Supplementary Materials for

ERP CORE: An Open Resource for Human Event-Related Potential Research

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Supplementary Materials and Methods

Stimuli and Tasks

Testing was conducted in a dimly lit, sound attenuated, and electrically shielded testing room. Visual stimuli were presented on a medium grey background (x = 0.35, y = 0.36, 25.9 cd/m^2) using a Hewlett-Packard ZR2440w LCD monitor with a resolution of 1280 x 1024, a refresh rate of 60 Hz, and a viewing distance of 100 cm. In LCD monitors, a substantial delay typically occurs between the video signal sent by the computer and the image presented on the display. We measured this delay using a photosensor, and the event codes for all visual stimuli were shifted offline by the measured value (26 ms) to align the event codes with the actual stimulus presentation onset.

Each visual paradigm included a white fixation point (0.15° visual angle) at the center of the display, and participants were instructed to maintain fixation on this point throughout the task and to withhold blinking until after making a response (in tasks that required a response). A height-adjustable table and chair were used to ensure a consistent and comfortable viewing position for each participant. Verbal instructions were given to the participant before the start of each task, followed by written instructions presented on the video display during the task. Reminder instructions were presented after each break.

Participants responded on a Logitech Precision gamepad. Unless otherwise specified, responses were made using the index and middle fingers of the dominant hand, and the stimulus-response mapping was counterbalanced across participants. Except as noted, participants were instructed to respond as quickly and accurately as possible.

The order of the six tasks was randomized across participants, and the task parameters were counterbalanced within participants wherever possible (see individual task descriptions below for details). Interstimulus intervals (ISIs) were jittered using a rectangular distribution to prevent phase-locking of alpha-band EEG oscillations to the stimulus sequence. Each block of trials began with a sequence of "Ready," "Set," "Go" screens. Participant-controlled rest breaks were provided between blocks.

Face perception N170. The N170 component was elicited in a face perception task, using the stimuli from Rossion & Caharel (2011). Figure 1A shows an example stimulus sequence. On each trial, a stimulus was selected at random from one of four categories: faces, cars, scrambled faces, and scrambled cars. Each stimulus subtended 3.32 x 3.78° of visual angle and was presented at the center of the screen for 300 ms, separated by an ISI of 1100-1300 ms during which only the fixation point was visible.

Face images excluded all background, clothing, and hair; car images excluded any background. The scrambled faces and scrambled cars were phase-randomized versions of the faces and cars (see Rossion & Caharel, 2011 for further details). Participants made a two-alternative buttonpress response on each trial to indicate whether the stimulus was an object (either face or car) or a texture (either scrambled face or scrambled car).

Each participant completed a total of 320 trials. Each category included 40 exemplars, each of which was presented twice, yielding 80 total trials of each stimulus category. The stimuli were presented in a randomly shuffled sequence, with the constraint that a given exemplar was presented only once in the first half and once in the second half of the session. The task was divided into blocks of 40 trials.

Passive auditory oddball MMN. The MMN was elicited in a passive auditory oddball task. Figure 1B shows an example stimulus sequence. The stimuli were 1000 Hz pure auditory tones, 100 ms in duration (including 5 ms rise and fall times), separated by a silent ISI of 450-550 ms. Tones were presented on two free-field speakers (Ensemble III, Cambridge SoundWorks, Cambridge, MA, USA), located 195 cm in front of the participant and 90 cm to the left or right of midline. The standard (p = .8) and deviant (p = .2) tones differed only in intensity. Standard stimuli were presented at 80 dB SPL (A weighted) and deviant stimuli were presented at 70 dB SPL (A weighted). The deviant was less intense than the standard to ensure that an increased ERP response to the deviant stimulus could not be the result of a greater intensity. To establish the auditory context for the standard, a stream of 15 standard stimuli was presented at the start of the task; all remaining stimuli were presented in a random order with the specified probabilities, except with the constraint that no two deviant tones could be presented sequentially. To avoid the problem of differential overlap that can arise from this constraint, the analysis involved comparing deviants (which were always preceded by a standard) to the subset of standards that were preceded by a standard. A total of 1000 tones were presented (including the initial stream of 15 standards), consisting of 800 standards and 200 deviants. Participants watched a silent movie of sand drawings (by artist Kseniya Simonova, https://www.youtube.com/watch?v=TtBOuPMZdoQ) that was presented in the center of the video display (5 x 5° visual angle) while the tones were presented. Participants were instructed to ignore the tones and to keep their eyes focused on the silent movie during the task, which was presented in a single block of trials. The timing of events in the movie was random with respect to the timing of the tones.

Simple visual search N2pc. The N2pc was elicited in a visual search task. Figure 1C shows an example stimulus sequence. On each trial, 12 items were presented in the left visual field and 12 items were presented in the right visual field. Each item was an outlined square (0.45 x 0.45°) with a gap (0.3° visual angle) on one side. The items were randomly scattered on each trial within an invisible box (2.5 x 5° visual angle) positioned starting 0.2° from fixation on either side, with a minimum distance of 0.1° between items. Eleven of the items in each visual field were black and had either a left-side or right-side gap (randomly and independently determined). In addition, one blue square (x = 0.28, y = 0.33, 116 cd/m^2) and one pink square (x = 0.35, y = 0.30, 118 cd/m^2) with a gap on either the top or bottom (randomly and independently determined) were presented on each trial. The blue and pink were equally distant from the gray background in the CIE (1976) color space. The pink item and blue item were always presented in opposite visual fields, with the location randomized across trials.

Each stimulus array was presented for 500 ms, separated by an ISI of 900-1100 ms. The fixation point was always visible. The blue item was the target for half of the task, and the pink item was the target for the other half; the order was counterbalanced across participants. Participants pressed a button to indicate the location of the gap in the target square using the index finger (top gap) and middle finger (bottom gap) of the dominant hand. Because the response mapping was natural (e.g., an upper buttonpress for a gap on the top), and the data were eventually collapsed across top and bottom gap positions, the stimulus-response mapping was held consistent across participants. Each participant completed a total of 320 trials, divided into blocks of 40.

Word pair judgment N400. The N400 was elicited in a semantic relatedness judgment task, in which each target word was preceded by a semantically associated or unassociated prime word. Figure 1D shows an example stimulus sequence. Words were selected using freely available association strength data (Kiss et al., 1973; Nelson et al., 2004), such that associated primes had an average forward association strength of 0.82 (range = 0.73 to 0.94) and unassociated primes had an average forward association strength of 0.0002 (range = 0 to 0.01). Associated and unassociated primes were matched in length (associated: mean = 5.417, range = 2-10;

unassociated: mean = 5.633, range = 3-10; t(59) = .614, $p = .541$) and lexical frequency (using logSUBTLwf values; associated: mean = 2.827, range = 1.079-5.698; unassociated: mean = 2.571, range = 1.301-4.650; t(57) = 1.273, $p = .208$; ref.[42]). Target words were an average of 4.65 characters long (range = 2–10) and had an average lexical frequency of 3.674 (range = 1.00–5.55). Each target word was presented twice in the experiment, once preceded by an associated prime word and once preceded by an unassociated prime word. Participants received a total of 60 associated word pairs and 60 unassociated word pairs. The order of word pairs was randomized with the constraint that each target word occurred only once within each half of the experiment.

The prime word on each trial was presented for 200 ms in red ($x = 0.65$, $y = 0.33$, 5.8 cd/m^2), followed by an ISI of 900-1100 ms. The target word was then presented for 200 ms in green ($x = 0.32$, $y = 0.60$, 13.6 cd/m^2), followed by an intertrial interval (ITI) of 1400-1600 ms. The prime and target words were presented in different colors to make it easier for participants to determine which word in the pair required a response. Participants were instructed to press one button if the target word was semantically related to the prime word and another button if the words were unrelated.

Words were presented in uppercase, Geneva font, with each letter in a word subtending approximately 1 x 1° of visual angle. Each word was centered at the fixation point, which was continuously visible. Each participant completed 120 trials, divided into blocks of 20.

Active visual oddball P3. The P3 was elicited in an active visual oddball paradigm. Figure 1E shows an example stimulus sequence. On each trial, one of five uppercase letters (A, B, C, D, or E, Geneva font, each subtending 2.5 x 2.5° of visual angle) was presented for 200 ms in the center of the screen over the fixation point. Successive stimuli were separated by an ISI of 1200-1400 ms.

Participants completed a total of 200 trials, divided into five blocks of 40 trials each. In each block, one letter was designated the target stimulus and the other four letters were designated non-targets. Participants pressed one button for targets and another button for non-targets. Each of the five letters served as a target in one block of the experiment and as a non-target in the other four blocks, with the order of blocks randomized across participants. Each letter was presented with equal probability within a block of trials ($p = .2$), such that the target category was rare ($p = .2$) and the non-target category was frequent ($p = .8$). This design eliminates any possible sensory differences between the target and non-target stimuli, including differential sensory adaptation of the individual target and non-target stimuli (see Luck, 2014).

Flankers ERN and LRP. The LRP and ERN were elicited using a variant of the Eriksen flanker task. Figure 1F shows an example stimulus sequence. A horizontal array of five arrowhead stimuli was presented on each trial, centered on a continuously visible fixation point. Each array was presented for 200 ms, separated by an ISI of 1200-1400 ms. Each arrowhead subtended 1 x 1° of visual angle and pointed either leftward or rightward. The central arrowhead was designated the target, and participants made either a left-hand or right-hand button press corresponding to the direction of the target. The flanking arrowheads either pointed in the same direction as the target (congruent trials) or in the opposite direction (incongruent trials), with equal probability.

Each participant completed a total of 400 trials, divided into blocks of 40. The four combinations of target direction (leftward, rightward) and flanker type (congruent, incongruent) occurred equally across the experiment, and trial types were randomly intermixed. To ensure an appropriate error rate, feedback was provided at the end of each trial block: if the error rate for that block was below 10%, a message of “Try to respond a bit faster” was presented; if the error rate was above 20%, a message of “Try to respond more accurately” was presented; if the error rate was between 10-20%, a message of “Good job!” was presented. Because leftward- and rightward-pointing arrowheads are naturally associated with left- and right-hand responses, respectively, the stimulus-response mapping was held consistent across participants.

Component Isolation with Difference Waves

N170 Difference Waves. For the N170 task, we created stimulus-locked averages for faces and for cars and then created a faces-minus-cars difference wave to isolate face-specific processing. Our N170 task also included scrambled versions of the face and car images, which allow even better isolation of face-specific processing by eliminating any physical stimulus differences between the face and car images. As a secondary analysis, we created a difference waveform by subtracting the ERP waveform for scrambled cars from the ERP waveform for scrambled faces (scrambled faces minus scrambled cars). We then created a double difference waveform by subtracting the scrambled difference waveform from the original waveform ([faces minus cars] minus [scrambled faces minus scrambled cars]). These double difference waveforms are provided in the online resource.

MMN Difference Waves. For the MMN task, we created stimulus-locked averages for deviant tones and for standard tones. Because deviant tones were always preceded by standard tones, our averaged ERPs for the standard tones only included standards that were preceded by standards. We used these averaged ERP waveforms to isolate the MMN with a deviant-minus-standard difference waveform.

N2pc Difference Waves. For the N2pc task, we created separate stimulus-locked averages for left-side targets and right-side targets, collapsed across target color. The waveforms were then collapsed across visual fields into contralateral waveforms (i.e., right hemisphere electrode sites for left-side targets averaged with left hemisphere electrode sites for right-side targets) and ipsilateral waveforms (i.e., right hemisphere electrode sites for right-side targets averaged with left hemisphere electrode sites for left-side targets). We then computed a contralateral-minus-ipsilateral difference waveform to isolate the N2pc.

N400 Difference Waves. For the N400 task, we created stimulus-locked ERP waveforms for target words preceded by a related prime word and for target words preceded by an unrelated prime word. We then computed an unrelated-minus-related difference waveform to isolate the N400.

P3 Difference Waves. For the P3 task, we created stimulus-locked averages for rare targets and for frequent non-targets and then created a rare-minus-frequent difference waveform to isolate the P3.

LRP Difference Waves. For the LRP analyses in the flankers task, we created separate response-locked averages for left-hand and right-hand responses. The waveforms were then collapsed across hands into a contralateral waveform (i.e., right hemisphere electrode sites for left-hand responses averaged with left hemisphere electrode sites for right-hand responses) and an ipsilateral waveform (i.e., right hemisphere electrode sites for right-hand responses averaged with left hemisphere electrode sites for left-hand responses). We then computed a contralateral-minus-ipsilateral difference waveform to isolate the LRP. The main analyses were collapsed across congruent and incongruent trials, but separated data are provided in the online resource. Only trials with correct behavioral responses were included in these waveforms.

ERN Difference Waves. For the ERN analyses in the flankers task, we created response-locked ERP waveforms for trials with correct responses and for trials with incorrect responses. We then created an incorrect-minus-correct difference wave to isolate the ERN. These waveforms were collapsed across congruent and incongruent trials; many subjects had too few errors on congruent trials to compute separate congruent and incongruent averages.

References for Supplementary Materials

Kiss, G. R., Armstrong, C., Milroy, R. & Piper, J., 1973. An associative thesaurus of English and its computer analysis. In: Aitken, A. J., Bailey, R. W. & Hamilton-Smith, N. (Eds.), The Computer and Literary Studies, University Press, Edinburgh, pp 153–166.

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Nelson, D. L., McEvoy, C. L. & Schreiber, T. A, 2004. The University of South Florida free association, rhyme, and word fragment norms. *Behav. Res. Methods Instrum. Comput*. 36, 402–407.

Rossion, B., Caharel, S., 2011. ERP evidence for the speed of face categorization in the human brain: disentangling the contribution of low-level visual cues from face perception. *Vision Res* 51, 1297–1311.

Supplementary Table 1

Mean reaction time and accuracy for each trial type (standard deviations in parentheses)

ERP Component	Trial Type	Mean RT (ms)	Accuracy (% correct)
N170	Faces	391.30 (69.86)	95.69 (4.35)
	Cars	408.88 (71.72)	92.05 (6.06)
	Scrambled Faces	400.66 (66.56)	91.32 (6.66)
	Scrambled Cars	407.99 (66.67)	92.22 (7.36)
N2pc	Left Target	523.72 (65.01)	87.91 (6.51)
	Right Target	521.64 (68.90)	89.60 (7.40)
N400	Unrelated	702.02 (126.41)	95.38 (5.42)
	Related	557.70 (121.21)	94.71 (4.90)
P3	Rare	424.57 (67.67)	89.81 (7.94)
	Frequent	378.08 (66.03)	98.90 (1.51)
LRP	Left Response, Compatible	348.93 (40.22)	98.02 (2.76)
	Right Response, Compatible	347.17 (38.99)	98.07 (2.04)
	Left Response, Incompatible	411.87 (38.38)	80.25 (12.54)
	Right Response, Incompatible	409.14 (37.42)	82.01 (9.71)
ERN	Compatible, All	327.80 (57.48)	97.99 (2.15)
	Incompatible, All	361.86 (54.59)	80.63 (10.38)
	Compatible, Correct	344.31 (31.57)	-
	Compatible, Incorrect	310.32 (72.39)	-
	Incompatible, Correct	407.43 (33.09)	-
	Incompatible, Incorrect	316.29 (26.06)	-

Supplementary Table 2

Mean amplitude of the parent ERP waveforms

ERP Component	Trial Type	Mean Amplitude (μV)
N170	Faces	0.631 (5.444)
	Cars	3.997 (4.810)
MMN	Deviants	0.121 (1.433)
	Standards	1.977 (1.135)
N2pc	Contralateral	3.697 (3.264)
	Ipsilateral	4.837 (3.319)
N400	Unrelated	1.104 (3.887)
	Related	8.713 (5.308)
P3	Rare	10.860 (4.883)
	Frequent	4.569 (2.703)
LRP	Contralateral	3.377 (4.245)
	Ipsilateral	5.779 (4.175)
ERN	Incorrect	-2.905 (6.564)
	Correct	6.360 (5.345)

Supplementary Table 3

Range (Minimum, Maximum), first (Q1) and third (Q3) quartiles, and interquartile range (IQR) of the ERP difference waveform measures across participants

ERP Component	Statistic	Mean Amplitude (μV)	Peak Amplitude (μV)	Peak Latency (ms)	50% Area Latency (ms)	Onset Latency (ms)
N170	Minimum	-10.87	-16.16	109.38	113.28	19.53
	Maximum	2.04	1.09	148.44	148.44	128.91
	Q1	-4.85	-7.37	125.00	125.00	84.96
	Q3	-1.34	-3.50	145.51	136.72	113.28
	IQR	3.52	3.87	20.51	11.72	28.32
MMN	Minimum	-5.08	-7.22	148.44	156.25	46.88
	Maximum	0.41	-0.37	218.75	210.94	191.41
	Q1	-2.53	-4.53	172.85	171.88	128.91
	Q3	-0.97	-2.23	202.15	199.22	173.83
	IQR	1.56	2.30	29.30	27.34	44.92
N2pc	Minimum	-5.95	-8.56	207.03	226.56	117.19
	Maximum	0.69	0.16	273.44	265.62	265.62
	Q1	-1.45	-2.49	243.16	246.09	206.05
	Q3	-0.67	-0.81	269.53	250.00	234.38
	IQR	0.78	1.68	26.37	3.91	28.32
N400	Minimum	-15.18	-24.62	300.78	347.66	214.84
	Maximum	-1.74	-3.96	496.09	425.78	414.06
	Q1	-10.65	-14.17	335.94	375.00	261.72
	Q3	-5.31	-7.47	400.39	398.44	303.71
	IQR	5.33	6.70	64.45	23.44	41.99
P3	Minimum	0.72	3.18	300.78	347.66	242.19
	Maximum	17.75	24.50	593.75	519.53	523.44
	Q1	3.99	7.07	355.47	421.88	285.16
	Q3	7.70	12.60	468.75	445.31	335.94
	IQR	3.71	5.53	113.28	23.44	50.78
LRP	Minimum	-4.22	-6.32	-85.94	-70.31	-156.25
	Maximum	-0.42	-1.09	-19.53	-27.34	-58.59
	Q1	-2.98	-4.07	-62.50	-54.69	-102.54
	Q3	-1.81	-2.79	-39.06	-42.97	-85.94
	IQR	1.18	1.28	23.44	11.72	16.60
ERN	Minimum	-28.95	-37.41	19.53	31.25	-101.56
	Maximum	3.42	-1.46	82.03	85.94	58.59
	Q1	-11.21	-16.13	46.88	46.88	-3.91
	Q3	-6.26	-9.26	62.50	58.59	17.58
	IQR	4.95	6.87	15.62	11.72	21.48

Supplementary Table 4

Range (Min, Max), first (Q1) and third (Q3) quartiles, and interquartile range (IQR) of the baseline noise in the unfiltered ERP waveforms across participants

ERP Component	Trial Type	Min	Max	Q1	Q3	IQR
N170	Faces	0.322	2.234	0.679	1.127	0.448
	Cars	0.215	2.329	0.614	0.964	0.350
	Faces-Cars	0.399	4.062	0.900	1.411	0.511
MMN	Deviants	0.207	1.549	0.620	0.975	0.355
	Standards	0.212	1.459	0.468	0.844	0.375
	Deviants-Standards	0.334	2.114	0.502	0.758	0.256
N2pc	Contralateral	0.213	1.349	0.335	0.619	0.283
	Ipsilateral	0.162	1.351	0.368	0.638	0.269
	Contralateral-Ipsilateral	0.236	1.123	0.385	0.714	0.329
N400	Unrelated	0.709	3.164	1.135	1.725	0.591
	Related	0.712	2.283	1.054	1.871	0.817
	Unrelated-Related	0.605	3.290	1.268	1.909	0.640
P3	Rare	0.787	2.615	1.119	2.150	1.031
	Frequent	0.340	1.629	0.633	0.968	0.335
	Rare-Frequent	0.616	2.570	1.242	1.944	0.702
LRP	Contralateral	0.240	1.137	0.383	0.589	0.207
	Ipsilateral	0.222	1.172	0.412	0.611	0.198
	Contralateral-Ipsilateral	0.191	0.846	0.277	0.466	0.189
ERN	Incorrect	0.676	4.761	1.092	2.079	0.987
	Correct	0.327	3.025	0.637	0.952	0.314
	Incorrect-Correct	0.874	5.035	1.188	2.311	1.123

Supplementary Table 5

Range (Min, Max), first (Q1) and third (Q3) quartiles, and interquartile range (IQR) of the measurement time window noise in the unfiltered ERP waveforms across participants

ERP Component	Trial Type	Min	Max	Q1	Q3	IQR
N170	Faces	0.189	1.505	0.338	0.789	0.451
	Cars	0.127	0.977	0.254	0.660	0.406
	Faces-Cars	0.239	2.018	0.527	0.905	0.378
MMN	Deviants	0.245	1.257	0.404	0.647	0.243
	Standards	0.144	1.079	0.219	0.358	0.139
	Deviants-Standards	0.257	1.036	0.485	0.741	0.256
N2pc	Contralateral	0.122	0.511	0.271	0.361	0.090
	Ipsilateral	0.103	0.537	0.211	0.387	0.176
	Contralateral-Ipsilateral	0.135	0.660	0.298	0.504	0.205
N400	Unrelated	0.403	1.738	0.759	1.090	0.331
	Related	0.471	2.119	0.808	1.213	0.404
	Unrelated-Related	0.803	2.967	0.963	1.653	0.690
P3	Rare	0.689	2.461	1.056	1.648	0.592
	Frequent	0.378	1.169	0.504	0.868	0.364
	Rare-Frequent	0.943	2.679	1.152	1.805	0.653
LRP	Contralateral	0.104	0.785	0.272	0.440	0.168
	Ipsilateral	0.125	1.050	0.268	0.448	0.180
	Contralateral-Ipsilateral	0.119	1.047	0.209	0.369	0.160
ERN	Incorrect	0.534	5.677	1.077	3.281	2.204
	Correct	0.167	0.638	0.281	0.451	0.169
	Incorrect-Correct	0.580	5.823	1.172	3.158	1.986

Figure S1

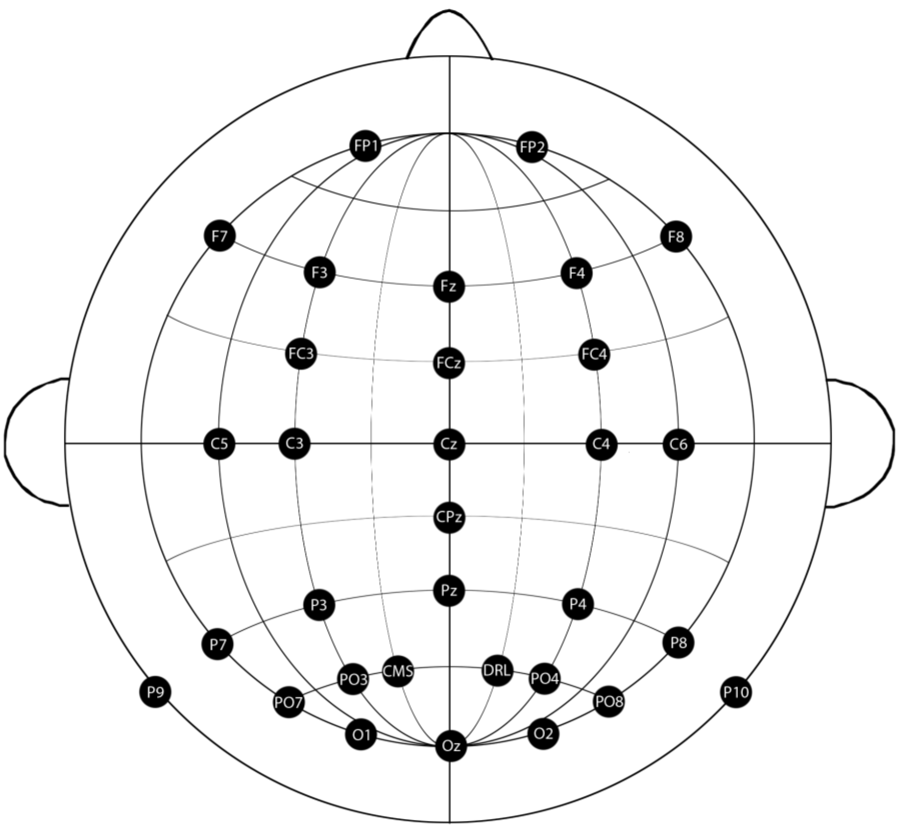

Figure S1. Electrode recording montage.

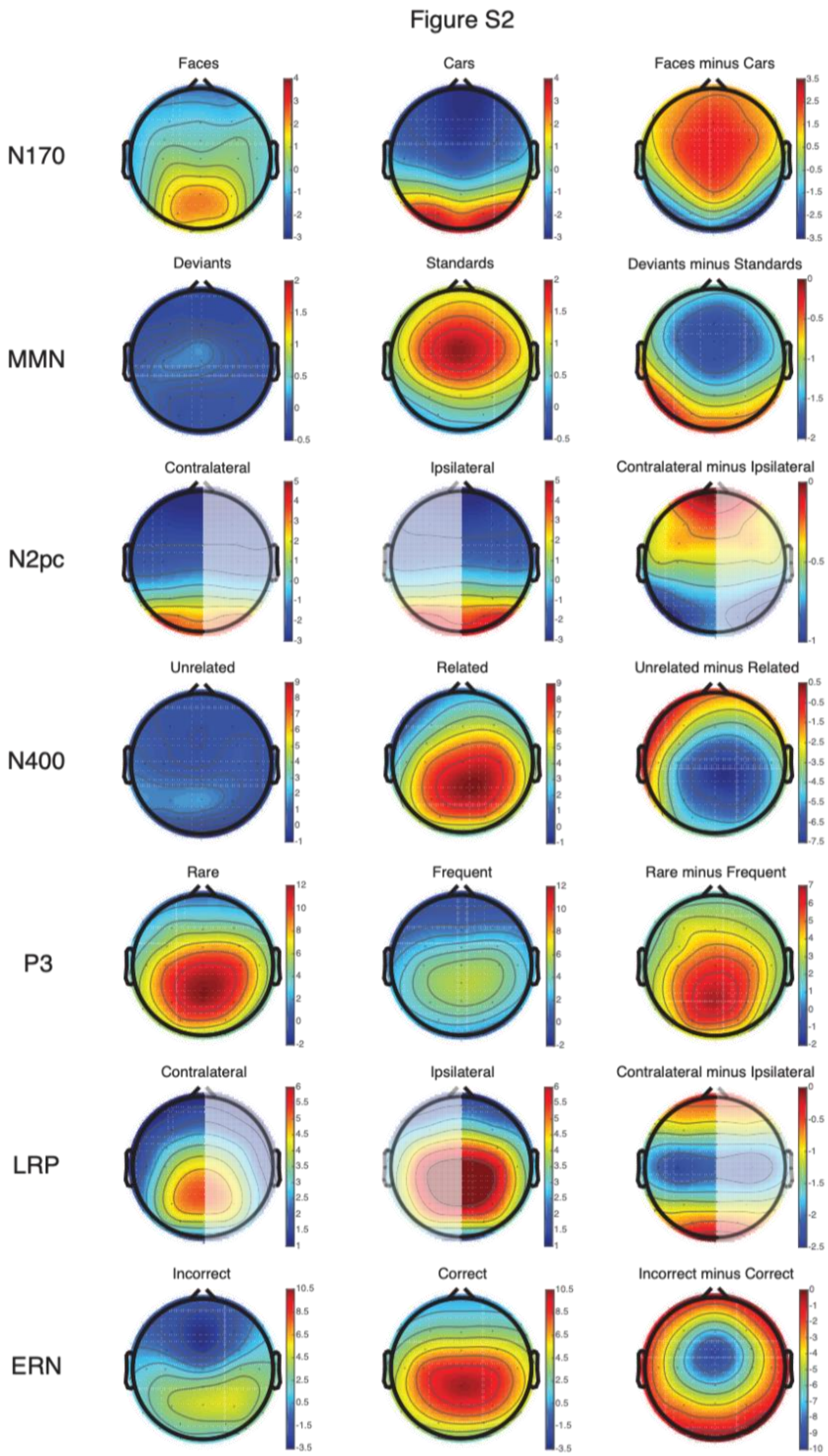

Figure S2. Grand average topographic maps of the mean amplitude for the parent waveforms (left, middle) and difference waveforms (right) during the time window of each component. The N170 was referenced to the average of all 33 sites; all other components were referenced to the average of P9 and P10. Because the N2pc and LRP data are collapsed across hemispheres, the data are presented mirrored in the left and right hemispheres.

Figure S3

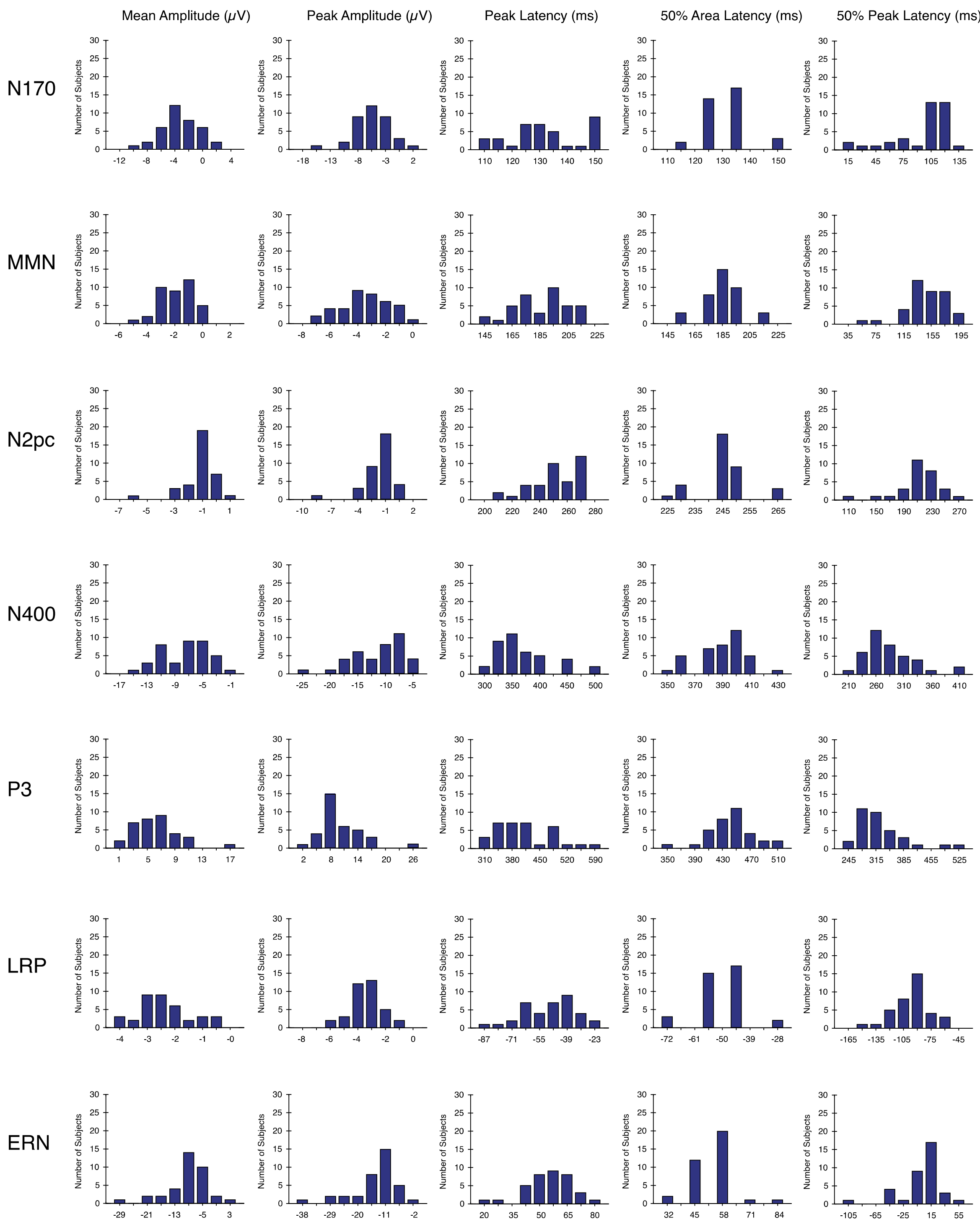

Figure S3. Histograms of the single-participant amplitude and latency values for each component. Note that the scale (bin values and bin width) varies across histograms; the x-axis indicates the midpoint value for each bin

Figure S4

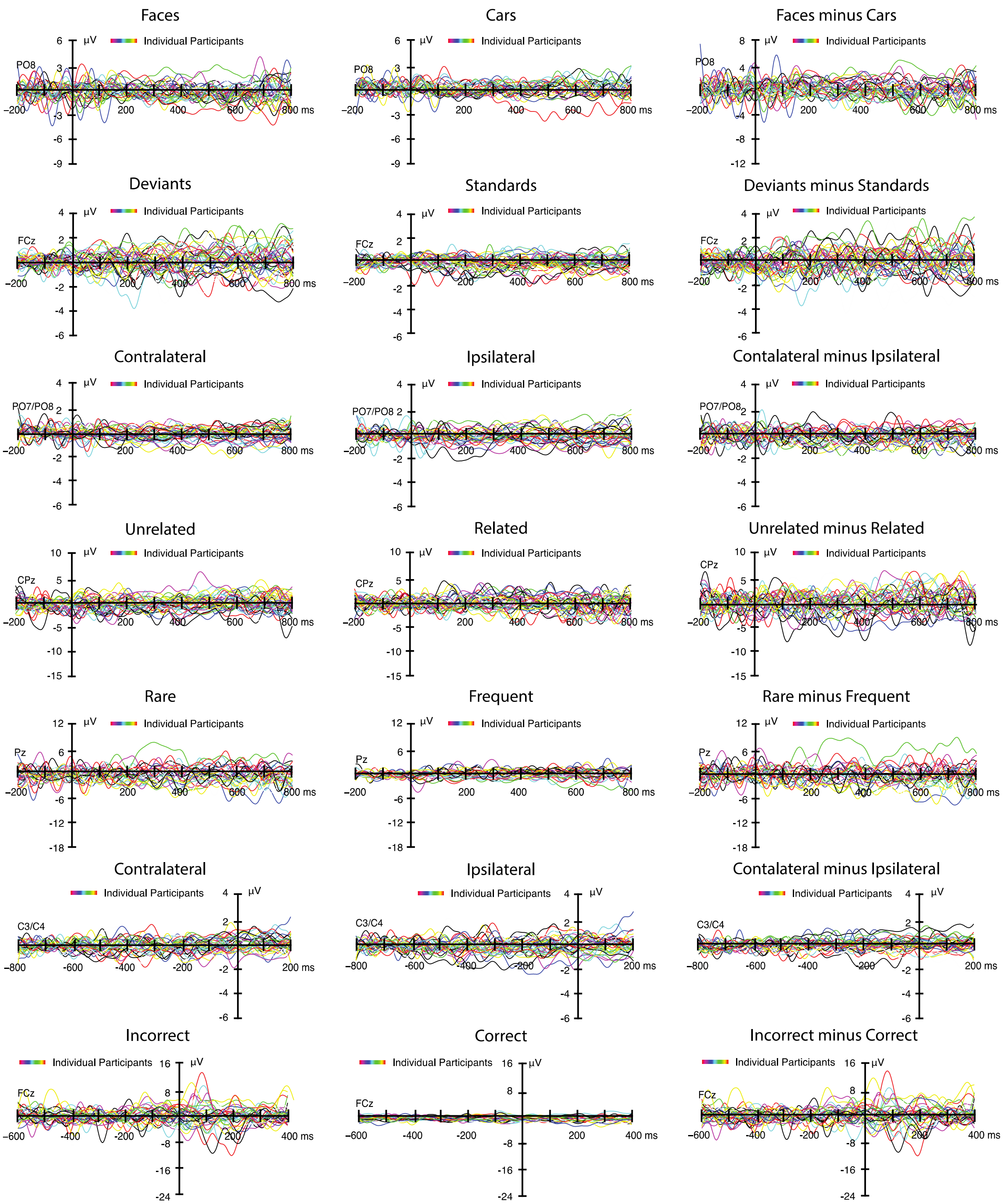

Figure S4. Plus-minus averages overlaid for individual participants (colored lines) for the parent waveforms (left, middle) and difference waveforms (right) for each ERP component at the electrode site where that component was maximal.