Supporting Information

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SI Materials and Methods

Data Acquisition. Brains’ hemodynamic responses were measured with fNIRS using the ETG-4000 machine (Hitachi), allowing for simultaneous recording from 24 channels. The separation between emitters and detectors was 3 cm, the sampling rate 10 Hz, and the total laser power 0.75 mW.

Probe Placement. Two silicon chevron-shaped probes provided by the manufacturer were horizontally placed on the neonate’s head (one probe over the left and one over the right hemisphere) using skull landmarks, as reported in previous studies (10–12, 52). Specifically, the probes were placed directly above the ear using the bilateral preauricular points as the reference to align the bottom finger of the probe (channels 3, 6, 8, and 11 in the left hemisphere; channels 17, 19, 22, and 24 in the right hemisphere) with the temporal areas (T3 to T5 and T4 to T6 lines in the left and right hemispheres, respectively). Thereafter, the fibers exiting the silicon holders were oriented in such a way that they crossed symmetrically above the glabella (midpoint between the eyebrows) in the center of the forehead. A stretchy cap was used to keep the probes in place.

The location of the frontal and parietal channels and its correspondence with referential 10–20 system positions was approximately calculated as the optodes were held within fixed silicon arrays ensuring that the source-detector distances were kept equal across infants. In the parietal lobe, P3 was roughly located in the middle of channels 7, 9, and 10 (left hemisphere) and P4 in the middle of channels 8, 21, and 20 (right hemisphere). F3 and F4 in the frontal lobes corresponded to the location of channels 2 (left hemisphere) and 13 (right hemisphere) (see Fig. L4 and Fig. S1).

Given the variability of newborns’ head sizes and shapes, we chose to refer to broad regions (i.e., lobes) when referring to the ROIs. Still, like other recent neonate fNIRS studies (65), we approximately localized the cortical regions underlying the channels by projecting the optode configuration over a neonate MRI template and stereotaxic atlas (66). As depicted in Fig. S1, channels included in the frontal ROIs were positioned over the inferior-middle frontal areas, channels in temporal ROIs were mostly located over the superior and also middle temporal gyrus, whereas channels on the parietal ROIs were placed over the postcentral gyrus, supramarginal gyrus, and the inferior parietal lobule. Note that bordering channels, which might not reliably fall within the same lobes across infants (see ref. 67 referring to this critical issue concerning temporal and inferior frontal areas), or posterior channels that were noisy across participants were not included in the ROIs.

Data Processing. The signal was bandpass-filtered between 0.02 and 1.00 Hz. Single channels from specific blocks were eliminated if light absorption was less than 1% of the total light emitted or in case of movement artifacts (defined as changes in the signal greater than 0.1 mmol-mm in an interval of 0.2 s). Blocks with more than 12 rejected channels were excluded. Participants were included in the analysis only if the amount of rejected data was less than 30%. A baseline was linearly fitted between the mean of the 5 s preceding the onset of the block and between the 15th second and the 20th second after the offset of the block. The mean signal over the 9 s following the end of the auditory stimulation was used to carry out the statistical analysis. This analysis period corresponds to the time window in which the maximum amplitudes of the hemodynamic responses are expected based on previous fNIRS studies with newborns. OxyHb concentrations of six ROIs (bilateral frontal, temporal, and parietal regions) were used for the data analysis. The channels included in the ROIs were identical to those used in previous studies on newborns’ memory and speech processing using fNIRS (10–12, 52).

Directional Brain Network Analysis Using SEM. The connectivity analysis of the fNIRS data using SEM consisted of the following steps:

- **Specification of the theoretical/hypothesized anatomical model**: The model included the six ROIs and directional connections between them (Fig. S2). Hypothetical connections were defined on the basis of anatomical connections among these areas identified in previous studies (41–43). Based on modification indices, a small number of additional connections were added to improve model fit. AMOS uses an iterative maximum likelihood method to obtain a solution for each path coefficient representing the effective connectivity between each node (i.e., anatomical ROI) of the network. The best solution of the set of equations provided by the software minimizes the difference between the observed and predicted covariance matrices. Adding connections to an a priori theoretically and anatomically defined model is a standard procedure of the SEM approach (61–64). This allows identification of interactions potentially missed by an a priori model and can also be used to improve it, a key feature required for ensuring that no strong connections are missed.

- **Generation of the covariance matrices and structural equations**: Mean time series were computed for each ROI, condition, and the total laser power 0.75 mW.

- **Goodness of fit evaluation**: The model's goodness of fit was evaluated using chi-square statistics to assess the magnitude of discrepancy between the observed and fitted covariance matrices (69). It is generally considered that a good model fit would provide no significant differences between the predicted and the observed data.

- **Comparison between models**: The adaptation response was conspicuous when analyzing the first three blocks of the encoding phase. Accordingly, three models (one for each block) were constructed to identify coherent functional changes related to this adaptation. Four additional models (two for each group) were constructed as a means to investigate the connectivity changes associated with the hemodynamic response differences observed in the first two blocks of the test phase, where the recognition response was identified.
Fig. S1. Photograph of a neonate with the probe set on the head and a projection from the scalp surface to the intensity model and label map of the neonate MRI templates (templates from ref. 66 are publicly available at http://bric.unc.edu/ideagroup/free-softwares/). Red diamonds correspond to emitters/sources and blue diamonds to detectors. The yellow numbered squares, between adjacent emitter-detector pairs, correspond to the channels.

Fig. S2. Hypothetical starting model including the six ROIs and directional connections between them.

Fig. S3. Hemodynamic curves of the same-word and novel-word groups in the RF area during the first block of the test phase. The x axis shows time in seconds from the start of stimulation, and the gray rectangle indicates the stimulation period. Asterisks indicate Bonferroni-corrected $P < 0.01$. 