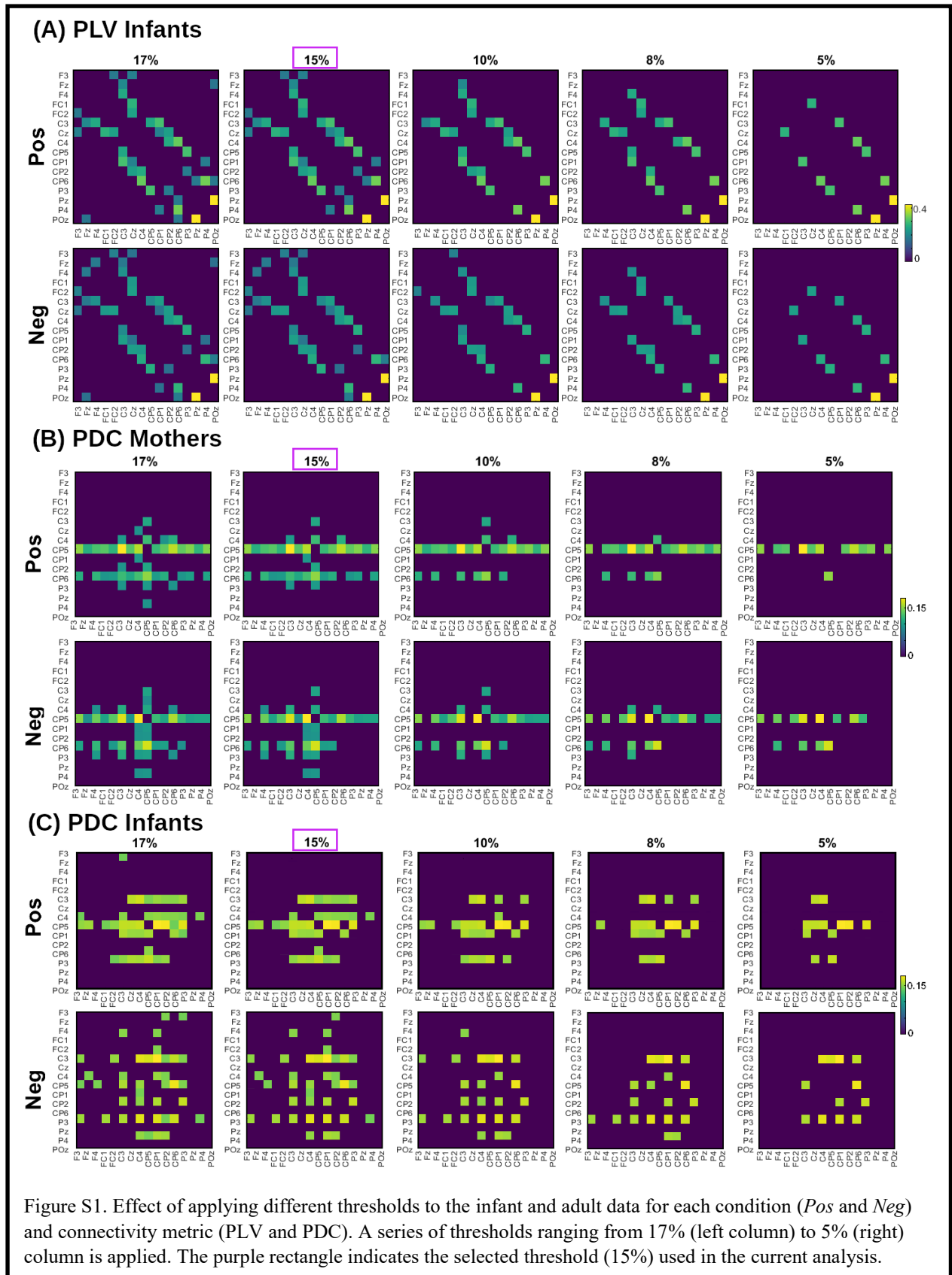


SUPPLEMENTARY MATERIALS

S.1. Thresholding effects



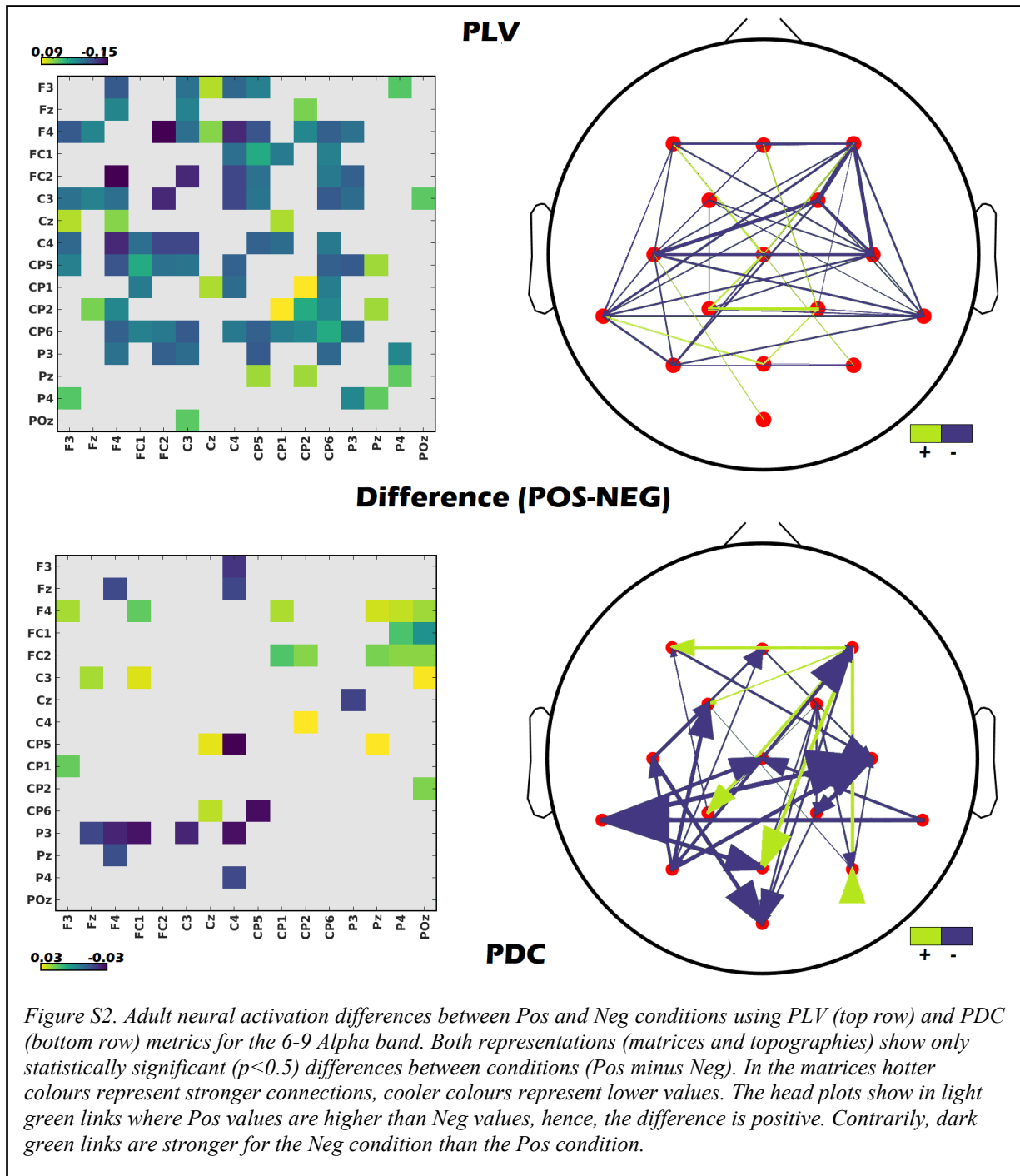
S.2. Intra-brain activation across conditions

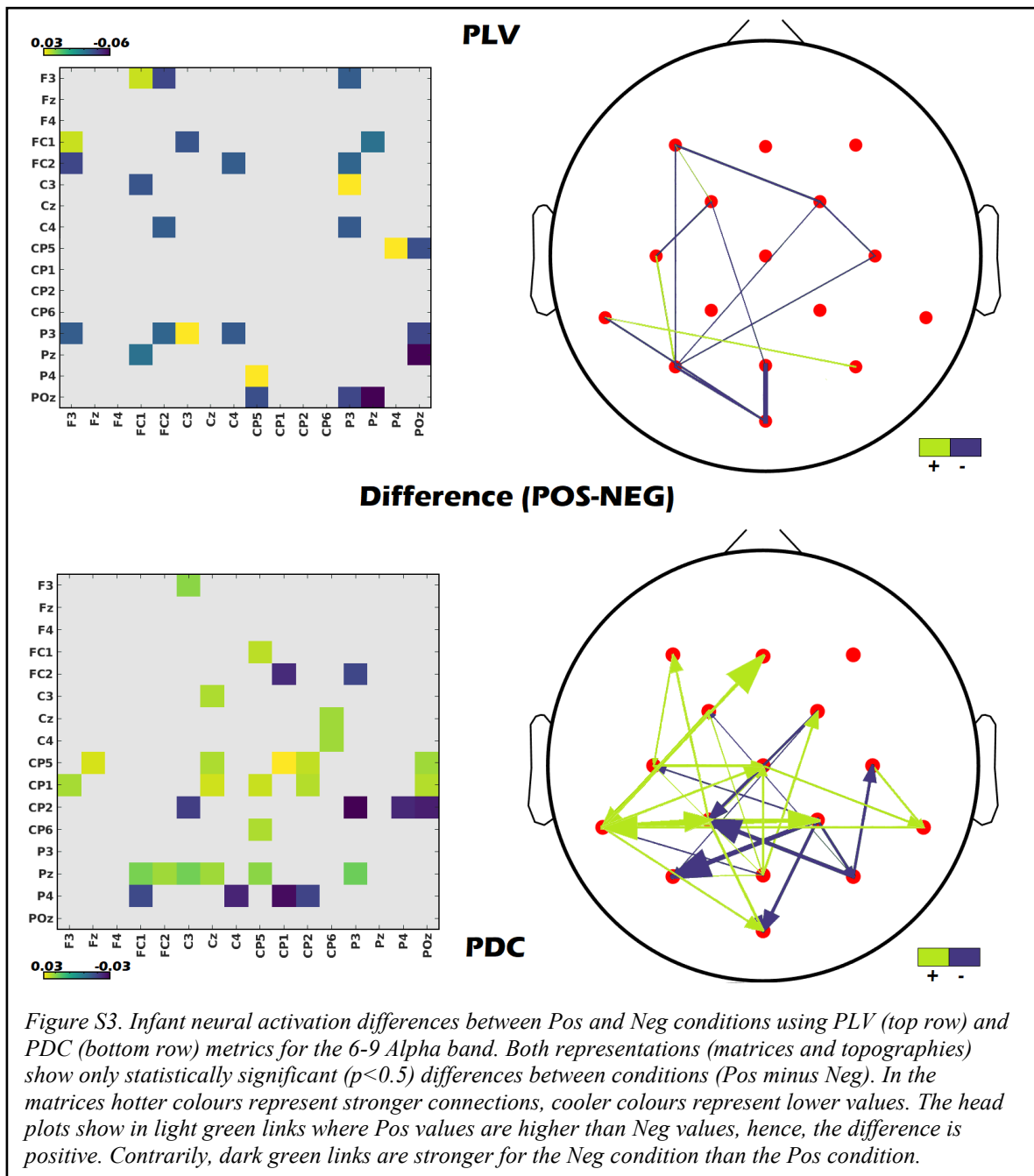
To directly contrast neural activation between *Pos* and *Neg* conditions, two-sample t-tests were performed using the statistically validated (but non-thresholded) individual connections for PLV and PDC measures. Trials where at least one condition value (*Pos* or *Neg*) was not significantly above chance were excluded (yielding different numbers of number of trials across conditions). A significance level of 5% was used, posteriorly adjusted for multiple comparisons using the false discovery rate (FDR) procedure (Benjamini & Yekutieli, 2001). Figures S2 and S3 show the results for adults and infants respectively in the 6-9 Hz band using PLV (top row) and PDC (bottom row).

Mothers showed predominantly stronger activation for the *Neg* condition than the *Pos* condition across both PLV and PDC connectivity metrics. In the scalp plots of Figure S2, this may be observed as a larger number of dark green (*Neg*>*Pos*) than light green (*Pos*>*Neg*) connections. These differences were widely distributed across all scalp regions and could reflect the increased arousal (i.e. stress) and cognitive effort that was required by mothers to model a negative emotion to their infants.

By contrast, infants showed more restricted differences between *Pos* and *Neg* conditions (see Figure S3). First, for both PLV and PDC metrics, *increased* activation for the *Pos* condition was observed over the *left* parieto-occipital region, which is consistent with prior reports on left-hemisphere processing of positive emotions (Coan & Allen, 2004; Davidson, 1984). By contrast, stronger activation for the *Neg* condition was observed in the posterior occipital and central scalp regions. We also observed a larger number of significantly-different connections for the PDC metric (32 significant connections) as compared to the PLV metric (13 significant connections) for the infant data. This difference could reflect the sensitivity of the PDC measure to changes in both EEG power and phase,

whereas the PLV measure detects only phase differences.





S.3. Effect of maternal speech acoustic parameters on connectivity analyses

Here, we assess whether the parent-infant inter-brain network is significantly modulated by the emotional valence of social interaction. However, it is possible that any observed neural connectivity differences across *Pos* and *Neg* conditions may in fact arise from sensorimotor differences in the production or perception of *Pos* versus *Neg* maternal utterances. Accordingly, we sought to establish (1) whether there were significant differences in the acoustic properties of maternal *Pos* and *Neg* utterances, and if so (2) whether these acoustic differences accounted for our observed results. We addressed the second aim by conducting ANCOVA analyses, where the relevant acoustic parameters were added as covariates to the original analyses. Due to technical difficulties, measurements of pitch and loudness could not be obtained from two out of the fifteen dyads, thus the following analyses are based on data from thirteen (87%) dyads. As reported in detail below, the addition of loudness (which differed across conditions) as a covariate in our statistical analyses did not produce any major systematic changes to the main results on inter-brain connectivity.

a) Acoustic differences across conditions

As reported in the main text, maternal speech duration did not differ significantly across conditions ($p=0.40$, Hedges' $g=0.10$). To further assess whether maternal pitch or loudness differed, we performed t-tests with bootstrapping correction ($n=10000$) across participants for each metric. The results revealed that there was a significant difference across conditions for loudness ($p<0.01$) but not for pitch ($p=0.1$).

| | Mean diff (Pos-Neg) | SD | p | t | df | Hedges'g |
|----------|------------------------|-------|----------------|-------|----|----------|
| Loudness | 60.766 | 38.38 | 0.001** | 5.708 | 12 | 1.6093 |
| Pitch | 2.009 | 4.11 | 0.101 | 1.761 | 12 | 0.47014 |

b) Inter-brain ANCOVA connectivity analysis

Since loudness differed significantly across *Pos* and *Neg* conditions (whilst duration and pitch did not), we introduced loudness as a covariate in the inter-brain connectivity analyses for Strength, Divisibility and Inter-Brain Density (IBD). In the following, all calculations were corrected by bootstrapping (n=1000).

i. Strength:

| PDC | F (1,22) | <i>p</i> | η^2 | PLV | F(1,22) | <i>p</i> | η^2 |
|-----------|----------|---------------|----------|-----------|---------|----------------|----------|
| Loudness | 0.052 | 0.802 | 0.002 | Loudness | 0.208 | 0.565 | 0.009 |
| Condition | 2.819 | 0.019* | 0.109 | Condition | 27.602 | 0.001** | 0.545 |

For both PDC and PLV metrics, loudness did not emerge as a significant covariate in the inter-brain Strength ANCOVA analysis ($p > 0.5$). Significant differences across conditions were still observed for both PDC and PLV metrics ($p < 0.05$ and $p < 0.01$ respectively) even after adding loudness as a covariate, replicating the results reported in the main text.

ii. Divisibility:

| PDC | F (1,23) | <i>p</i> | η^2 | PLV | F(1,23) | <i>p</i> | η^2 |
|-----------|----------|----------|----------|-----------|---------|----------------|----------|
| Loudness | 0.368 | 0.509 | 0.016 | Loudness | 1.052 | 0.300 | 0.044 |
| Condition | 1.149 | 0.103 | 0.048 | Condition | 18.131 | 0.005** | 0.441 |

For both PDC and PLV metrics, loudness did not emerge as a significant covariate in the inter-brain Divisibility ANCOVA analysis ($p > 0.3$). After adding loudness as a covariate, there was still a significant difference across conditions for the PLV metric ($p < 0.01$), in line with the results reported in the main text. However, for the PDC metric, there was now only a trend toward significance ($p = 0.1$).

ii. Inter-brain density (IBD):

| PDC | F (1,23) | <i>p</i> | η^2 | PLV | F(1,23) | <i>p</i> | η^2 |
|------------------|----------|----------|----------|------------------|---------|----------------|----------|
| Loudness | 3.848 | 0.062 | 0.143 | Loudness | 3.052 | 0.094 | 0.117 |
| Condition | 0.273 | 0.610 | 0.012 | Condition | 5.687 | 0.005** | 0.198 |

Finally, loudness was a marginally-significant covariate in the ANCOVA analysis of inter-brain density for both PLV and PDC ($p < 0.1$). However, the addition of this covariate did not change the results as reported in the main text. Namely, there was still a significant difference between *Pos* and *Neg* conditions for the PLV metric ($p < 0.01$), but no difference for the PDC metric ($p > 0.6$), see Figure 8.

S.4. Effect of muscular artifacts (rejected trials) on connectivity analyses

Here we assessed whether variations in level of muscular artifact could account for the observed inter-brain connectivity effects. We addressed this issue by conducting ANCOVA analyses, taking the percentage of trials rejected due to muscle artifacts as a covariate in each statistical analysis. As reported in detail below, the addition of this artifact covariate in our statistical analyses did not produce any major systematic changes to the main results on inter-brain connectivity.

i. Strength:

| PDC | F (1,22) | <i>p</i> | η^2 | PLV | F(1,22) | <i>p</i> | η^2 |
|-----------|----------|--------------|----------|-----------|---------|---------------------|----------|
| %Rejected | 0.274 | 0.606 | 0.012 | %Rejected | 0.009 | 0.927 | 0.000 |
| Condition | 4.38 | 0.05* | 0.149 | Condition | 41.518 | <0.001*** | 0.644 |

ii. Divisibility:

| PDC | F (1,23) | <i>p</i> | η^2 | PLV | F(1,23) | <i>p</i> | η^2 |
|-----------|----------|----------|----------|-----------|---------|---------------------|----------|
| %Rejected | 0.345 | 0.563 | 0.015 | %Rejected | 0.589 | 0.451 | 0.025 |
| Condition | 3.639 | 0.07 | 0.136 | Condition | 40.335 | <0.001*** | 0.637 |

iii. Inter-brain density (IBD):

| PDC | F (1,23) | <i>p</i> | η^2 | PLV | F(1,23) | <i>p</i> | η^2 |
|-----------|----------|----------|----------|-----------|---------|---------------------|----------|
| %Rejected | 0.002 | 0.962 | 0.000 | %Rejected | 2.950 | 0.099 | 0.114 |
| Condition | 0.792 | 0.383 | 0.033 | Condition | 20.839 | <0.001*** | 0.475 |

S.5. Neural connections rejected in first validation step (surrogate data) for intra- and inter-brain connectivity analyses

The tables below list the mean percentage of connections (across epochs) that were rejected for each participant, condition and connectivity metric, following the first surrogate step (see Methods Section 2.8) for intra-infant, intra-adult and inter-brain analyses respectively.

| | Infant | | | | Adult | | | |
|--------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | PLV | | PDC | | PLV | | PDC | |
| | <i>Pos</i> | <i>Neg</i> | <i>Pos</i> | <i>Neg</i> | <i>Pos</i> | <i>Neg</i> | <i>Pos</i> | <i>Neg</i> |
| P1 | 0.59 | 0.60 | 0.55 | 0.54 | 0.57 | 0.49 | 0.68 | 0.67 |
| P2 | 0.61 | 0.56 | 0.56 | 0.56 | 0.41 | 0.39 | 0.73 | 0.67 |
| P3 | 0.50 | 0.48 | 0.45 | 0.47 | 0.37 | 0.32 | 0.68 | 0.70 |
| P4 | 0.58 | 0.51 | 0.53 | 0.50 | 0.42 | 0.35 | 0.61 | 0.61 |
| P5 | 0.61 | 0.64 | 0.65 | 0.69 | 0.43 | 0.34 | 0.67 | 0.74 |
| P6 | 0.57 | 0.64 | 0.59 | 0.64 | 0.51 | 0.45 | 0.76 | 0.75 |
| P7 | 0.60 | 0.71 | 0.54 | 0.61 | 0.43 | 0.58 | 0.70 | 0.76 |
| P8 | 0.59 | 0.61 | 0.54 | 0.57 | 0.46 | 0.49 | 0.75 | 0.75 |
| P9 | 0.51 | 0.55 | 0.42 | 0.43 | 0.44 | 0.47 | 0.54 | 0.58 |
| P10 | 0.53 | 0.62 | 0.51 | 0.59 | 0.43 | 0.43 | 0.68 | 0.73 |
| P11 | 0.60 | 0.39 | 0.61 | 0.52 | 0.45 | 0.38 | 0.70 | 0.62 |
| P12 | 0.69 | 0.71 | 0.62 | 0.68 | 0.57 | 0.60 | 0.75 | 0.78 |
| P13 | 0.57 | 0.58 | 0.54 | 0.49 | 0.44 | 0.48 | 0.73 | 0.78 |
| P14 | 0.48 | 0.49 | 0.43 | 0.48 | 0.28 | 0.28 | 0.62 | 0.68 |
| P15 | 0.66 | 0.63 | 0.66 | 0.73 | 0.40 | 0.44 | 0.75 | 0.79 |
| Total | 0.58±0.05 | 0.58±0.09 | 0.55±0.07 | 0.55±0.09 | 0.44±0.07 | 0.43±0.09 | 0.69±0.06 | 0.70±0.06 |

Table S.5.1. Mean percentage of rejected connections after first-step surrogate analysis for intra-brain infant (left) and adult (right).

| | PLV | | PDC (MtoI) | | PDC (ItoM) | |
|--------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | <i>Pos</i> | <i>Neg</i> | <i>Pos</i> | <i>Neg</i> | <i>Pos</i> | <i>Neg</i> |
| P1 | 0.79 | 0.71 | 0.83 | 0.81 | 0.86 | 0.86 |
| P2 | 0.85 | 0.78 | 0.74 | 0.71 | 0.83 | 0.70 |
| P3 | 0.69 | 0.70 | 0.69 | 0.67 | 0.55 | 0.74 |
| P4 | 0.76 | 0.74 | 0.66 | 0.71 | 0.66 | 0.53 |
| P5 | 0.76 | 0.80 | 0.77 | 0.80 | 0.73 | 0.73 |
| P6 | 0.77 | 0.80 | 0.74 | 0.77 | 0.83 | 0.77 |
| P7 | 0.70 | 0.82 | 0.75 | 0.83 | 0.90 | 0.95 |
| P8 | 0.78 | 0.83 | 0.76 | 0.77 | 0.79 | 0.87 |
| P9 | 0.67 | 0.70 | 0.60 | 0.62 | 0.59 | 0.65 |
| P10 | 0.75 | 0.79 | 0.68 | 0.78 | 0.63 | 0.69 |
| P11 | 0.80 | 0.67 | 0.74 | 0.67 | 0.65 | 0.57 |
| P12 | 0.79 | 0.83 | 0.78 | 0.80 | 0.77 | 0.89 |
| P13 | 0.72 | 0.79 | 0.75 | 0.84 | 0.82 | 0.79 |
| P14 | 0.64 | 0.61 | 0.67 | 0.74 | 0.57 | 0.63 |
| P15 | 0.78 | 0.83 | 0.78 | 0.85 | 0.75 | 0.73 |
| Total | 0.75±0.05 | 0.76±0.07 | 0.73±0.06 | 0.76±0.07 | 0.73±0.11 | 0.74±0.12 |

Table S.5.2. Mean percentage of rejected inter-brain connections after first-step surrogate analysis for PLV (left) and PDC (last two columns) metrics.

S.6. Objects used for the experimental task

S.6.1. Set of objects used



Figure S.4. Pairs of novel objects used

S.6.2. Infant within-pair object selection

Four pairs of ambiguous novel objects were used in this task. For all four pairs of items (#1-#4), both items in the pair (A and B) were equally selected by infants overall (Binomial test, $p > .24$ for all pairs), as detailed in the table below.

| Item pair | Number (percentage) choice for item A | Number (percentage) choice for item B | Binomial test (Z, p) |
|-----------|---------------------------------------|---------------------------------------|----------------------|
| #1 | 51 (49.5%) | 52 (50.5%) | Z=.00, p=.50 |
| #2 | 56 (51.4%) | 53 (48.6%) | Z=.19, p=.42 |
| #3 | 69 (53.5%) | 60 (46.5%) | Z=.70, p=.24 |
| #4 | 61 (50.0%) | 61 (50.0%) | Z=.00, p=.50 |

S.7. Flowchart of EEG processing pipeline

