Emotional Arousal Predicts Pupil Responses When Attended Luminance Changes

Affective Science

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Online Resource

Supplementary Methods

Block-specific emotional-rating slope summaries

To aid interpretation of the nonsignificant rating-by-block interactions in the main time-resolved mixed-effects analysis, we derived block-specific slopes for arousal and valence from the fitted fixed-effect coefficients. In the main model, block was effect-coded as −0.5 for block 1 and +0.5 for block 2. Therefore, the coefficient for each rating-by-block interaction represented the difference in the corresponding rating slope between block 2 and block 1.

For each 100-ms time bin from 0 to 6 s after sound onset, the block-specific arousal slope for block 1 was calculated as the arousal main-effect coefficient minus one half of the arousal-by-block interaction coefficient, and the block-specific arousal slope for block 2 was calculated as the arousal main-effect coefficient plus one half of the arousal-by-block interaction coefficient. Block-specific valence slopes were derived analogously from the valence main-effect coefficient and the valence-by-block interaction coefficient.

These block-specific slopes were summarized descriptively in Fig. S2 and Table S2. Formal inference about block differences was based on the arousal-by-block and valence-by-block interaction terms in the main analysis; because neither interaction survived Benjamini–Hochberg false discovery rate correction, the block-specific slope summaries were interpreted descriptively.

Arousal–valence association and multicollinearity diagnostics

Because arousal and valence ratings were entered simultaneously in the main mixed-effects model, we examined their association and assessed multicollinearity among the fixed-effect predictors. Arousal and valence ratings were z-standardized within each participant at the trial level. We then computed the Pearson correlation between arousal and valence ratings across included trials. Participant-level Pearson correlations were also calculated to describe the distribution of within-participant arousal–valence associations.

Variance inflation factors were calculated for the fixed-effect predictors included in the main model: arousal, valence, block, the arousal-by-block interaction, and the valence-by-block interaction. VIFs were computed as design-matrix diagnostics and did not use pupil responses as an outcome variable. These diagnostics are summarized in Fig. S3 and Table S3.

Window-level random-slope robustness analysis

To test whether the arousal effect was robust when the post-sound pupil response was summarized over time, we fitted window-level mixed-effects models using the mean pupil response across the full 0–6 s post-sound interval as the dependent variable. The fixed-effect structure was the same as in the main model and included arousal, valence, block, the arousal-by-block interaction, and the valence-by-block interaction.

We fitted models with different random-effects structures, including a random-intercept model, a model with a subject-specific random slope for arousal, and models with subject-specific random slopes for both arousal and valence. This analysis tested whether the positive arousal effect was preserved when the post-sound response was summarized as a single window-level outcome and when the arousal effect was allowed to vary across participants. Fixed-effect estimates from these models are summarized in Table S4

Baseline pupil-size covariate robustness analysis

To examine whether the arousal effect could be explained by trial-to-trial variation in pre-sound pupil size, we repeated the bin-wise mixed-effects analysis after adding trial-level baseline pupil size as a covariate. Baseline pupil size was defined as the mean filtered pupil size during the 500-ms pre-sound baseline interval, from −0.5 to 0 s relative to sound onset. This was the same baseline interval used to compute the percentage-change pupil response. The baseline pupil-size covariate was z-standardized at the trial level and entered as an additional predictor.

The model included arousal, valence, block, baseline pupil size, the arousal-by-block interaction, and the valence-by-block interaction, with subject-specific random intercepts. As in the main analysis, models were fitted separately for each 100-ms time bin, and Benjamini–Hochberg false discovery rate correction was applied across time bins for each effect. The arousal effect after baseline adjustment and the baseline pupil-size covariate effect are shown in Fig. S4 and summarized in Table S5.

Eye-movement covariate robustness analysis

To evaluate whether the arousal-related pupil effect could be accounted for by concurrent eye-movement-related activity, we repeated the bin-wise mixed-effects analysis after adding trial-level eye-movement covariates computed over the 0–6 s post-sound interval. Two covariates were used: quick-phase rate and mean absolute eye velocity. Quick-phase rate was defined as the number of detected quick phases whose onset occurred between 0 and 6 s after sound onset, divided by the 6-s interval duration. Mean absolute eye velocity was defined as the trial-level mean Euclidean eye speed over the same interval. Invalid gaze samples, zero-valued gaze samples, samples flagged by the gross gaze mask, nonpositive sampling intervals, nonfinite velocities, and speeds greater than 1000 deg/s were excluded before computing the velocity measure.

The eye-movement covariates were z-standardized at the trial level and entered into three robustness models: one model including quick-phase rate, one model including mean absolute eye velocity, and one model including both covariates. A corresponding model without eye-movement covariates was also included for comparison. Models were fitted separately for each 100-ms time bin, and p values were adjusted across time bins using the Benjamini–Hochberg procedure separately for each model and effect. The arousal effect across eye-movement covariate models and the corresponding covariate effects are shown in Fig. S5 and summarized in Table S6.

Within-block trial-order robustness analysis

Because block order was fixed, global trial number was confounded with block. Therefore, to assess fatigue, habituation, or time-on-task effects without duplicating the block factor, we used within-block trial order as a covariate. Within-block trial order was defined as the dense rank of trial number within each subject and block and was z-standardized at the trial level.

We fitted three bin-wise models. The first was the reference model without a trial-order covariate. The second added within-block trial order as an additional covariate. The third additionally included the arousal-by-trial-order interaction to test whether the arousal effect itself changed over the course of each block. These models were fitted separately for each 100-ms time bin, and p values were adjusted across time bins using the Benjamini–Hochberg procedure separately for each model and effect. The arousal effect across trial-order robustness models and the trial-order-related effects are shown in Fig. S6 and summarized in Table S7.

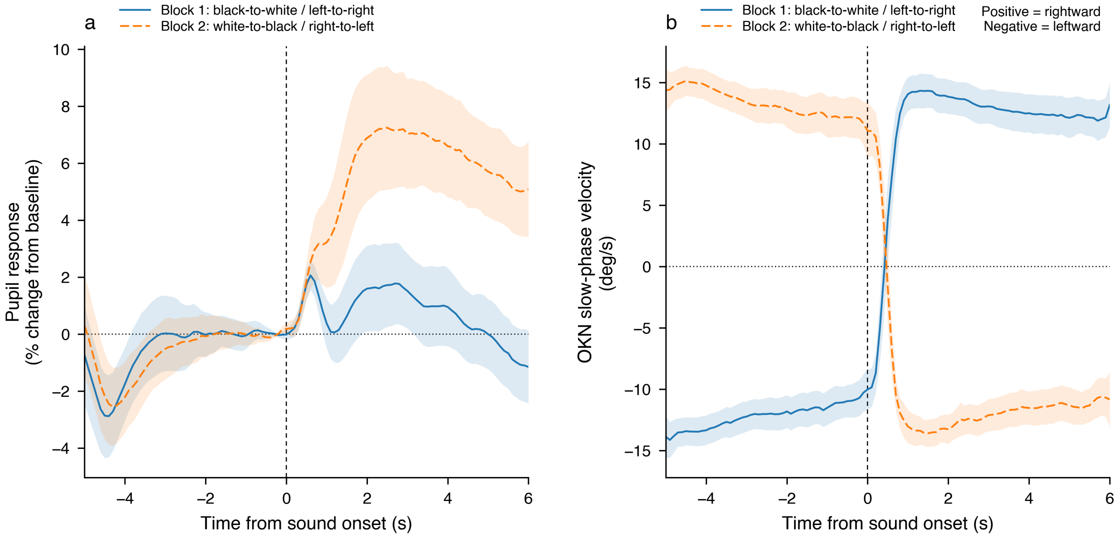

Fig. S1 Long-window pupil and optokinetic response time courses. (a) Grand-average pupil responses from −5 to 6 s relative to sound onset, expressed as percentage change from the 500-ms pre-sound baseline. The pupil traces are baseline-corrected for visualization of the broader time course and were not used to test pre-sound block differences. (b) Grand-average OKN slow-phase velocity over the same interval. Positive OKN slow-phase velocity values indicate rightward motion on the screen, whereas negative values indicate leftward motion. Trial-averaged responses were first computed within each participant and then averaged across participants separately for block 1 and block 2. Block 1 corresponds to the black-to-white, left-to-right condition, and block 2 corresponds to the white-to-black, right-to-left condition. Shaded areas indicate 95% t-based confidence intervals across participants

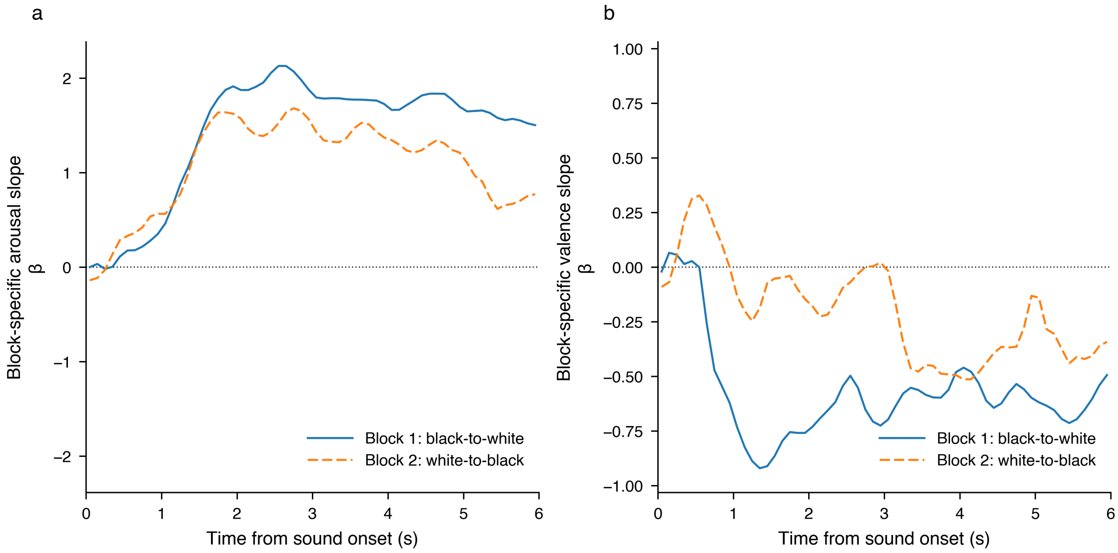

Fig. S2 Block-specific emotional-rating slopes. (a) Block-specific arousal slopes derived from the fitted arousal-by-block interaction model. (b) Block-specific valence slopes derived from the fitted valence-by-block interaction model. Block 1 corresponds to the black-to-white condition, and block 2 corresponds to the white-to-black condition. These block-specific slopes are shown descriptively; formal tests of block differences were based on the rating-by-block interaction terms shown in Fig. 4c and 4d, neither of which survived Benjamini–Hochberg false discovery rate correction

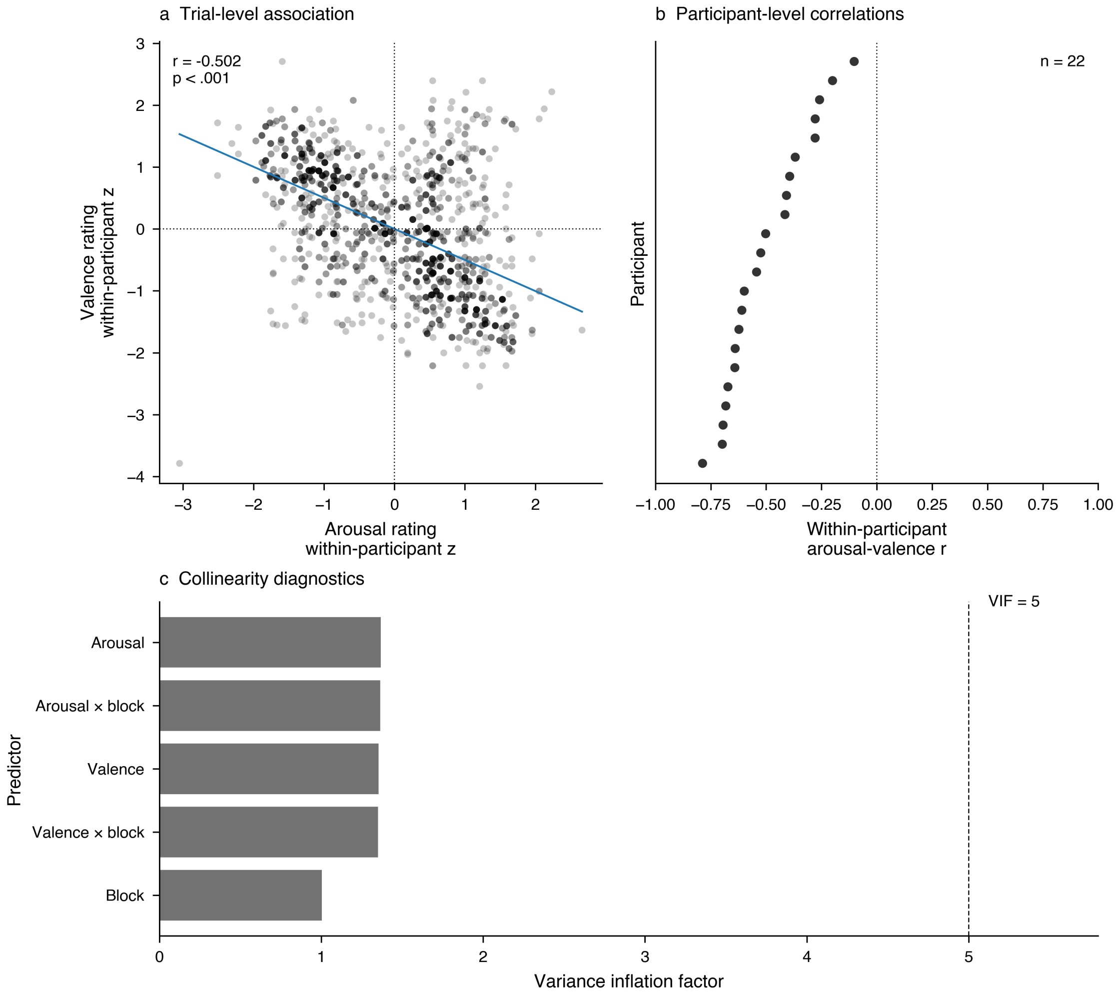

Fig. S3 Arousal–valence association and multicollinearity diagnostics. (a) Trial-level association between within-participant z-standardized arousal and valence ratings. Points indicate individual trials, and the line indicates the fitted linear trend. (b) Distribution of participant-level Pearson correlations between arousal and valence ratings. (c) Variance inflation factors for fixed-effect predictors included in the main model. The dashed horizontal line indicates VIF = 5

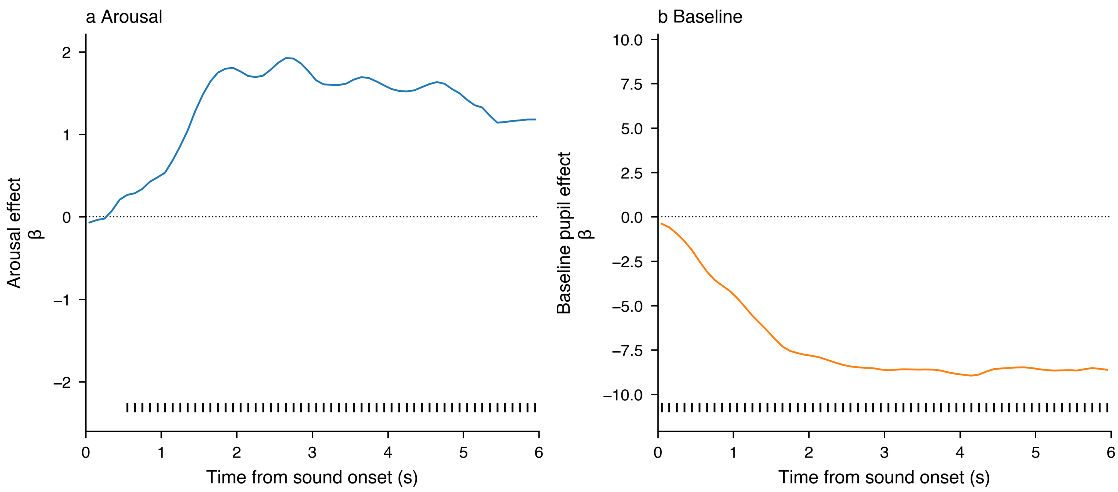

Fig. S4 Baseline pupil-size covariate robustness analysis. (a) Time-resolved arousal effect after adding trial-level baseline pupil size as a covariate. (b) Time-resolved effect of baseline pupil size on post-sound pupil responses. Black rug marks indicate time bins surviving Benjamini–Hochberg false discovery rate correction at $q < .05$

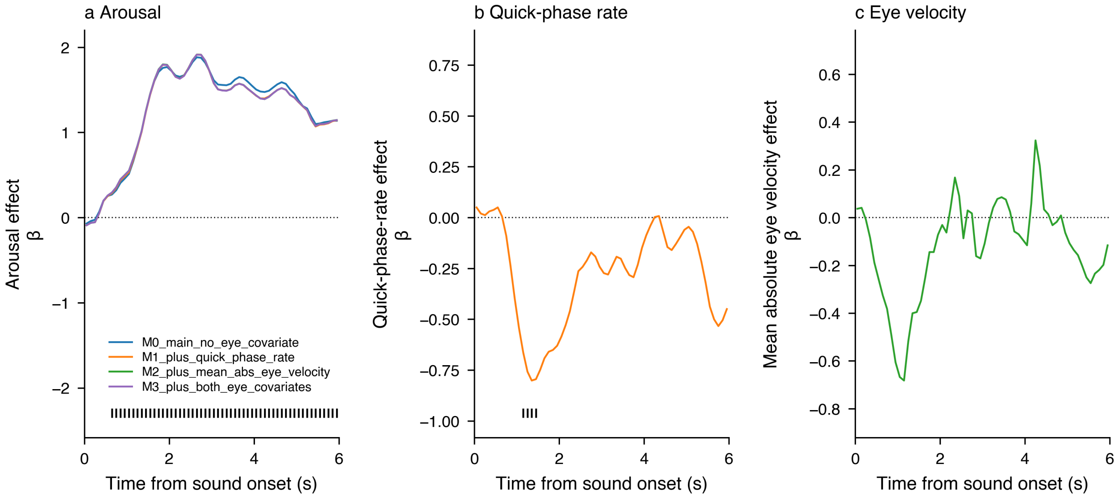

Fig. S5 Eye-movement covariate robustness analysis. (a) Time-resolved arousal effects across models with no eye-movement covariate, quick-phase rate, mean absolute eye velocity, or both eye-movement covariates. (b) Time-resolved effect of quick-phase rate. (c) Time-resolved effect of mean absolute eye velocity. Quick-phase rate and mean absolute eye velocity were computed over the 0–6 s post-sound interval. Black rug marks in a indicate FDR-significant bins for the fully adjusted model including both eye-movement covariates; black rug marks in b indicate FDR-significant bins for the quick-phase-rate covariate effect. No time bins survived FDR correction for the mean absolute eye velocity effect in c

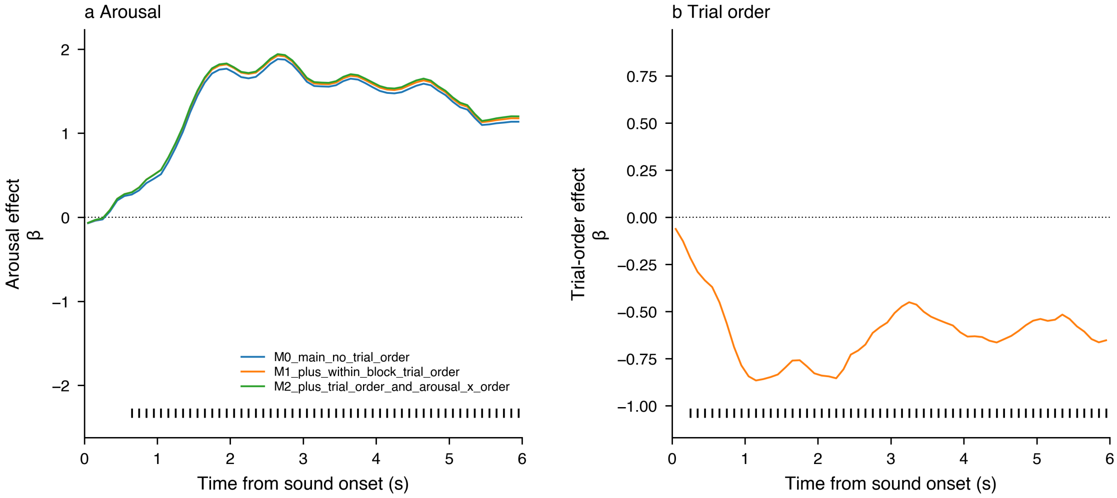

Fig. S6 Trial-order robustness analysis. (a) Time-resolved arousal effects across models with and without within-block trial-order covariates. (b) Time-resolved effect of within-block trial order. In a, M0 denotes the reference model, M1 denotes the model including within-block trial order as an additional covariate, and M2 denotes the model additionally allowing the arousal effect to vary with trial order. Black rug marks in a indicate FDR-significant bins for the trial-order-adjusted model; black rug marks in b indicate FDR-significant bins for the trial-order covariate effect

Table S1 Sound stimuli selected from the IADS-E database

Stimulus ID	Source	Description	Category	Sound ID	BE Classification	AroMN	AroSD	ValMN	ValSD	DomMN	DomSD	FearMN	FearSD	HapMN	HapSD	SadMN	SadSD
1	Expanded	Machine18	Daily Routine Sound	0762	F	8.46	0.83	2.33	1.09	2.88	1.90	6.29	1.85	2.00	1.47	2.46	1.84
2	Expanded	Electronic Sound37	Electric sound	0759	F	8.33	0.70	2.17	1.40	2.92	2.48	7.04	1.08	1.75	1.33	2.71	2.20
3	Expanded	Bomb3	Breaking Sound	0295	F	8.04	0.86	3.04	1.30	3.04	2.16	6.54	1.89	2.33	1.71	2.58	2.24
4	Expanded	Hurricane2	Nature	0777	F	7.83	0.82	2.13	1.12	2.83	1.76	6.92	1.84	1.58	0.88	3.25	2.21
5	Expanded	VideoGame8	Electric sound	0771	FH	7.50	0.78	4.33	1.81	3.83	1.97	4.25	2.40	4.50	2.67	1.46	0.83
6	Expanded	Documentary7	Sound Effect	0325	F	7.23	1.38	4.32	1.43	3.64	2.24	5.32	1.86	3.36	2.38	2.18	1.56
7	Expanded	Jazz1	Music	1073	H	6.77	1.63	7.95	1.46	6.27	2.03	1.27	0.46	7.50	1.90	1.59	1.14
8	Expanded	Scared	People	0355	FS	6.50	1.79	1.82	1.30	4.18	2.77	6.50	2.30	1.36	0.95	4.86	2.90
9	Expanded	Siren6	Transport	1039	F	6.29	1.49	3.00	1.79	3.13	1.73	5.29	2.49	2.25	1.80	3.13	2.05
10	Expanded	Wings2	Animals	0373	U	5.88	1.51	4.08	1.38	4.64	2.31	3.72	2.35	3.20	1.73	2.88	2.15
11	Expanded	Wolking	People	0278	FH	5.45	1.37	4.91	1.27	5.82	1.92	3.09	2.43	2.77	1.77	1.68	1.29
12	Expanded	Machine6	Daily Routine Sound	0376	F	4.73	1.58	3.95	1.62	5.00	1.98	3.77	2.60	2.27	1.49	1.77	1.07
13	Expanded	Thunder4	Nature	0999	F	4.42	2.15	3.29	1.60	4.67	2.33	4.96	2.58	1.92	1.25	3.21	2.34
14	Expanded	Sci-Fi mystery3	Sound Effect	0195	U	4.00	1.20	5.09	1.41	5.09	2.07	3.45	2.32	2.73	1.83	2.59	1.71
15	Expanded	Cicada2	Animals	0335	H	3.79	1.96	7.04	1.65	5.29	2.60	1.92	1.41	5.29	2.18	2.96	2.29
16	Expanded	LightMusic18	Music	1161	H	3.46	1.28	6.42	1.10	5.46	2.04	2.08	1.47	4.75	1.89	2.92	2.55
17	Expanded	Documentary11	Sound Effect	1165_b	HS	3.14	1.73	6.55	1.77	6.64	1.81	2.73	2.07	3.82	1.94	3.86	2.46
18	Expanded	LightMusic22	Music	1170_b	HS	2.83	1.27	7.13	1.42	5.58	2.43	1.79	1.25	3.50	2.04	2.79	1.74
19	Expanded	LightMusic3	Music	1122	H	2.23	1.72	7.50	1.54	6.05	2.66	1.59	0.85	5.59	2.26	3.27	2.33
20	Expanded	LightMusic12	Music	1133	H	1.91	1.06	7.41	1.26	6.59	1.99	1.59	1.01	5.14	2.25	2.14	1.28
21	Expanded	Country Music7	Music	1085	H	7.77	1.02	8.09	1.19	6.50	1.82	1.32	0.65	8.00	1.51	1.18	0.39
22	Expanded	Piano4	Music	1074_b	H	3.45	1.71	8.05	1.43	6.14	1.86	1.36	0.73	5.00	2.51	3.55	2.39
23	Expanded	Birds2	Animals	0419	H	4.55	2.36	7.86	0.99	6.68	2.01	1.18	0.39	6.95	1.17	1.41	0.80
24	Expanded	LightMusic19	Music	1162	H	3.41	2.11	7.55	1.14	6.09	1.51	1.68	0.99	4.64	1.87	2.45	1.34
25	Expanded	Water Tap	Daily Routine Sound	1038	H	3.40	2.00	7.08	2.06	6.76	2.24	2.08	2.10	4.36	2.46	2.52	2.38
26	Expanded	Suspense Film18	Sound Effect	0089	H	4.68	2.03	6.77	1.15	5.27	1.98	2.00	1.31	5.05	1.62	2.41	1.56
27	Expanded	Brook2	Nature	0298	H	3.71	1.81	6.46	1.38	5.92	2.47	1.92	1.25	4.58	2.00	2.08	1.18
28	Expanded	School Bell	Daily Routine Sound	0491	H	5.71	1.73	6.04	1.23	6.04	2.05	2.04	1.30	5.21	1.96	2.75	2.03
29	Expanded	Train3	Transport	0255	H	5.91	1.44	5.50	1.30	5.45	1.68	2.05	1.21	6.09	1.48	1.68	0.89
30	Expanded	FunkMusic1	Music	1091	H	6.50	1.74	5.13	1.96	4.58	1.95	2.83	1.99	5.13	2.44	2.13	1.39
31	Expanded	Fire1	Daily Routine Sound	0688	U	3.54	1.28	4.79	0.98	6.54	1.86	2.83	1.79	2.46	1.53	2.21	1.50
32	Expanded	Wind9	Nature	1045	F	4.50	1.62	4.38	1.53	4.88	2.09	4.54	2.32	2.17	1.49	3.33	2.20
33	Expanded	Mystery BGM15	Sound Effect	1378	U	4.36	1.84	3.82	1.68	4.77	2.47	5.68	2.53	2.00	1.60	3.73	2.23
34	Expanded	Airplane1	Transport	1377	F	5.18	1.47	3.41	1.53	4.45	1.82	5.82	1.82	2.55	1.60	3.23	1.82
35	Expanded	Hog	Animals	0553	F	7.17	0.76	3.25	1.19	3.13	1.85	5.96	2.24	2.29	1.65	2.33	1.81
36	Expanded	BabyLaugh2	People	1386	F	4.77	1.82	2.82	0.96	4.77	2.43	5.95	2.63	1.95	1.25	2.64	2.24
37	Expanded	Firearm	Breaking Sound	0604	F	7.32	2.15	2.52	1.39	2.64	2.31	7.36	1.47	2.08	1.53	4.56	2.62
38	Expanded	VideoGame9	Electric sound	0775	F	7.36	1.47	2.36	1.33	4.05	2.38	4.32	2.92	2.18	1.87	2.18	1.65
39	Expanded	Sci-Fi18	Sound Effect	0128	F	6.05	1.68	1.68	0.89	2.59	1.26	6.95	1.33	2.18	1.56	3.91	1.80
40	Expanded	CarHorn	Transport	0379	F	7.80	1.71	1.28	0.54	3.32	3.11	6.92	2.14	1.20	0.50	3.72	2.70

Note. Stimulus ID indicates the identifier assigned to each sound stimulus in the present experiment. All other columns were taken from the IADS-E database. Sound ID indicates the original IADS-E sound identifier. Aro, Val, and Dom indicate normative arousal, valence, and dominance ratings, respectively; MN and SD indicate the mean and standard deviation of the normative ratings. Fear, Hap, and Sad indicate normative fear, happiness, and sadness ratings, respectively. BE Classification indicates the basic-emotion classification provided in the IADS-E database.

Table S2 Block-specific slope summaries for emotional-rating effects

effect	term	n_bins	mean_beta	median_beta	min_beta	max_beta	n_positive_bins	n_negative_bins	minimum_q_for_interaction	n_fdr_significant_interaction_bins
arousal	Block 1: black-to-white	60	1.42339	1.706159	-0.019435	2.129138	58	2	0.677667	0
arousal	Block 2: white-to-black	60	1.073728	1.268618	-0.140283	1.681685	57	3	0.677667	0
arousal	Block 2 minus Block 1 arousal slope	60	-0.349662	-0.367037	-0.964015	0.256803	8	52	0.677667	0
valence	Block 1: black-to-white	60	-0.568804	-0.608351	-0.921094	0.065621	4	56	0.458185	0
valence	Block 2: white-to-black	60	-0.200811	-0.193804	-0.513917	0.327836	11	49	0.458185	0
valence	Block 2 minus Block 1 valence slope	60	0.367992	0.338744	-0.134394	0.838277	54	6	0.458185	0

Note:The table summarizes block-specific arousal and valence slopes derived from the fitted interaction models, together with the corresponding rating-by-block interaction summaries. Block-specific slopes are interpreted descriptively because neither the arousal-by-block nor valence-by-block interaction survived Benjamini–Hochberg false discovery rate correction.

Table S3 Arousal–valence association and multicollinearity diagnostics

section	term	estimate	p_value	ci_low	ci_high	n	vif	tolerance	r2
Overall arousal-valence correlation	Arousal vs valence	-0.502	<.001	-0.538	-0.464	1602			
Block-wise arousal-valence correlation	Block 1: black-to-white	-0.471	<.001	-0.523	-0.416	813			
Block-wise arousal-valence correlation	Block 2: white-to-black	-0.536	<.001	-0.584	-0.485	789			
Participant-level arousal-valence correlations	Across participants	-0.496		-0.58	-0.413	22			
Participant-level arousal-valence correlations	Across participants	-0.534		-0.787	-0.102	22			
Variance inflation factor	Arousal					1602	1.367	0.732	0.268
Variance inflation factor	Valence					1602	1.354	0.739	0.261
Variance inflation factor	Block					1602	1.003	0.997	0.003
Variance inflation factor	Arousal × block					1602	1.364	0.733	0.267
Variance inflation factor	Valence × block					1602	1.351	0.74	0.26

Note: Arousal and valence ratings were z-standardized within participant before computing correlations and VIFs. Estimates for correlation rows indicate Pearson’s r. VIFs were computed for the fixed-effect predictors in the main mixed-effects model.

Table S4 Window-level random-slope robustness analysis

Model	Term	Estimate	SE	df	t	p	95% CI low	95% CI high
M0_random_intercept	arousal_z	1.248708	0.17747	1579.654286	7.036173	0	0.900607	1.596809
M1_random_intercept_arousal_slope	arousal_z	1.252894	0.19024	97.96638	6.585865	0	0.875368	1.630421
M2_random_intercept_arousal_valence_slopes_correlated	arousal_z	1.24699	0.189262	29.503596	6.588699	0	0.860193	1.633788
M3_random_intercept_arousal_valence_slopes_uncorrelated	arousal_z	1.248708	0.17747	1579.654286	7.036173	0	0.900607	1.596809
M0_random_intercept	arousal_z:block_ec	-0.348402	0.355893	1581.959663	-0.978951	0.327754	-1.046475	0.34967
M1_random_intercept_arousal_slope	arousal_z:block_ec	-0.314547	0.355368	1581.850461	-0.885129	0.376222	-1.01159	0.382496
M2_random_intercept_arousal_valence_slopes_correlated	arousal_z:block_ec	-0.325193	0.35538	1556.919168	-0.915056	0.360304	-1.022268	0.371882
M3_random_intercept_arousal_valence_slopes_uncorrelated	arousal_z:block_ec	-0.348402	0.355893	1581.959663	-0.978951	0.327754	-1.046475	0.34967
M0_random_intercept	block_ec	4.778265	0.302392	1581.024097	15.801576	0	4.185134	5.371396
M1_random_intercept_arousal_slope	block_ec	4.776427	0.301963	1580.977769	15.817942	0	4.184137	5.368716
M2_random_intercept_arousal_valence_slopes_correlated	block_ec	4.771746	0.301921	1578.480504	15.804607	0	4.179537	5.363954
M3_random_intercept_arousal_valence_slopes_uncorrelated	block_ec	4.778265	0.302392	1581.024096	15.801576	0	4.185134	5.371396
M0_random_intercept	valence_z	-0.38457	0.176627	1579.647656	-2.1773	0.029606	-0.731018	-0.038122
M1_random_intercept_arousal_slope	valence_z	-0.375575	0.176467	1578.749971	-2.128301	0.033467	-0.72171	-0.029441
M2_random_intercept_arousal_valence_slopes_correlated	valence_z	-0.379986	0.17937	33.903213	-2.118444	0.041546	-0.744548	-0.015423
M3_random_intercept_arousal_valence_slopes_uncorrelated	valence_z	-0.38457	0.176627	1579.647656	-2.1773	0.029606	-0.731018	-0.038122
M0_random_intercept	valence_z:block_ec	0.373713	0.355718	1585.314229	1.050589	0.293608	-0.324014	1.07144
M1_random_intercept_arousal_slope	valence_z:block_ec	0.388069	0.355135	1584.808938	1.092736	0.274676	-0.308515	1.084652
M2_random_intercept_arousal_valence_slopes_correlated	valence_z:block_ec	0.380194	0.355146	1559.419253	1.070528	0.284547	-0.316421	1.076809
M3_random_intercept_arousal_valence_slopes_uncorrelated	valence_z:block_ec	0.373713	0.355718	1585.314229	1.050589	0.293608	-0.324014	1.07144

Note. Estimates are fixed-effect coefficients from window-level mixed-effects models using the mean pupil response across the 0–6 s post-sound interval. CI = confidence interval.

Table S5 Baseline pupil-size covariate robustness analysis

analysis	term	n_bins	mean_beta	beta_range	minimum_q	n_fdr_significant_bins	first_fdr_significant_time_s	last_fdr_significant_time_s
Baseline pupil-size covariate robustness	Arousal	60	1.284745	-0.069 to 1.925	0	55	0.55	5.95
Baseline pupil-size covariate robustness	Valence	60	-0.304174	-0.506 to 0.192	0.072489	0		
Baseline pupil-size covariate robustness	Block	60	1.075191	-1.018 to 1.897	0.000096	55	0.25	5.95
Baseline pupil-size covariate robustness	Baseline pupil	60	-7.149923	-8.942 to -0.386	0	60	0.05	5.95
Baseline pupil-size covariate robustness	Arousal × block	60	-0.21304	-0.800 to 0.328	0.803445	0		
Baseline pupil-size covariate robustness	Valence × block	60	0.336592	-0.138 to 0.795	0.30052	0		

Note. β values are fixed-effect estimates from bin-wise mixed-effects models including baseline pupil size as an additional covariate. n_bins indicates the number of 100-ms time bins from 0 to 6 s after sound onset. q values were obtained using Benjamini–Hochberg false discovery rate correction.

Table S6 Eye-movement covariate robustness analysis

analysis	term	n_bins	mean_beta	beta_range	minimum_q	n_fdr_significant_bins	first_fdr_significant_time_s	last_fdr_significant_time_s
Eye-movement covariate robustness: M0_main_no_eye_covariate	Arousal	60	1.248559	-0.070 to 1.883	0	54	0.65	5.95
Eye-movement covariate robustness: M0_main_no_eye_covariate	Valence	60	-0.384808	-0.578 to 0.170	0.076252	0		
Eye-movement covariate robustness: M0_main_no_eye_covariate	Block	60	4.777595	-0.111 to 6.353	0	54	0.65	5.95
Eye-movement covariate robustness: M0_main_no_eye_covariate	Quick-phase rate	0				0		
Eye-movement covariate robustness: M0_main_no_eye_covariate	Mean absolute eye velocity	0				0		
Eye-movement covariate robustness: M0_main_no_eye_covariate	Arousal × block	60	-0.349662	-0.964 to 0.257	0.677667	0		
Eye-movement covariate robustness: M0_main_no_eye_covariate	Valence × block	60	0.367992	-0.134 to 0.838	0.458185	0		
Eye-movement covariate robustness: M1_plus_quick_phase_rate	Arousal	60	1.226224	-0.090 to 1.914	0	53	0.75	5.95
Eye-movement covariate robustness: M1_plus_quick_phase_rate	Valence	60	-0.365374	-0.598 to 0.212	0.145454	0		
Eye-movement covariate robustness: M1_plus_quick_phase_rate	Block	60	4.817202	0.017 to 6.272	0	54	0.65	5.95
Eye-movement covariate robustness: M1_plus_quick_phase_rate	Quick-phase rate	60	-0.284873	-0.801 to 0.050	0.037403	4	1.15	1.45
Eye-movement covariate robustness: M1_plus_quick_phase_rate	Mean absolute eye velocity	0				0		
Eye-movement covariate robustness: M1_plus_quick_phase_rate	Arousal × block	60	-0.147449	-0.625 to 0.350	0.942821	0		
Eye-movement covariate robustness: M1_plus_quick_phase_rate	Valence × block	60	0.572009	-0.054 to 1.122	0.099511	0		
Eye-movement covariate robustness: M2_plus_mean_abs_eye_velocity	Arousal	60	1.230063	-0.091 to 1.914	0	54	0.65	5.95
Eye-movement covariate robustness: M2_plus_mean_abs_eye_velocity	Valence	60	-0.377138	-0.608 to 0.223	0.113858	0		
Eye-movement covariate robustness: M2_plus_mean_abs_eye_velocity	Block	60	4.805599	0.033 to 6.240	0	55	0.55	5.95
Eye-movement covariate robustness: M2_plus_mean_abs_eye_velocity	Quick-phase rate	0				0		
Eye-movement covariate robustness: M2_plus_mean_abs_eye_velocity	Mean absolute eye velocity	60	-0.126149	-0.682 to 0.323	0.145688	0		
Eye-movement covariate robustness: M2_plus_mean_abs_eye_velocity	Arousal × block	60	-0.151271	-0.629 to 0.346	0.942619	0		
Eye-movement covariate robustness: M2_plus_mean_abs_eye_velocity	Valence × block	60	0.565953	-0.052 to 1.107	0.106558	0		
Eye-movement covariate robustness: M3_plus_both_eye_covariates	Arousal	60	1.228803	-0.091 to 1.913	0	54	0.65	5.95
Eye-movement covariate robustness: M3_plus_both_eye_covariates	Valence	60	-0.360416	-0.608 to 0.220	0.145338	0		
Eye-movement covariate robustness: M3_plus_both_eye_covariates	Block	60	4.835479	0.030 to 6.289	0	54	0.65	5.95
Eye-movement covariate robustness: M3_plus_both_eye_covariates	Quick-phase rate	60	-0.279497	-0.779 to 0.072	0.05033	0		
Eye-movement covariate robustness: M3_plus_both_eye_covariates	Mean absolute eye velocity	60	-0.106827	-0.638 to 0.325	0.265067	0		
Eye-movement covariate robustness: M3_plus_both_eye_covariates	Arousal × block	60	-0.146635	-0.622 to 0.351	0.941114	0		
Eye-movement covariate robustness: M3_plus_both_eye_covariates	Valence × block	60	0.570765	-0.052 to 1.117	0.107234	0		

Note. β values are fixed-effect estimates from bin-wise mixed-effects models including eye-movement covariates. n_bins indicates the number of 100-ms time bins from 0 to 6 s after sound onset. q values were obtained using Benjamini–Hochberg false discovery rate correction. Quick-phase rate and mean absolute eye velocity were computed over the 0–6 s post-sound interval.

Table S7 Trial-order robustness analysis

analysis	term	n_bins	mean_beta	beta_range	minimum_q	n_fdr_significant_bins	first_fdr_significant_time_s	last_fdr_significant_time_s
Trial-order robustness: M0_main_no_trial_order	Arousal	60	1.248559	-0.070 to 1.883	0	54	0.65	5.95
Trial-order robustness: M0_main_no_trial_order	Valence	60	-0.384808	-0.578 to 0.170	0.076252	0		
Trial-order robustness: M0_main_no_trial_order	Block	60	4.777595	-0.111 to 6.353	0	54	0.65	5.95
Trial-order robustness: M0_main_no_trial_order	Trial order	0				0		
Trial-order robustness: M0_main_no_trial_order	Arousal × block	60	-0.349662	-0.964 to 0.257	0.677667	0		
Trial-order robustness: M0_main_no_trial_order	Valence × block	60	0.367992	-0.134 to 0.838	0.458185	0		
Trial-order robustness: M0_main_no_trial_order	Arousal × trial order	0				0		
Trial-order robustness: M1_plus_within_block_trial_order	Arousal	60	1.286231	-0.066 to 1.924	0	55	0.55	5.95
Trial-order robustness: M1_plus_within_block_trial_order	Valence	60	-0.401371	-0.592 to 0.161	0.047814	3	1.15	1.35
Trial-order robustness: M1_plus_within_block_trial_order	Block	60	4.746181	-0.126 to 6.320	0	54	0.65	5.95
Trial-order robustness: M1_plus_within_block_trial_order	Trial order	60	-0.609154	-0.866 to -0.062	0	58	0.25	5.95
Trial-order robustness: M1_plus_within_block_trial_order	Arousal × block	60	-0.375222	-0.987 to 0.228	0.677676	0		
Trial-order robustness: M1_plus_within_block_trial_order	Valence × block	60	0.376947	-0.133 to 0.851	0.409379	0		
Trial-order robustness: M1_plus_within_block_trial_order	Arousal × trial order	0				0		
Trial-order robustness: M2_plus_trial_order_and_arousal_x_order	Arousal	60	1.299535	-0.066 to 1.942	0	55	0.55	5.95
Trial-order robustness: M2_plus_trial_order_and_arousal_x_order	Valence	60	-0.391855	-0.588 to 0.160	0.052466	0		
Trial-order robustness: M2_plus_trial_order_and_arousal_x_order	Block	60	4.758142	-0.127 to 6.341	0	54	0.65	5.95
Trial-order robustness: M2_plus_trial_order_and_arousal_x_order	Trial order	60	-0.614258	-0.866 to -0.062	0	58	0.25	5.95
Trial-order robustness: M2_plus_trial_order_and_arousal_x_order	Arousal × block	60	-0.393477	-1.008 to 0.230	0.648468	0		
Trial-order robustness: M2_plus_trial_order_and_arousal_x_order	Valence × block	60	0.366837	-0.135 to 0.844	0.417505	0		
Trial-order robustness: M2_plus_trial_order_and_arousal_x_order	Arousal × trial order	60	0.211684	-0.034 to 0.379	0.36662	0		

Note. β values are fixed-effect estimates from bin-wise mixed-effects models including within-block trial-order covariates. n_bins indicates the number of 100-ms time bins from 0 to 6 s after sound onset. q values were obtained using Be