Supplementary Information for:

Brain state dynamics reflect emotion transitions induced by music

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Supplementary Materials

Additional retrospective recall analyses

In addition to timing, we tested if the intensity of post-listening emotions ratings varied by emotional context, i.e. if the version of the piece that a person heard systematically altered how people remembered those moments within the musical piece. If self-report ratings varied by piece version, this would suggest that the proceeding emotional context is influencing how the music is being experienced and providing strong motivation for Aim 3 of our proposed fMRI analysis. Repeated measures ANOVAs (*rm_anova* function from the Pingouin Python package ⁷⁴) were used to determine if ratings (vividness, surprise, emotional intensity) varied by version of the piece and emotional label. All post-hoc comparisons were made with Tukey's Honestly significant difference test (HSD) and significant results after multiple-comparison correction are presented below.

For *vividness* ratings, joy clips that were preceded by calm clips were remembered more vividly than when preceded by anxious clips ($M_{calm} = 5.00$, $M_{anxious} = 4.46$, p-value = 0.004) and sad clips ($M_{sad} = 4.48$, p-value = 0.043). In addition, sad clips preceded by calm clips were remembered more vividly than those preceded by joy ($M_{calm} = 4.46$, $M_{joy} = 4.46$, p-value = 0.016) or anxious ($M_{anxious} = 3.87$, p-value = 0.025). For *intensity* of felt-emotions ratings, joy clips that were preceded by anxious clips were rated as less joyful than those that were preceded by sad clips ($M_{anxious} = 4.85$, $M_{sad} = 5.74$, p-value = 0.024). For *surprise* ratings, sad clips that were preceded by calm were rated as more surprising than those preceded by anxious ($M_{calm} = 3.06$, $M_{anxious} = 2.58$, p-value = 0.04). Finally, for *enjoyment* ratings, anxious clips that were preceded by joyful clips were significantly less enjoyed than when preceded by calm ($M_{joy} = 2.91$, $M_{calm} = 3.86$, p-value = 0.001) or sad clips ($M_{sad} = 3.51$, p-value = 0.003).

Spatial correlations accounting for hemodynamic lag

It is possible that the spatial patterns that reflect differences in musical context that we observed are due to lag in the fMRI signal bleeding over from the preceding event. If this were the case, then it could be that the results simply reflect that the group that heard the piece in the same context (piece A vs. piece B) show more similar activation patterns for events because the preceding event was the same as well and not that the spatial signal in the auditory cortex is reflecting any change in context. To address this, we re-ran the analyses above, including only brain data from the second half of each musical, emotional event. In this way, we can ensure that the mean signal across the second half of the event would not include any spillover signal from the event before.

The results are largely similar when using only the second half of each event as compared to the entire event. Significant differences as a result of context are still observed in the left and right temporal lobe, including the primary and secondary auditory cortex and anterior temporal lobe. The results in the right precentral gyrus and sulcus, however, were no longer statistically significant.

Significantly greater pattern similarity for same context musical events (2nd half only)



Fig S1. Context-based changes in spatial brain patterns using only data from the second half of each emotional event. Brain regions in which spatial patterns of the second half of each emotional event were significantly more similar in pairs of participants who heard them in the same condition (all in piece A or B, within group) as compared to pairs of participants who heard the music in different conditions (one in piece A other in B, across group). Colors correspond to z-stats of the ratio of across group vs. within group correlations as compared to a null model in which group membership was randomly permuted. Resulting statistical maps were cluster-corrected at p value < 0.05.

Piece A, Version 1							Piece A, Version 2					
Event Num	Emotion	Exemplar Num	Transition Type	Onset	Offset	Duration	Emotion	Exemplar Num	Transition Type	Onset	Offset	Duration
1	Dreamy/Nostalgic	1	NA	0	60	60	Dreamy/Nostalgic	1	NA	0	60	60
2	Calm/Relaxing	1	NA	69	123	54	Jayous/Cheerful	1	NA	69	120	51
3	Joyous/Cheerful	1	PP	132	183	51	Calm/Relaxing	1	PP	129	181	52
4	Sad/Depressing	1	PN	192	240	48	Sad/Depressing	1	PN	192	231	39
5	Anxious/Tense	1	NN	249	297	48	Anxious/Tense	1	NN	234	291	57
6	Joyous/Cheerful	2	NP	306	360	54	Joyous/Cheerful	2	NP	300	348	48
7	Calm/Relaxing	2	PP	366	408	42	Calm/Relaxing	2	PP	357	393	36
8	Anxious/Tense	2	PN	417	474	57	Anxious/Tense	2	PN	402	441	39
9	Sad/Depressing	2	NN	483	522	39	Sad/Depressing	2	NN	447	496	49
10	Calm/Relaxing	3	NP	525	561	36	Calm/Relaxing	3	NP	504	546	42
11	Joyous/Cheerful	3	PP	570	618	48	Joyous/Cheerful	3	PP	555	609	54
12	Sad/Depressing	3	PN	627	675	48	Anxious/Tense	3	PN	615	663	48
13	Anxious/Tense	3	NN	684	723	39	Sad/Depressing	3	NN	672	720	48
14	Joyous/Cheerful	4	NP	729	768	39	Calm/Relaxing	4	NP	729	780	51
15	Calm/Relaxing	4	PP	774	825	51	Joyous/Cheerful	4	PP	789	828	39
16	Dreamy/Nostalgic	2	NA	834	894	60	Dreamy/Nostalgic	2	NA	834	894	60
Piece R. Vereign 1							, ,					
		Piece	B Version 1				, ,		Piece B. Ver	eion 2		
		Piece	B, Version 1						Piece B, Vers	sion 2		
Event Num	Emotion	Piece Exemplar Num	B, Version 1 Transition Type	Onset	Offset	Duration	Emotion	Exemplar Num	Piece B, Vers	sion 2 Onset	Offset	Duration
Event Num	Emotion Dreamy/Noslalgic	Piece Exemplar Num	B, Version 1 Transition Type	Onset 0	Offset 36	Duration 36	Emotion Dreamy/Noslalgic	Exemplar Num	Piece B, Vers	sion 2 Onset	Offset	Duration 36
Event Num 1 2	Emotion Dreamy/Noslalgic Sad/Depressing	Piece Exemplar Num 3 4	B, Version 1 Transition Type NA NA	Onset 0 45	Offset 36 93	Duration 36 48	Emotion Dreamy/Nostalgic Anxious/Tense	Exemplar Num 3 4	Piece B, Vers Transition Type NA NA	onset	Offset 36 93	Duration 36 48
Event Num 1 2 3	Emotion Dreamy/Noslalgic Sad/Depressing Anxious/Tense	Piece Exemplar Num 3 4 4	B, Version 1 Transition Type NA NA NN	Onset 0 45 102	Offset 36 93 150	Duration 36 48 48	Emotion Dreamy/Noslalgic Anxious/Tense Sad/Depressing	Exemplar Num 3 4 4	Piece B, Vers Transition Type NA NA NN	0 0 45 102	Offset 36 93 150	Duration 36 48 48
Event Num 1 2 3 4	Emotion Dreamy/Noslalgic Sad/Depressing Anxious/Tense Catm/Relaxing	Piece Exemplar Num 3 4 4 5	B, Version 1 Transition Type NA NA NN NP	Onset 0 45 102 159	Offset 36 93 150 210	Duration 36 48 48 51	Emotion Dreamy/Nostalgic Anxious/Tense Sad/Depressing Joyous/Chccrful	Exemplar Num 3 4 4 5	Piece B, Vers Transition Type NA NA NN NP	sion 2 Onset 0 45 102 159	Offset 36 93 150 210	Duration 36 48 48 51
Event Num 1 2 3 4 5	Emotion Dreamy/Noslalgic Sad/Depressing Anxious/Tense Calm/Rclaxing Joyous/Cheerful	Piece Exemplar Num 3 4 4 5 5 5	B, Version 1 Transition Type NA NA NN NP FP T	Onset 0 45 102 159 219	Offset 36 93 150 210 267	Duration 36 48 48 51 48	Emotion Dreamy/Noslalgic Anxious/Tense Sad/Depressing Joyous/Chcorful Calm/Relaxing	Exemplar Num 3 4 4 5 5	Piece B, Vers Transition Type NA NA NN NP PP	onset 0 45 102 159 219	Offset 36 93 150 210 270	Duration 36 48 48 51 51
Event Num 1 2 3 4 5 6	Emotion Dreamy/Noslalgic Sad/Depressing Anxious/Tense Calm/Rolaxing Joyous/Cheerful Anxious/Tense	Piece Exemplar Num 3 4 5 5 5 5 5	B, Version 1 Transition Type NA NA NN NP PP PN	Onset 0 45 102 159 219 279 279	Offset 36 93 150 210 267 327	Duration 36 48 48 51 48 48 48	Emotion Dreamy/Noslalgic Anxious/Tense Sad/Depressing Joyous/Chocrful Joyous/Chocrful Calm/Relaxing Anxious/Tense	Exemplar Num 3 4 4 5 5 5 5	Piece B, Vers Transition Type NA NA NN NP PP PN	sion 2 Onset 45 102 159 219 279	Offset 36 93 150 210 270 327	Duration 36 48 48 51 51 48
Event Num 1 2 3 4 5 6 7	Emotion Dreamy/Noslalgic Sad/Depressing Anxious/Tense Catin/Relaxing Joyous/Chearful Anxious/Tense Sad/Depressing	Piece Exemplar Num 3 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5	B, Version 1 Transition Type NA NN NP PP PN NN	Onset 0 45 102 159 219 279 336	Offset 36 93 150 210 267 327 390	Duration 36 48 48 51 48 48 48 48 54	Emotion Dreamy/Noslalgic Anxious/Tense Sad/Depressing Joyous/Chccrful Calm/Relaxing Anxious/Tense Sad/Depressing	Exemplar Num 3 4 5 5 5 5 5 5 5	Piece B, Vers Transition Type NA NN NP PP PN NN	sion 2 Onset 0 45 102 159 219 279 336	Offset 36 93 150 210 270 327 384	Duration 36 48 48 51 51 48 48
Event Num 1 2 3 4 5 6 6 7 8	Emotion Dreamy/Nosialgic Sad/Depressing Anxicus/Tense Calm/Relaxing Joyous/Cheerful Anxicus/Tense Sad/Depressing Joyous/Cheerful	Piece Exemplar Num 3 4 5 5 5 5 6	B, Version 1 Transition Type NA NA NN NP PP PN NN NP PN NN NP	Onset 0 45 102 159 219 279 336 389	Offset 36 93 150 210 267 327 390 426	Duration 36 48 48 51 48 48 48 54 27	Emotion Dream y/Noslalgic Anxious/Tense Sad/Depressing Joyous/Chocrful Calm/Relaxing Anxious/Tense Sad/Depressing Calm/Relaxing	Exemplar Num 3 4 5 5 5 5 6	Piece B, Vers Transition Type NA NA NN NP PP PN NN NP NN NP	sion 2 Onset 0 45 102 159 219 279 336 393	Offset 36 93 150 210 270 327 384 459	Duration 36 48 48 51 51 48 48 48 66
Event Num 1 2 3 4 5 6 7 8 9	Emotion Dreamy/Noslaigic Sad/Depressing Anxious/Tense Calm/Relaxing Joyous/Cheerful Anxious/Tense Sad/Depressing Joyous/Cheerful Calm/Relaxing	Piece Exemplar Num 3 4 4 5 5 5 6 6 6 6 6	B, Version 1 Transition Type NA NA NN NP PP PN NN NP PP PN NP	Onset 0 45 102 159 219 279 336 399 435	Offset 36 93 150 210 267 327 390 426 501	Duration 36 48 48 51 48 51 48 51 54 27 66	Emotion Dreamy/Nosialgic Anxious/Tense Sad/Depressing Joyous/Chcerful Calm/Relaxing Anxious/Tense Sad/Depressing Calm/Relaxing Joyous/Chcerful	Exemplar Num 3 4 5 5 5 5 6 6 6	Piece B, Vers Transition Type NA NA NN PF PN NN NP PP PN NP PP	sion 2 Onset 0 45 102 159 219 279 336 333 468 57 57 57 57 57 57 57 57 57 57	Offset 36 93 150 210 270 327 384 459 455	Duration 36 48 51 51 48 66 66 27
Event Num 1 2 3 4 5 6 7 8 9 10	Emotion Dreamy/Nosialgic Sad/Depressing Anxious/Tense Catm/Relaxing Joyous/Cheerful Anxious/Tense Sad/Depressing Joyous/Cheerful Sad/Depressing	Piece Exemplar Num 3 4 4 5 5 5 6 6 6 6 6	B, Version 1 Transition Type NA NA NP PP PN NN NP PP PN PN PN	Onset 0 45 102 219 279 336 399 435 510	Offset 36 93 150 210 267 327 390 426 501 558	Duration 36 48 48 51 48 48 54 48 54 48 54 66 66 48	Emotion Dream y/Noslaigic Anxious/Tense Sad/Depressing Anxious/Tense Sad/Depressing Calm/Relaxing Joyous/Cheerful Sad/Depressing	Exemplar Num 3 4 4 5 5 5 5 6 6 6 6	Piece B, Vers Transition Type NA NA NP PP PN NN NP PP PP PP	sion 2 Onset 0 45 102 159 219 279 336 333 468 504	Offset 36 93 150 210 270 327 384 459 495 558	Duration 36 48 48 51 51 48 48 48 48 66 27 27 54
Event Num 1 2 3 4 5 6 7 8 9 10 11	Emotion Dreamy/Noslalgic Sad/Depressing Anxious/Tense Calm/Relaxing Joyous/Chearful Anxious/Tense Sad/Depressing Joyous/Chearful Calm/Relaxing Sad/Depressing Anxious/Tense	Piece Exemplar Num 4 4 5 5 5 6 6 6 6 6	B, Version 1 Transition Type NA NA NA NP PP PN NN NP PP PP PN NN NP PP P	Onset 0 45 102 219 279 336 399 435 510 567	Offset 36 93 150 210 267 327 390 426 501 558 615	Duration 36 48 48 51 48 48 54 48 54 27 66 48 48 48	Emotion Dream y/Noslalgic Anxious/Tense Sad/Depressing Joyous/Chocrful Calm/Relaxing Anxious/Tense Sad/Depressing Calm/Relaxing Joyous/Cheerful Sad/Depressing Anxious/Tense	Exemplar Num 3 4 4 5 5 5 5 6 6 6 6 6 6	Piace B, Ver: Transition Type NA NA NA NP PP PN NN NP PP PN NN NN NN	sion 2 Onset 0 45 102 159 219 336 333 468 504 567	Offset 36 93 150 210 270 327 384 459 495 558 615	Duration 36 48 48 51 51 48 48 48 66 27 54 48
Event Num 1 2 3 4 5 6 7 8 9 10 11 12	Emotion Dreamy/Nosialgic Sad/Depressing Anxious/Tense Calm/Relaxing Joyous/Cheerful Anxious/Tense Sad/Depressing Sad/Depressing Sad/Depressing Calm/Relaxing	Piece Exemplar Num 3 4 4 5 5 5 6 6 6 6 6 6 7	B, Version 1 Transition Type NA NA NN NP PP PN NN PP PN NN NP PN NN N	Onset 0 45 102 159 219 279 336 339 435 510 567 624	Offset 36 93 150 210 267 327 390 426 501 558 615 615 672	Duration 36 48 48 51 48 51 54 27 66 48 48 48 48 48 48 48 48 48 48	Emotion Dreamy/Noslaigic Anxious/Tense Sad/Depressing Joyous/Cheerful Calm/Relaxing Anxious/Tense Sad/Depressing Calm/Relaxing Joyous/Cheerful Sad/Depressing Anxious/Tense Joyous/Cheerful	Exemplar Num 3 4 5 5 5 5 6 6 6 6 7	Piece B, Vers Transition Type NA NA NN NN PP PN NN NP PP PN NN NN NN NN NN	sion 2 Onset 0 45 102 159 219 279 336 333 468 504 567 627	Offeet 36 93 150 210 277 327 384 459 495 558 615 675	Duration 36 48 48 51 51 48 48 48 48 66 27 54 48 48 48 48 48 48 48 48 48 4
Event Num 1 2 3 4 5 6 7 8 9 10 11 12 13	Emotion Dreamy/Nosialgic Sad/Depressing Anxious/Tense Catm/Relaxing Joyous/Cheerful Catm/Relaxing Sad/Depressing Joyous/Cheerful Catm/Relaxing Sad/Depressing Anxious/Tense Catm/Relaxing Joyous/Cheerful	Piece Exemplar Num 3 4 5 5 6 6 6 7	B, Version 1 Transition Type NA NA NA NP PN NN PP PN NN PP PN NN PP PN NN PP PN PN PN PN PN PN PP PN PP PN PN	Onset 0 45 102 159 219 279 336 399 435 510 567 624 678	Offset 36 93 150 210 267 327 390 426 501 558 615 572 726	Duration 36 48 48 51 48 54 27 66 48 48 48 54 27 66 48 48 48 48 48 48 48 48 48 48	Emotion Dream y/Noslaigic Anxious/Tense Sad/Depressing Joyous/Chocrful Calm/Relaxing Anxious/Tense Sad/Depressing Calm/Relaxing Joyous/Cheerful Sad/Depressing Anxious/Tense Joyous/Cheerful Calm/Relaxing	Exemplar Num 3 4 5 5 5 5 6 6 6 6 6 6 7 7	Piece B, Vers Transition Type NA NA NP PP PN NN NP PP PN NN NN NN NP PP PN NN N	sion 2 Onset 0 45 102 159 219 279 336 393 4468 504 567 684	Offset 36 93 150 210 270 327 324 459 495 558 615 575 727	Duration 36 48 48 51 51 48 48 48 48 66 27 54 48 48 43
Event Num 1 2 3 4 5 6 7 8 9 9 10 11 12 13 14 -	Emotion Dreamy/Noslalgic Sad/Depressing Anxious/Cheefful Joyous/Cheefful Anxious/Tense Sad/Depressing Sad/Depressing Sad/Depressing Anxious/Tense Calm/Relaxing Joyous/Cheefful Anxious/Tense	Piece Exemplar Num 3 4 5 5 5 6 6 6 6 7 7 7 7	B, Version 1 Transition Type NA NA NP PP PN NP PN NP PN NN NP PN NN N	Onset 0 45 102 219 219 2279 336 399 435 5510 567 624 678 735	Cffset 36 83 150 210 267 390 428 551 558 651 558 615 672 725 725	Duration 36 48 48 48 48 48 48 48 48 48 48	Emotion Dreamy/Noslaigic Anxious/Tense Sad/Depressing Joyous/Chcorful Calm/Relaxing Anxious/Tense Sad/Depressing Calm/Relaxing Joyous/Cheerful Sad/Depressing Anxious/Tense Joyous/Cheerful Calm/Relaxing Sad/Depressing	Exemplar Num 3 4 5 5 5 6 6 6 7 7 7 7	Piece B, Vers Transition Type NA NA NN NP PP PN NN NP PP PN NN NP PP PN NN N	sion 2 Onset 0 45 102 159 219 279 336 339 3468 504 567 627 684 735	Offeet 36 93 150 210 270 327 384 459 495 558 815 675 727 807	Duration 36 48 51 51 48 48 48 48 48 48 27 54 48 48 43 43 72

Supplementary Table 1: Event order and timing for both versions of the two musical pieces. Onset, offset, and duration are in seconds. PP = positive to positive transition; PN = positive to negative transition; NP = negative to positive transition; NN = negative transition; NA = not applicable.