted components (see methods) are displayed (note: subjects with *less* than four accepted SSD components were discarded for further analysis; for subjects with *more* than four accepted components, all of these components went into the further analyses but only the first four patterns are shown here). For SPoC the pattern associated with the component that yielded the strongest correlation between target and source power is displayed. For CSP the patterns associated with the components that maximized power during states of low and high emotional arousal are shown.

Supplementary Tables

Subject	SPoC_λ	SPoC_r	SPoC_p	CSP_{acc}	CSP_p	LSTM_{acc}	LSTM_p
S02	0.081	0.099	0.999	0.683	0.000	0.683	0.000
S03	-0.194	-0.224	0.401	0.617	0.002	0.633	0.000
S04	-0.405	-0.245	0.040	0.617	0.002	0.561	0.117
S05	-0.934	-0.180	0.127	0.672	0.000	0.600	0.009
S06	-0.266	-0.281	0.032	0.639	0.000	0.572	0.062
S08	-0.185	-0.239	0.155	0.517	0.709	0.583	0.030
S11	-0.408	-0.219	0.022	0.594	0.014	0.611	0.004
S13	-0.328	-0.218	0.386	0.539	0.333	0.533	0.412
S14	-0.210	-0.332	0.013	0.650	0.000	0.572	0.062
S15	-0.227	-0.288	0.086	0.550	0.205	0.583	0.030
S17	-1.088	-0.336	0.018	0.567	0.086	0.594	0.014
S18	-0.254	-0.201	0.098	0.533	0.412	0.533	0.412
S21	-0.322	-0.274	0.337	0.722	0.000	0.672	0.000
S22	-0.639	-0.204	0.053	0.572	0.062	0.522	0.602
S25	-1.491	-0.531	0.000	0.600	0.009	0.589	0.021
S26	-0.464	-0.276	0.303	0.778	0.000	0.656	0.000
S28	-0.215	-0.153	0.128	0.617	0.002	0.556	0.157
S29	-0.360	-0.170	0.148	0.472	0.502	0.589	0.021
S30	-0.432	-0.198	0.737	0.672	0.000	0.644	0.000
S34	-0.813	-0.527	0.000	0.589	0.021	0.617	0.002
S35	-0.442	-0.259	0.166	0.694	0.000	0.650	0.000
S36	-0.771	-0.411	0.012	0.656	0.000	0.644	0.000
S37	-0.665	-0.335	0.095	0.650	0.000	0.561	0.117
S39	-0.147	-0.185	0.732	0.489	0.823	0.539	0.333
S42	-0.357	-0.261	0.219	0.517	0.709	0.539	0.333
S44	-0.492	-0.231	0.172	0.611	0.004	0.611	0.004

Figure 10 − figure supplement 1. Results per decoding approach and participant (nomov condition). *SPoC:* values for the component with the smallest (i.e., most negative) correlation between its alpha power and the emotional arousal ratings. *λ:* covariance; *r:* Spearman correlation coefficient; *p:* *p*-values obtained from the permutation test (see *Methods*) on the single subject level; *CSP* and *LSTM:* classification results. *acc:* proportion of correctly classified samples across the cross-validation folds. *p:* *p*-values obtained from the exact binomial test on the single subject level (see *Methods*).

Subject	$SPoC_\lambda$	$SPoC_r$	$SPoC_p$	CSP_{acc}	CSP_p	$LSTM_{acc}$	$LSTM_p$
S02	0.029	0.042	0.978	0.556	0.157	0.550	0.205
S04	-0.228	-0.188	0.262	0.578	0.044	0.594	0.014
S06	-0.155	-0.201	0.302	0.556	0.157	0.594	0.014
S08	-0.354	-0.249	0.212	0.656	0.000	0.622	0.001
S14	-0.132	-0.225	0.098	0.533	0.412	0.589	0.021
S18	-0.358	-0.264	0.063	0.567	0.086	0.617	0.002
S21	-0.493	-0.157	0.462	0.561	0.117	0.589	0.021
S22	-0.567	-0.369	0.000	0.483	0.709	0.544	0.263
S25	-1.496	-0.527	0.001	0.711	0.000	0.711	0.000
S28	-0.473	-0.217	0.039	0.556	0.157	0.583	0.030
S29	-0.591	-0.319	0.006	0.578	0.044	0.583	0.030
S31	-0.342	-0.302	0.006	0.650	0.000	0.539	0.333
S34	-0.051	-0.077	0.925	0.717	0.000	0.667	0.000
S35	-0.177	-0.272	0.087	0.578	0.044	0.622	0.001
S36	-0.375	-0.271	0.095	0.689	0.000	0.633	0.000
S37	-1.117	-0.464	0.029	0.600	0.009	0.661	0.000
S39	-0.364	-0.374	0.004	0.667	0.000	0.656	0.000
S42	-0.108	-0.197	0.625	0.633	0.000	0.633	0.000
S44	-0.567	-0.264	0.083	0.678	0.000	0.656	0.000

Figure 10 − figure supplement 2. Results per decoding approach and participant (mov condition). Variables like in Figure 10−figure supplement 1.

Subject	resting state	nomov	mov
S01	11.322	NaN	NaN
S02	10.715	10.787	11.190
S03	10.535	10.711	NaN
S04	10.097	9.865	10.241
S05	10.299	9.969	10.236
S06	10.277	12.293	12.503
S07	11.589	10.701	NaN
S08	11.194	11.450	11.056
S09	9.961	10.917	11.905
S10	9.423	NaN	NaN
S11	11.396	11.831	9.349
S13	11.185	9.633	10.535
S14	10.482	9.300	10.573
S15	10.271	11.498	NaN
S16	10.554	NaN	NaN
S17	9.711	9.080	11.424
S18	8.830	10.740	10.384
S19	11.082	NaN	NaN
S20	10.355	11.131	12.139
S21	10.717	12.405	12.307
S22	9.403	10.823	10.307
S23	9.413	NaN	NaN
S24	10.876	9.701	8.825
S25	11.034	11.489	11.283
S26	10.993	11.146	NaN
S27	10.475	11.686	12.253
S28	9.118	11.026	11.161
S29	9.975	11.586	11.893
S30	9.247	10.195	NaN
S31	9.011	10.050	11.070
S32	9.733	NaN	NaN
S33	8.758	NaN	NaN
S34	10.879	12.205	12.246
S35	9.689	10.087	10.568
S36	10.067	10.254	10.316
S37	9.499	10.588	9.942
S38	8.570	NaN	NaN
S39	10.065	10.961	11.096
S40	9.924	NaN	NaN
S41	9.712	NaN	NaN
S42	10.393	11.840	12.111
S43	10.121	NaN	NaN
S44	10.564	10.376	10.853
S45	10.324	NaN	NaN

Figure 2 – figure supplement 1. Selected alpha peaks (8-13 Hz) per participant and condition.

Results of FOOF for three conditions: eyes-closed resting state, nomov, and mov.

Subject	LSTM	FC	l.rate	reg.	reg. strength	activ.func.	components
S02	30,20	0	5e-4	l2	1.44	elu	1,2
S03	20,10	0	1e-3	l1	0.72	elu	1,2
S04	30,30	30	5e-4	l1	1.44	relu	1,2,3,4,5,6,7,8
S05	50,40	10	5e-4	l2	0.00	relu	1,2,3,4
S06	30,25	0	5e-4	l1	0.36	elu	1,2,3,4,5,6,7
S08	80,50	25	1e-3	l1	0.00	relu	1,2,3
S11	30,25	0	5e-4	l1	0.36	elu	1,2,3,4,5,6,7
S13	40,20	10	5e-4	l1	0.00	relu	1
S14	30,25	0	5e-4	l1	0.36	elu	1,2,3,4,5,6,7
S15	40,15	0	1e-3	l1	0.72	relu	1,2,3,4,5
S17	30,30	30	5e-4	l1	1.44	relu	1,2,3,4,5,6,7,8
S18	30,25	0	5e-4	l1	0.36	elu	1,2,3,4,5,6,7
S21	30,25	0	5e-4	l1	0.36	elu	1,2,3,4,5,6,7
S22	30,25	0	5e-4	l1	0.36	elu	1,2,3,4,5,6,7
S25	20,15	10	1e-3	l1	0.00	relu	1,2,3,4,5,6,7
S26	40,15	0	1e-3	l1	0.72	relu	1,2,3,4,5
S28	30,20	0	5e-4	l2	1.44	elu	1,2
S29	50,40	10	5e-4	l2	0.00	relu	1,2,3,4
S30	30,30	30	5e-4	l1	1.44	relu	1,2,3,4,5,6,7,8
S34	30,25	0	5e-4	l1	0.36	elu	1,2,3,4,5,6,7
S35	100100	0	5e-4	l1	0.00	elu	1,2,3,4
S36	20,15	10	1e-3	l1	0.00	relu	1,2,3,4,5,6,7
S37	30,25	0	5e-4	l1	0.36	elu	1,2,3,4,5,6,7
S39	40,20	10	5e-4	l1	0.00	relu	1
S42	30,20	0	5e-4	l2	1.44	elu	1,2
S44	40,30	10	5e-4	l2	0.72	elu	1,2,3,4,5,6,7

Figure 4 − figure supplement 1. LSTM hyperparameter search (nomov condition). *LSTM*: number of cells per layer. *FC*: number of hidden units in fully connected layer, before final output neuron. *l.rate*: learning rate. *reg.*: type of weight regularizer. *reg. strength*: respective regularization strength. *activ.func*: intermediate layer activation function. *components*: individually selected components for training after SSD selection. *mean accuracy*: mean classification accuracy across 10 folds of cross validation.

Subject	LSTM	FC	l.rate	reg.	reg. strength	activ.func.	components
S02	65,30	25	5e-4	l2	0.18	relu	1,2,3,4,5,6,8
S04	40,15	10	1e-3	l2	1.44	relu	1,2,3,4,6
S06	30,25	0	1e-3	l2	0.00	elu	1,2,3,4,5,6,7
S08	65,30	25	5e-4	l2	0.18	relu	1,2,3,4,5,6,7
S14	50,50	15	1e-2	l1	0.00	elu	1,2,3,4,5,6,7,8
S18	15,15	10	1e-3	l2	0.72	relu	1
S21	40,15	10	1e-3	l2	1.44	relu	1,2,3,4,6
S22	80	0	5e-4	l2	0.18	elu	1,2
S25	15,15	10	1e-3	l2	0.72	relu	1
S28	30,25	0	1e-3	l2	0.00	elu	1,2,3,4,5,6,7
S29	65,30	25	5e-4	l2	0.18	relu	1,2,3,4,5
S31	40	0	1e-2	l2	0.18	elu	1,2,3,4
S34	65,30	25	5e-4	l2	0.18	relu	1,2,3,4,5
S35	65,30	25	5e-4	l2	0.18	relu	1,2,3,4,5,6,8
S36	65,30	25	5e-4	l2	0.18	relu	1,2,3,4,5,6,8
S37	65,30	25	5e-4	l2	0.18	relu	1,2,3,4,5,6,8
S39	65,30	25	5e-4	l2	0.18	relu	1,2,3,4,5
S42	10	0	1e-3	l2	0.72	relu	1
S44	65,30	25	5e-4	l2	0.18	relu	1,2,3,4,5

Figure 4 – figure supplement 2. LSTM hyperparameter search (mov condition). Variables

like in Figure 4–figure supplement 1.