Supplementary data

Part I. The motion denoise process and Δ[HbO] and Δ[Hb] signals extraction

We used the kurtosis-based wavelet filtering (kbWF) algorithm to diminish the motion noise. The kbWF is iterative and based on the evaluation of the fourth standardized moment (kurtosis) of discrete wavelet transformation (DWT) coefficients for the chose decomposition level [1]. There are three parameters needed for the Kurtosis-based Wavelet Filtering. The first one is the kurtosis threshold, empirically, the value was set between 3.1 and 3.5. Based on the suggestion of reference of [1], we set the kurtosis threshold as 3.3 for all our data preprocessing. The second one is the mother wavelet, we chose a Daubechies 5 (db5) wavelet for the DWT. The third one is the decomposition level, we set the decomposition level as 10 in our data preprocessing.

Fig. S1 (a) showed the results of motion artifact detection and denoising based on the Kurtosis-based wavelet algorithm in the original Δ[Hb] and Δ[HbO]. There were distinct motion noises in the time range from 80 s to 120 s. Fig. S1 (b) was the enlarged figure of this time range. It can be seen that the motion noise is attenuated. Fig. S1(c) was the Δ[HbO] (red) and Δ[Hb] oscillations in 0.01-0.1 Hz after bandpass filtering.

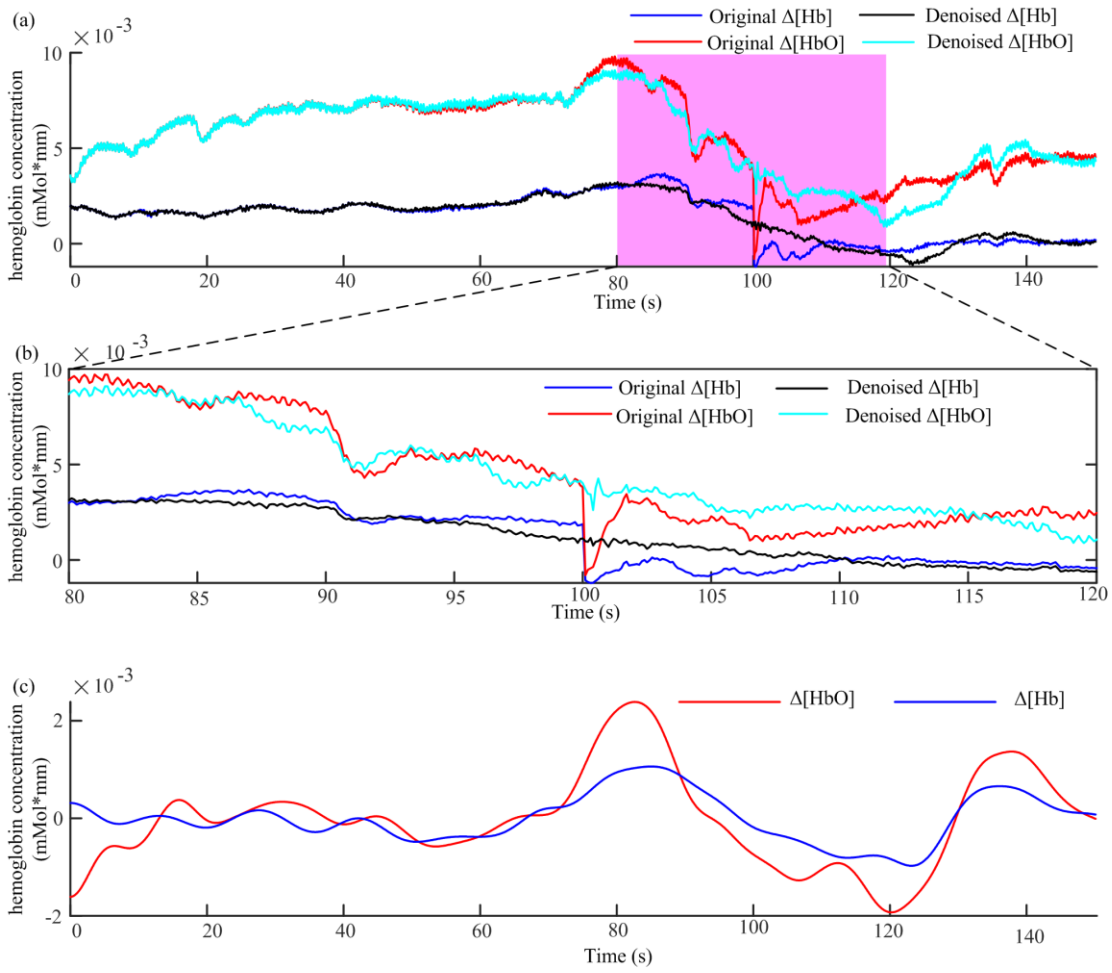

Fig. S1. The motion denoising and bandpass filtering of Δ[HbO] and Δ[Hb] for one channel. (a) The motion artifact detection and denoising are based on the Kurtosis-based wavelet algorithm. The red and blue curves are the original Δ[Hb] and Δ[HbO], respectively. The black and cyan curves are the signals after the removal of motion noise. The signals in the time range from 80 s to 120 s (pink rectangle)

were contaminated by head movement. (b) The enlarged signals from the time range from 80 s to120 s. (c) The low frequency band signals (0.01-0.1 Hz) of Δ[HbO] (red) and Δ[Hb] (blue), respectively.

Part II. The simulation of noise influence to phase difference and PLI measurements under two different scenarios.

In this part, two different scenarios were considered to analyze the noise effect on the anti-phase trend of Δ[Hb] and Δ[HbO] based on the modified Beer-Lambert law. For the first one, the random noise with different intensities was added to raw optical density signals, which has a clear cardiac component. Fig. S2 presents the raw optical density signals (690 nm and 830 nm) derived from the NIRS system and the different levels of noise from a NIRS channel were added to the original optical density signals (see Figs.S2 (a)-(c)). The Homer2 toolbox was used to convert the optical data into Δ[Hb] and Δ[HbO]. The toolbox uses the extinction factor proposed by Gratzer [2]. The power spectral (Figs.S2 (d)-(f)), the corresponding Δ[HbO] and Δ[Hb] signals (Figs.S2 g-i), and the Δ[HbO] and Δ[Hb] signals in 0.01-0.1 Hz (Figs.S2 (j)-(l)) were analyzed. As shown, the Δ[HbO] and Δ[Hb] signals of the raw optical density signals are in phase (see the green line in Fig.S2 (m)). The phase difference nears π as the noise intensity approaches -8 dB (the brown line in Fig. 3m). Combined with the Fig.S2 (n) and (l), we can see that the phase difference (i.e., Arg(Δ[HbO])-Arg(Δ[Hb])) shift near π/2 and the coupling strength (i.e., PLI) decreased from 0.7 to near to 0.2 when the SNR equal to 12.8 dB. Also, the coupling strength presents a u-shape curve based on the influence of the noise increase (see Fig.S2 (o)). Furthermore, the simulation results showed that the changes in the phase difference and coupling strength are not linearly related to the SNR. The Arg(Δ[HbO])-Arg(Δ[Hb]) as a function of SNR is a reverse sigmoid curve, while the PLI as a function is an U-shape curve. Compared with the phase difference, the PLI is more sensitive to the noise. We concluded that the raw signal which has distinct heart rate information is necessary for reliable phase difference calculation. It is necessary to ensure that the SNR more than 30 dB to get a robust estimation of phase difference and coupling strength.

The second scenario used a mathematical model to simulate the real optical density signals. The same process as scenario one was adopted to calculate Δ[Hb] and Δ[HbO]. The model simulations of the noise effect on the anti-phase trend of Δ[Hb] and Δ[HbO] were showed in Fig. S3. Similar to the first scenario, the phase difference trend was anti-phase when the SNR was less than 10 dB (see Fig. S3(n)). When the SNR is about 25 dB, the Arg(Δ[HbO])-Arg(Δ[Hb]) shifts more than π/2 and the PLI decreases nearly 80% compared with the original value. It also can be seen that the Arg(Δ[HbO])-Arg(Δ[Hb]) curve changes relatively small when the SNR is larger than 40 dB, and it trends sharply toward π/2 when the SNR is less than 40 dB. All these results indicate that the phase difference and coupling strength measurement are sensitive to the noise effect. Under the same condition, the impact of noise on PLI is greater.

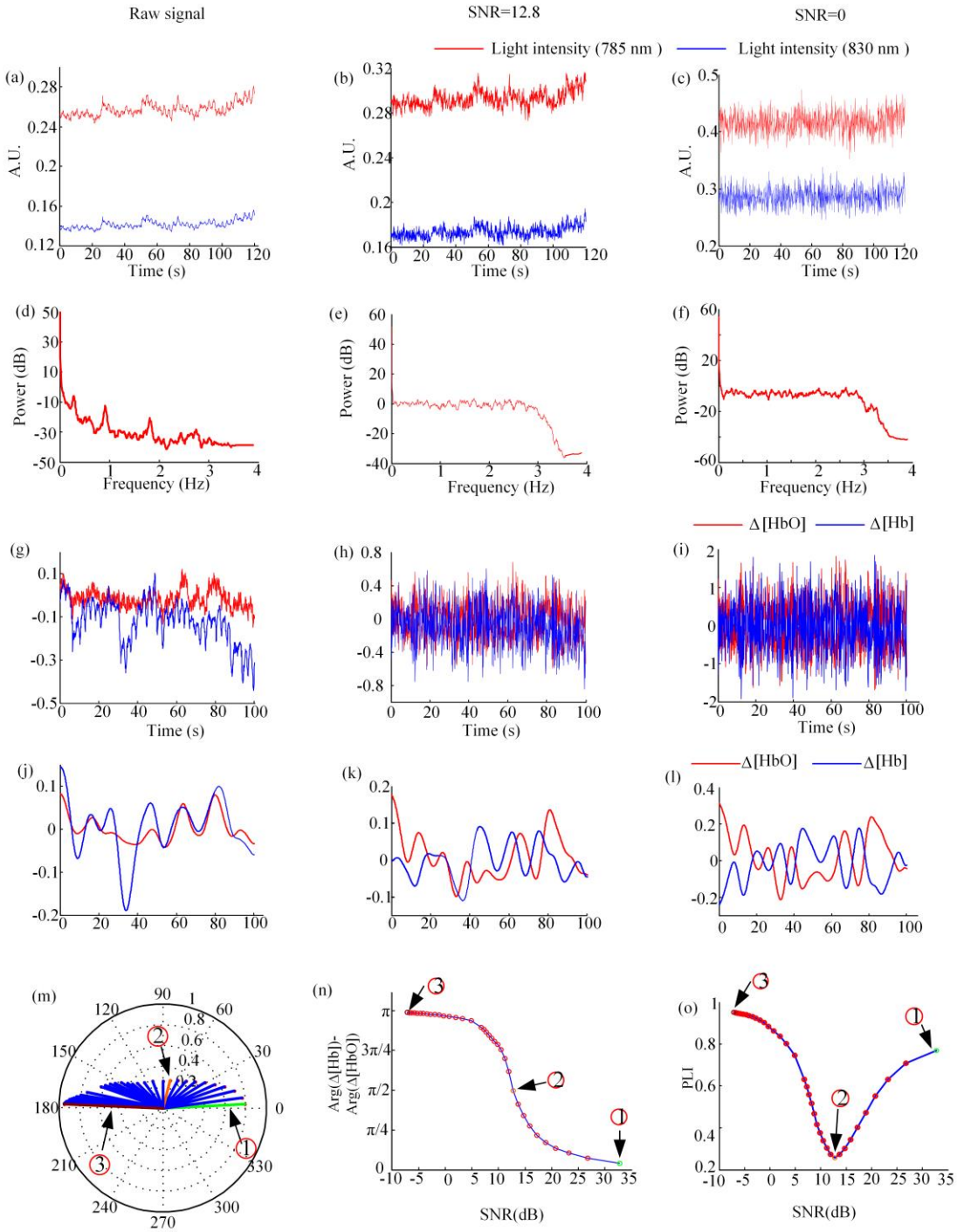

Fig. S2. Phase difference and PLI measurements of the light intensity signals with different noise intensities. (a)-(c) Light intensity signals for raw, SNR=12.8 dB, and SNR=0 dB. (d)-(f) Spectrum power of the 785 nm light intensity in the upper Figs. (g)-(i) Generated Δ[Hb] and Δ[HbO] signals calculated by the modified Beer-Lambert law from the raw signals in (a)-(c). (j)-(l) Filtered Δ[Hb] and Δ[HbO] in the 0.01-0.1 Hz frequency band derived from the upper Figs. (m) Phase difference and coupling strength indices of the Δ[Hb] and Δ[HbO] signals in the 0.01-0.01 Hz frequency band. (n) Arg(Δ[Hb])-Arg(Δ[HbO]) changes with SNR increase. (o) PLI changes with SNR increase. Three example points (1-3) were marked with different colors to indicate the phase shifts.

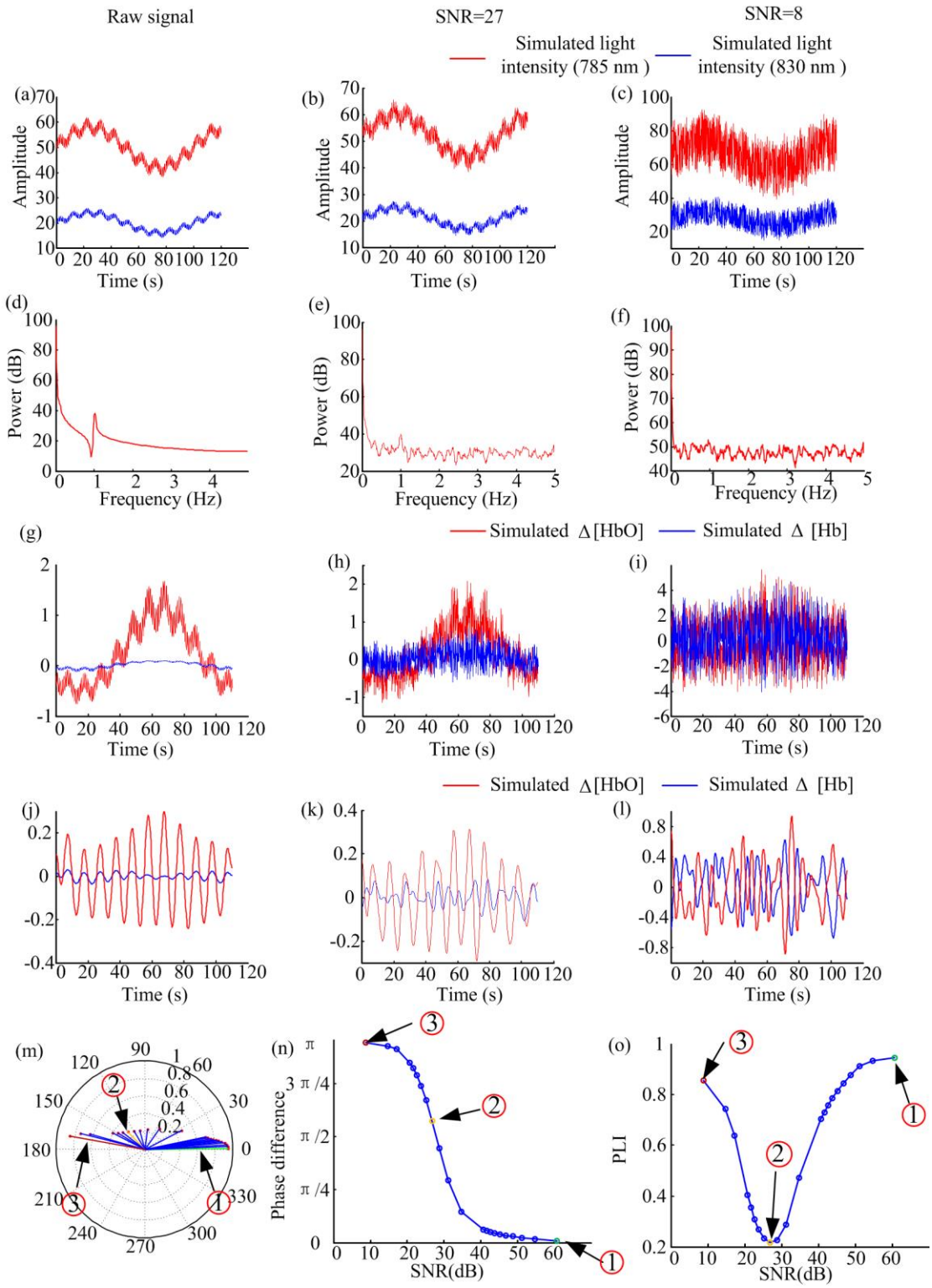

Fig. S3. Phase difference and PLI measurements of the simulated sinusoidal signals with different noise intensities. (a)-(c) Sinusoidal signals of raw, SNR=27, and 8 dB. (d)-(f) Spectrum power of the red curve in the upper Figures. (g)-(i) Generated simulated Δ[Hb] and Δ[HbO] signals calculated by the modified Beer-Lambert law from the raw signals in (a)-(c). (j)-(l) Filtered simulated Δ[Hb] and Δ[HbO] in the 0.01-0.1 Hz frequency band derived from the upper Figures. (m) Phase difference and coupling strength indices of the two oscillation signals in the 0.01-0.01 Hz frequency band after calculating the modified

Beer-Lambert law. (n) Phase difference changes with the SNR increase. (o) PLI changes with the SNR increase.

Part III. Impact of the device difference for the indices

In order to analyze the influence of the device difference to the indices we used, we conducted the resting-state experiments using two fNIRS systems (ETG-4000 and CW6) on the same participants. We recruited 9 healthy adult participants (3 males and 6 females, 23 to 30 years old, mean ± SD=26.78±2.50). All participants were right-handed Han Chinese with normal or corrected-to-normal version. The participants were given written informed consent before the experiments. Approval for this study was obtained from the Institutional Review Board of the State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University. The participants were instructed to sit in a comfortable chair in a dimly lit room. During the experiment, the participants were instructed to 1) keep motionless, 2) close their eyes, 3) stay awake and 4) not to think about anything. The recording time length of each participant was recorded in 10 minutes for each fNIRS system. For these two systems, the same layouts were used, which included 22 source-detector channels with a distance of 3 cm, to cover the left and right frontal cortices.

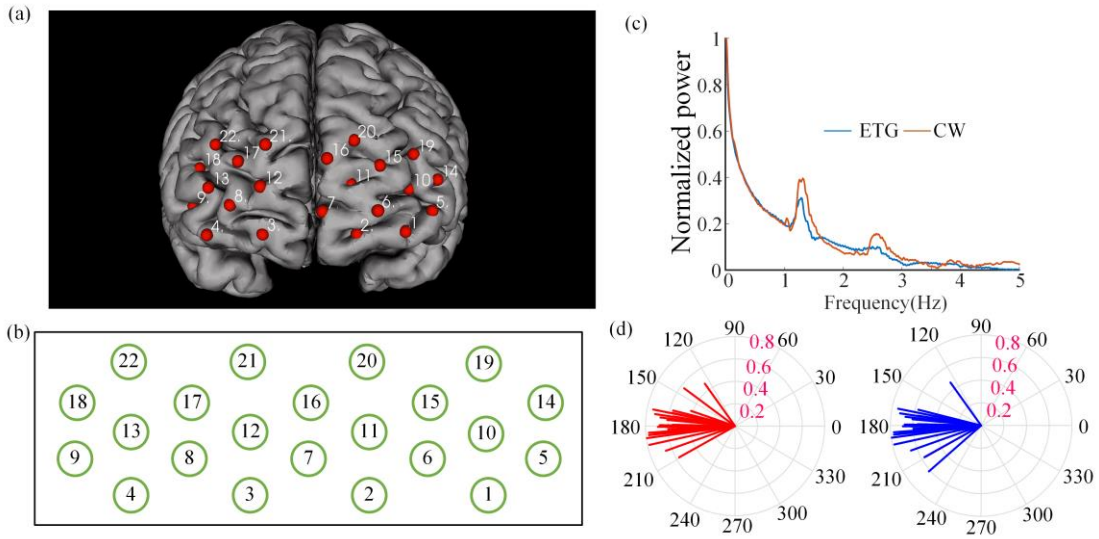

Figure S4. Schematic arrangement of fNIRS channels for the experiment (9 adults), power spectral and phasor diagrams of different devices (ETG-4000 NIRS system, CW6 NIRS system) from the same person. (a)-(b) the same layouts of the probes used in both systems, including 22 source-detector channels (3cm distance) to cover the left and right frontal cortices. (c) Normalized power for one channel in a subject. (d) Phasor diagrams in the same subject from different devices (red is ETG-4000 NIRS system, blue is CW6 NIRS system).

The layouts are shown in Fig. S4(a) and S4(b). The normalized power spectra of two systems over the same brain region were presented in Fig. S4(c). It can be seen that two curves are close with each other in the frequency of less than 5 Hz. We performed the same preprocessing steps to obtain the Δ[Hb] and Δ[HbO] variation in the frequency band of 0.01-0.1 Hz. The Arg(Δ[Hb])-Arg(Δ[HbO]), and PLI were then derived. As seen in Fig. S4(d), both the distribution of Arg(Δ[Hb])-Arg(Δ[HbO]) and the strength of PLI are similar between the systems of ETG-4000 (red) and CW6 (blue). The mean and SD of the

Arg(Δ[Hb])-Arg(Δ[HbO]) and PLI from two systems are similar (Tables S1 and S2). The results supported that there is no significant difference between these two systems for most participants. The possible reason for the significant differences in some frequency bands (bold numbers in table 10 and 11) observed in 1-2 subjects could be that 1) it is not a concurrent experiment. The difference can happen between two resting-state scans; 2) there could be different in instrumental noise and sensitivity profiles between two systems.

TABLE S1.THE MEAN AND SD OF ARG(Δ[HB])-ARG(Δ[HBO]) FOR ALL CHANNELS WITHIN EACH PARTICIPANT IN THE FREQUENCY BAND OF 0.01-0.05 HZ, 0.05-0.1 HZ, AND 0.01-0.1 HZ.

	0.01-0.05 Hz		0.05-0.1 Hz		0.01-0.1 Hz	
	Mean ± SD		Mean ± SD		Mean ± SD	
	ETG	CW6	ETG	CW6	ETG	CW6
#1	**3.25±0.51**	**2.81±0.34**	3.13±0.39	3.19±0.96	**3.30±0.65**	**2.88±0.40**
#2	2.43±0.47	2.83±0.51	3.11±0.66	3.05±1.24	2.54±0.52	2.75±0.31
#3	2.92±0.40	3.00±0.73	2.89±0.64	3.03±0.67	2.91±0.39	3.03±0.32
#4	2.83±0.48	2.92±0.41	2.78±0.69	2.88±1.16	2.52±0.53	2.66±0.62
#5	2.86±0.42	2.74±0.55	2.95±0.49	2.86±1.13	2.84±0.44	2.64±0.81
#6	2.76±0.30	2.37±0.51	2.26±0.83	2.19±1.26	**2.59±0.39**	**2.16±0.70**
#7	2.65±0.33	2.98±0.87	2.64±0.74	2.75±1.07	2.72±0.38	2.90±0.43
#8	2.84±0.36	2.89±0.46	2.27±0.74	2.30±1.02	2.75±0.41	2.64±0.67
#9	2.88±0.48	3.20±0.91	3.12±0.45	3.02±0.58	2.96±0.32	3.21±0.88

TABLE S2. THE MEAN AND SD OF PLI FOR ALL CHANNELS WITHIN EACH PARTICIPANT IN THE FREQUENCY BAND OF 0.01-0.05 HZ, 0.05-0.1 HZ AND 0.01-0.1 HZ

	0.01-0.05 Hz		0.05-0.1 Hz		0.01-0.1 Hz	
	Mean ± SD		Mean ± SD		Mean ± SD	
	ETG	CW6	ETG	CW6	ETG	CW6
#1	0.73±0.08	0.63±0.15	0.66±0.16	0.61±0.16	**0.65±0.09**	**0.54±0.16**
#2	0.68±0.10	0.70±0.15	0.64±0.14	0.66±0.13	0.62±0.13	0.58±0.16
#3	0.68±0.10	0.66±0.10	0.64±0.10	0.68±0.18	0.63±0.10	0.63±0.14
#4	**0.74±0.09**	**0.62±0.10**	0.79±0.13	0.73±0.15	0.70±0.09	0.67±0.13
#5	0.70±0.09	0.66±0.10	0.78±0.15	0.71±0.18	0.70±0.11	0.65±0.16
#6	0.61±0.10	0.57±0.10	0.59±0.14	0.62±0.17	0.53±0.09	0.49±0.11
#7	0.67±0.13	0.67±0.16	0.62±0.10	0.69±0.17	0.61±0.12	0.63±0.15
#8	0.74±0.09	0.68±0.14	0.67±0.10	0.63±0.15	0.67±0.07	0.68±0.10
#9	0.67±0.12	0.72±0.10	0.69±0.12	0.65±0.15	0.63±0.14	0.64±0.12

Part IV . The statistical analysis of the indices with all the channels

(1) The distribution of the time-varying phase differences with all the channels

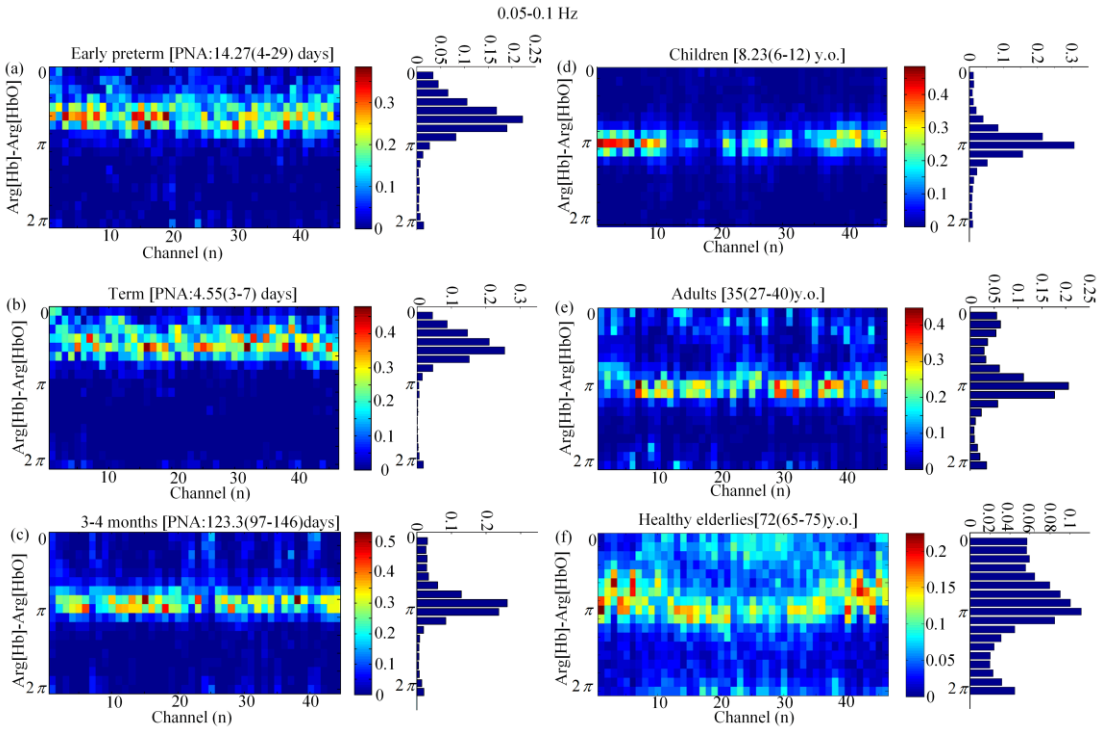

Fig. S5. Arg(Δ[Hb])-Arg(Δ[HbO]) distribution in each channel for all age groups in the 0.05-0.1 Hz frequency band. (a) Arg(Δ[Hb])-Arg(Δ[HbO]) distribution with every channel for early preterm infants (left part) and proportion of Arg(Δ[Hb])-Arg(Δ[HbO]) in each phase bin (right part). (b)-(f) similar measurement of the Arg(Hb)-Arg(HbO) for the term infants, 3-4-month-olds infants, children, adults, and elderly participants.

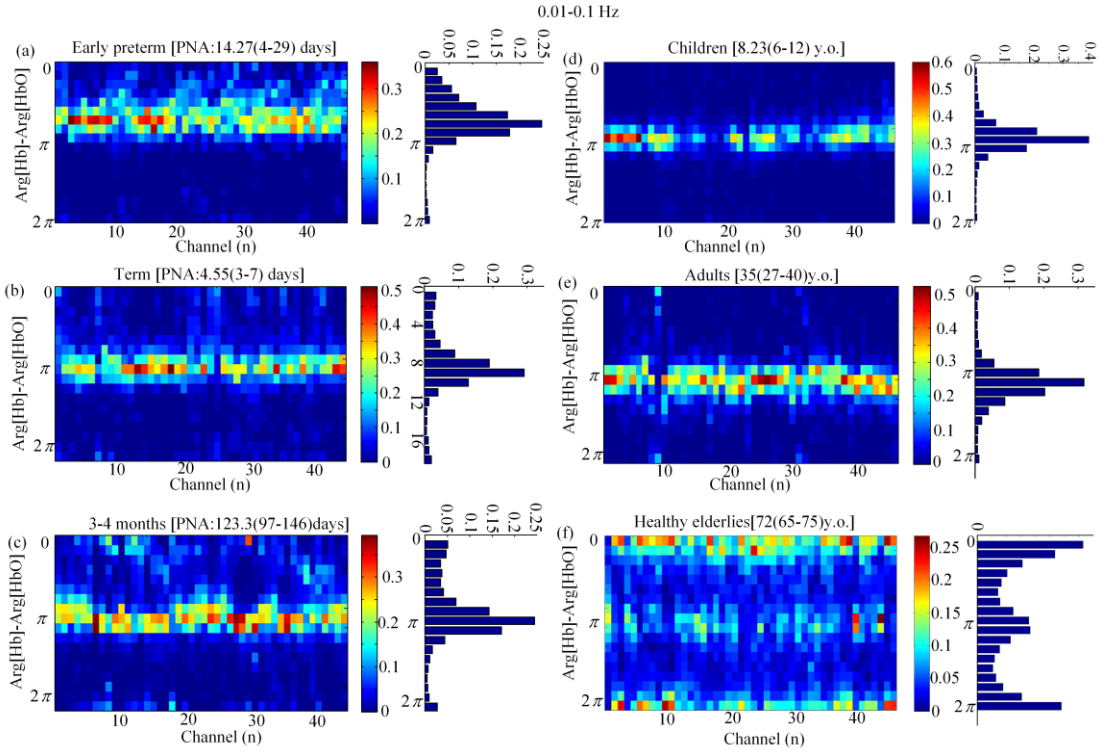

Fig. S6. Arg(Δ[Hb])-Arg(Δ[HbO]) distribution in each channel for all age groups in the 0.01-0.1 Hz frequency band. (a) Arg(Δ[Hb])-Arg(Δ[HbO]) distribution with every channel for early preterm infants (left part) and proportion of Arg(Δ[Hb])-Arg(Δ[HbO]) in each phase bin (right part). (b)-(f) similar measurement of the Arg(Hb)-Arg(HbO) for the term infants, 3-4-month-olds infants, children, adults, and elderly participants.

(2) The significance of the phase difference indices among different age groups

TABLE S3.THE SIGNIFICANT DIFFERENCE (P-VALUES) OF ARG(Δ[HB])-ARG(Δ[HBO]) WITH DIFFERENT AGE GROUPS IN 0.01-0.05 HZ.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		***	***	***	***	***
Term	***		***	***	***	***
3-4 months	***	***		*	***	***
Children	***	***	*		***	***
Adults	***	***	***	***		***
Healthy elderlies	***	***	***	***	***	

The symbols, "o", "*", "**" and "***" indicate the *p*-values $p>0.05/15=0.0033$, $p<0.05/15=0.0033$, $p<0.01/15=0.00067$ and $p<0.001/15=0.000067$, through Watson-Williams multi-sample test, respectively.

TABLE S4. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF ARG(Δ[HB])-ARG(Δ[HBO]) WITH DIFFERENT AGE GROUPS IN 0.05-0.1 HZ.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		***	***	***	***	***
Term	***		***	***	***	***
3-4 months	***	***		***	o	***
Children	***	***	***		***	***
Adults	***	***	o	***		o
Healthy elderlies	***	***	***	***	o	

The symbols, “o”, “*”, “**” and “***” indicate the *p*-values $p>0.05/15=0.0033$, $p<0.05/15=0.0033$, $p<0.01/15=0.00067$ and $p<0.001/15=0.000067$, through Watson-Williams multi-sample test, respectively.

TABLE S5. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF ARG(Δ[HB])-ARG(Δ[HBO]) WITH DIFFERENT AGE GROUPS IN 0.01-0.1 HZ.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		***	***	***	***	***
Term	***		***	***	***	***
3-4 months	***	***		o	***	***
Children	***	***	o			***
Adults	***	***	***	***	***	***
Healthy elderlies	***	***	***	***	***	

The symbols, “o”, “*”, “**” and “***” indicate the p-values $p>0.05/15=0.0033$, $p<0.05/15=0.0033$, $p<0.01/15=0.00067$ and $p<0.001/15=0.000067$, through Watson-Williams multi-sample test, respectively.

TABLE S6. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF PLI WITH DIFFERENT AGE GROUPS IN 0.01-0.05 HZ.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		o	o	***	***	***
Term	o		o	***	***	***
3-4 months	o	o		***	***	***
Children	***	***	***		***	***
Adults	***	***	***	***		***
Healthy elderlies	***	***	***	***	***	

The symbols, "o", “*”, “**” and “***” indicate the $p>0.05/15=0.0033$, $p<0.05/15=0.0033$, $p<0.01/15=0.00067$ and $p<0.001/15=0.000067$, respectively.

TABLE S7. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF PLI WITH DIFFERENT AGE GROUPS IN 0.05-0.1 Hz.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		o	o	***	***	***
Term	o		o	***	o	***
3-4 months	o	o		***	***	***
Children	***	***	***		***	***
Adults	***	o	***	***		***
Healthy elderlies	***	***	***	***	***	

The symbols, "o", "*", "**" and "***" indicate the p-values $p>0.05/15=0.0033$, $p<0.05/15=0.0033$, $p<0.01/15=0.00067$ and $p<0.001/15=0.000067$, respectively.

TABLE S8. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF PLI WITH DIFFERENT AGE GROUPS IN 0.01-0.1 Hz.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		o	o	***	***	***
Term	o		o	***	***	***
3-4 months	o	o		***	***	***
Children	***	***	***		***	***
Adults	***	***	***	***		***
Healthy elderlies	***	***	***	***	***	

The symbols, "o", "*", "**" and "***" indicate the *p*-values $p>0.05/15=0.0033$, $p<0.05/15=0.0033$, $p<0.01/15=0.00067$ and $p<0.001/15=0.000067$, respectively.

(3) The violin plots of phase difference and PLI indices.

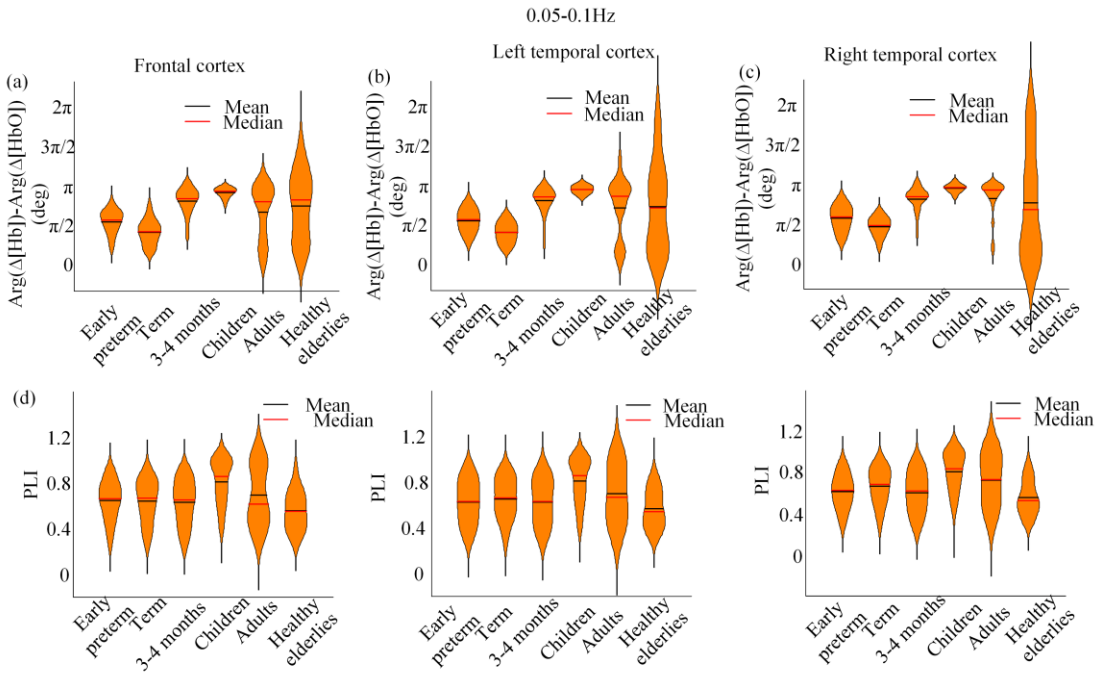

Fig. S7. Violin plots of the Arg(Δ[Hb])-Arg(Δ[HbO]) and PLI for different age groups in different spatial areas. (a)-(c) Violin plots of the Arg(Δ[Hb])-Arg(Δ[HbO]) for different age groups in the frontal, left temporal, and right temporal areas. The Arg(Δ[Hb])-Arg(Δ[HbO]) frequency band is 0.05-0.01 Hz. The black line and red line represent the mean and median of the indices, respectively. (d)-(f) Violin plots of the PLI with the age groups in the frontal, left temporal, and right temporal areas in 0.05-0.1 Hz.

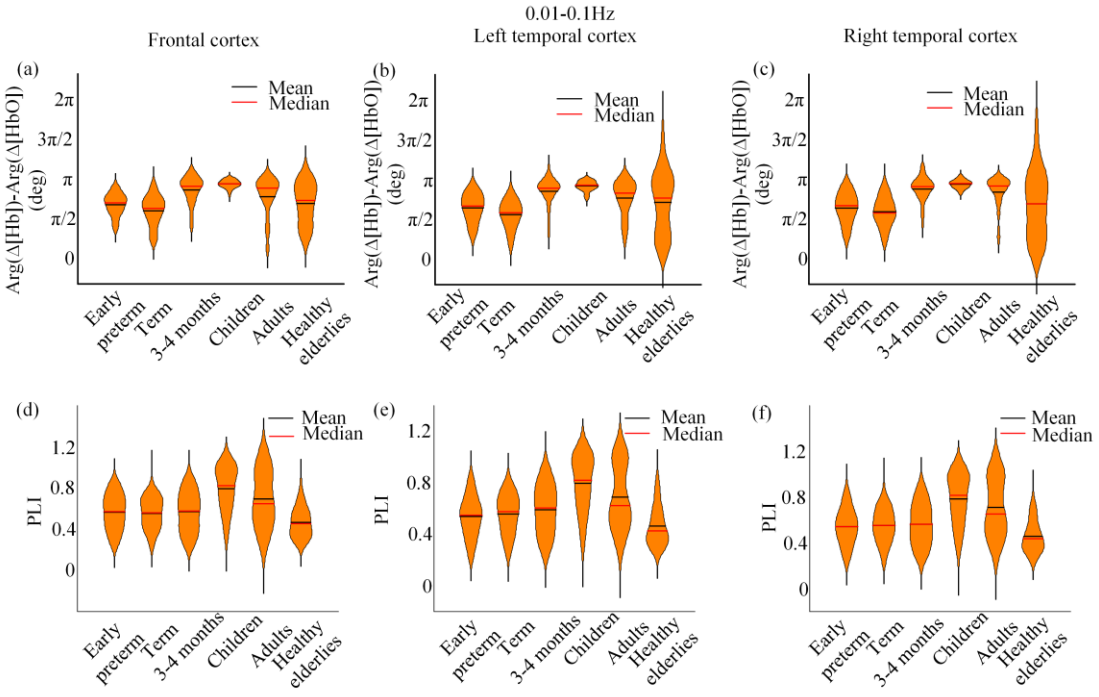

Fig. S8. Violin plots of the Arg(Δ[Hb])-Arg(Δ[HbO]) and PLI for different age groups in different spatial

areas. (a)-(c) Violin plots of the Arg(Δ[Hb])-Arg(Δ[HbO]) for different age groups in the frontal, left temporal, and right temporal areas. The Arg(Δ[Hb])-Arg(Δ[HbO]) frequency band is 0.01-0.1 Hz. The black line and red line represent the mean and median of the indices, respectively. (d)-(f) Violin plots of the PLI with the age groups in the frontal, left temporal, and right temporal areas in 0.01-0.1 Hz.

TABLE S9. THE STATISTICS OF ARG(Δ[HB])-ARG(Δ[HBO]) (RAD) WITH THE AGE GROUPS OF EARLY PRETERM, TERM, AND 3-4 MONTHS INFANTS, CHILDREN, ADULTS, AND HEALTHY ELDERLIES IN FRONTAL CORTEX, LEFT TEMPORAL, AND RIGHT TEMPORAL CORTICES IN DIFFERENT FREQUENCY BANDS (0.01-0.05 HZ, 0.05-0.1 HZ, AND 0.01-0.1 HZ)

		Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
		Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD
0.01-0.05 Hz	FC	2.24 ±0.50	2.02 ±0.66	2.75 ±0.58	2.94 ±0.13	2.56 ±0.41	2.29 ±,0.46
	LTC	2.21 ±0.62	1.94 ±0.66	2.68 ±0.60	2.93 ±0.23	2.37 ±0.78	2.37 ±1.04
	RTC	2.08 ±0.64	1.97 ±0.71	2.82 ±0.55	2.93 ±0.25	2.60 ±0.72	2.39 ±1.08
0.05-0.1 Hz	FC	1.73 ±0.47	1.32 ±0.49	2.55 ±0.51	2.94 ±0.15	2.03 ±0.87	2.40 ±1.23
	LTC	1.76 ±0.46	1.29 ±0.41	2.54 ±0.52	2.97 ±0.24	2.33 ±1.07	2.07 ±1.20
	RTC	1.79 ±0.49	1.47 ±0.38	2.55 ±0.47	2.99 ±0.19	2.86 ±0.49	2.38 ±1.20
0.01-0.1 Hz	FC	2.12 ±0.43	1.86 ±0.58	2.70 ±0.53	2.95 ±0.11	2.57 ±0.38	2.18 ±0.47
	LTC	2.02 ±0.55	1.75 ±0.54	2.67 ±0.52	2.92 ±0.24	2.20 ±0.84	2.20 ±1.13
	RTC	2.00 ±0.58	1.84 ±0.57	2.75 ±0.48	2.97 ±0.23	2.71 ±0.61	2.23 ±1.20

TABLE S10. THE STATISTICS OF PLI WITH THE AGE GROUPS OF EARLY PRETERM, TERM, AND 3-4 MONTHS INFANTS CHILDREN, ADULTS, AND THE HEALTHY ELDERLIES IN FRONTAL CORTEX, LEFT TEMPORAL, AND RIGHT TEMPORAL CORTICES IN DIFFERENT FREQUENCY BANDS (0.01-0.05 HZ, 0.05-0.1 HZ, AND 0.01-0.1 HZ)

		Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
		Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD
0.01-0.05 Hz	FC	0.62 ±0.17	0.60 ±0.17	0.59 ±0.19	0.80 ±0.13	0.67 ±0.14	0.56 ±0.15
	LTC	0.56 ±0.18	0.60 ±0.17	0.62 ±0.20	0.78 ±0.21	0.75 ±0.22	0.50 ±0.13
	RTC	0.59 ±0.18	0.58,0.17	0.59 ±0.19	0.79 ±0.21	0.76 ±0.22	0.50 ±0.14
0.05-0.1 Hz	FC	0.64 ±0.18	0.64 ±0.19	0.63 ±0.20	0.82 ±0.14	0.60 ±0.18	0.55 ±0.17
	LTC	0.63 ±0.19	0.68 ±0.19	0.62 ±0.20	0.77 ±0.21	0.71 ±0.26	0.58 ±0.17
	RTC	0.63 ±0.16	0.65 ±0.18	0.61 ±0.20	0.81 ±0.20	0.76 ±0.25	0.56 ±0.18
0..01-0.1 Hz	FC	0.57 ±017	0.57 ±0.16	0.57 ±0.20	0.79 ±0.13	0.60 ±0.17	0.50 ±0.16
	LTC	0.54 ±0.16	0.57 ±0.16	0.59 ±0.19	0.76 ±0.22	0.71 ±0.25	0.46 ±0.15
	RTC	0.54 ±0.17	0.56 ±0.16	0.56 ±0.18	0.78 ±0.23	0.74 ±0.25	0.45 ±0.14

(4) The statistical analysis of phase difference and PLI indices in all age groups in different cortical regions and frequency bands.

TABLE S11. THE F-VALUES AND P-VALUES OF THE ARG(Δ[HB])-ARG(Δ[HBO]) IN ALL AGE GROUPS IN DIFFERENT FREQUENCY BANDS

	Main effects		Interaction effects
	age	Cortical region	age*cortical region
0.01-0.05 Hz	F(5,3713)=161.355 *P*=0.000	F(2,3713)=2.163 *P*=0.115	F(10,3713)=1.518 *P*=0.126
0.05-0.1 Hz	F(5,3816)=260.166 *P*=0.000	F(2,3816)=10.634 *P*=0.000	F(10,3816)=3.490 *P*=0.000
0.01-0.1 Hz	F(5,2941)=227.080 *P*=0.000	F(2,2941)=7.117 *P*=0.001	F(10,2941)=1.749 *P*=0.065

TABLE S12. THE SIGNIFICANT DIFFERENCE (P-VALUE) OF ARG(Δ[HB])-ARG(Δ[HBO]) BETWEEN DIFFERENT AREAS IN ALL AGE GROUPS OF EARLY PRETERM, TERM, 3-4 MONTHS, CHILDREN, ADULTS, HEALTHY ELDERLIES RESPECTIVELY.

	0.01-0.05 Hz			0.05-0.1 Hz			0.01-0.1 Hz		
	F-LT	F-RT	LT-RT	F-LT	F-RT	LT-RT	F-LT	F-RT	LT-RT
Early preterm	o	*	o	o	o	o	o	o	o
term	o	o	o	o	o	o	o	o	o
3-4 months	o	o	*	o	o	*	o	o	*
Children	o	o	o	o	o	o	o	o	o
Adults	o	o	*	o	***	*	*	o	**
Healthy elderlies	o	o	o	**	o	**	o	o	o

F-LT: Frontal cortex vs. left temporal cortex

F-RT: Frontal cortex vs. right temporal cortex

LT-RT: Left temporal cortex vs. right temporal cortex

The symbols, "o", "*", "**" and "***" indicate the *p*-values $p>0.05$, $p<0.05$, $p<0.01$ and $p<0.001$, respectively. Two-way ANOVA test with a post-hoc test with Bonferroni correction was used to analyze the significant difference.

TABLE S13. THE SIGNIFICANT DIFFERENCE (P-VALUE) OF ARG(Δ[HB])-ARG(Δ[HBO]) BETWEEN THE AGE GROUPS IN THE CORTEX REGIONS OF FRONTAL, LEFT TEMPORAL, AND RIGHT TEMPORAL CORTICES IN 0.01-0.05 Hz.

		Term	3-4 months	Children	Adults	Healthy elderlies
Frontal cortex	Early Preterm	***	***	***	*	o
	Term		***	***	***	**
	3-4 months			o	o	***
	Children				o	o
	Adults					o
Left temporal cortex	Early Preterm	o	***	***	o	**
	Term		***	***	**	***
	3-4 months			*	o	***
	Children				***	***
	Adults					o
Right temporal cortex	Early Preterm	o	***	***	***	**
	Term		***	***	***	***
	3-4 months			o	o	***
	Children				o	***
	Adults					o

The symbols, "o", "*", "**" and "***" indicate the p-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, respectively. Two-way ANOVA test with a post-hoc test with Bonferroni correction was used to analyze the significant difference.

TABLE S14. THE SIGNIFICANT DIFFERENCE (P-VALUE) OF ARG(Δ[HB])-ARG(Δ[HBO]) BETWEEN THE AGE GROUPS IN THE CORTEX REGIONS OF FRONTAL, LEFT TEMPORAL, AND RIGHT TEMPORAL CORTICES IN 0.05-0.1 Hz.

		Term	3-4 months	Children	Adults	Healthy elderlies
Frontal cortex	Early Preterm	***	***	***	o	***
	Term		***	***	***	***
	3-4 months			***	***	o
	Children				***	***
	Adults					o
Left temporal cortex	Early Preterm	***	***	***	***	**
	Term		***	***	***	***
	3-4 months			***	o	***
	Children				***	***
	Adults					o
Right temporal cortex	Early Preterm	**	***	***	***	***
	Term		***	***	***	***
	3-4 months			***	o	o
	Children				o	***

	Adults	**

The symbols, "o", “*”, “**” and “***” indicate the *p*-values $p>0.05$, $p<0.05$, $p<0.01$ and $p<0.001$, respectively. Two-way ANOVA test with a post-hoc test with Bonferroni correction was used to analyze the significant difference.

TABLE S15. THE SIGNIFICANT DIFFERENCE (P-VALUE) OF ARG(Δ[HB])-ARG(Δ[HBO]) BETWEEN THE AGE GROUPS IN THE CORTEX REGIONS OF FRONTAL, LEFT TEMPORAL, AND RIGHT TEMPORAL CORTICES IN 0.01-0.01 Hz.

		Term	3-4 months	Children	Adults	Healthy elderlies
Frontal cortex	Early Preterm	***	***	***	***	o
	Term		***	***	***	***
	3-4 months			**	o	***
	Children				**	***
	Adults					**
Left temporal cortex	Early Preterm	**	***	***	o	o
	Term		***	***	**	***
	3-4 months			*	***	***
	Children				***	***
	Adults					o
Right temporal cortex	Early Preterm	o	***	***	***	*
	Term		***	***	***	***
	3-4 months			o	o	***
	Children				o	***
	Adults					***

The symbols, “o”, “*”, “**” and “***” indicate the *p*-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, respectively. Two-way ANOVA test with a post-hoc test with Bonferroni correction was used to analyze the significant difference.

TABLE S16. THE F-VALUES AND P-VALUES OF THE PLI IN ALL AGE GROUPS IN DIFFERENT FREQUENCY BANDS

	Main effects		Interaction effects
	age	Cortical region	age*cortical region
0.01-0.05 Hz	F(5,3713)=172.597 P=0.000	F(2,3713)=0.421 P=0.656	F(10,3713)=4.647 P=0.000
0.05-0.1 Hz	F(5,3816)=107.878 P=0.000	F(2,3816)=4.283 0.014	F(10,3816)=4.927 P=0.000
0.01-0.1 Hz	F(5,2941)=211.015 P=0.000	F(2,2941)=0.295 P=0.745	F(10,2941)=5.624 P=0.000

TABLE S17. THE SIGNIFICANT DIFFERENCES (P-VALUE) OF PLI BETWEEN DIFFERENT CORTICAL REGIONS IN THE AGE GROUPS OF EARLY PRETERM, TERM, 3-4 MONTHS, CHILDREN, ADULTS, HEALTHY ELDERLIES RESPECTIVELY.

	0.01-0.05 Hz			0.05-0.1 Hz			0.01-0.1 Hz		
	F-LT	F-RT	LT-RT	F-LT	F-RT	LT-RT	F-LT	F-RT	LT-RT
Early preterm	***	o	o	o	o	o	*	o	o
term	o	o	o	*	o	o	o	o	o
3-4 months	o	o	o	o	o	o	o	o	o
Children	o	o	o	*	o	o	o	o	o
Adults	*	**	o	***	***	o	***	***	o
Healthy elderlies	**	**	o	o	o	o	*	**	o

F-LT: Frontal cortex vs. left temporal cortex

F-RT: Frontal cortex vs. right temporal cortex

LT-RT: Left temporal cortex vs. right temporal cortex

The symbols, "o", "*", "**" and "***" indicate the p-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, respectively. Two-way ANOVA test with a post-hoc test with Bonferroni correction was used to analyze the significant difference.

TABLE S18. THE SIGNIFICANT DIFFERENCES (P-VALUE) OF PLI BETWEEN DIFFERENT AGE GROUPS IN THE CORTEX REGIONS OF FRONTAL, TEMPORAL, PARIETAL, AND OCCIPITAL CORTICES IN 0.01-0.05 HZ.

		Term	3-4 months	Children	Adults	Healthy elderlies
Frontal cortex	Early Preterm	o	o	***	o	**
	Term		o	***	*	o
	3-4 months			***	**	o
	Children				***	***
	Adults					***
Left temporal cortex	Early Preterm	o	o	***	***	**
	Term		o	***	***	*******
	3-4 months			***	***	***
	Children				o	***
	Adults					***
Right temporal cortex	Early Preterm	o	o	***	***	**
	Term		o	***	***	*******
	3-4 months			***	***	***
	Children				o	***
	Adults					***

The symbols, "o", "*", "**" and "***" indicate the p-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, respectively. Two-way ANOVA test with a post-hoc test with Bonferroni correction was used to analyze the significant difference.

TABLE S19.THE SIGNIFICANT DIFFERENCES (P-VALUE) OF PLI BETWEEN DIFFERENT AGE GROUPS IN THE CORTEX REGIONS OF FRONTAL, TEMPORAL, PARIETAL, AND OCCIPITAL CORTICES IN 0.05-0.1 HZ.

		Term	3-4 months	Children	Adults	Healthy elderlies
Frontal cortex	Early Preterm	o	o	***	o	***
	Term		o	***	o	*****
	3-4 months			***	o	***
	Children				***	***
	Adults					o
Left temporal cortex	Early Preterm	o	o	***	*	*
	Term		**	***	o	*****
	3-4 months			***	**	*
	Children				o	***
	Adults					***
Right temporal cortex	Early Preterm	o	o	***	***	***
	Term		o	***	***	*****
	3-4 months			***	***	*
	Children				o	***
	Adults					***

The symbols, "o", "*", "**" and "***" indicate the *p*-values $p>0.05$, $p < 0.05$, $p<0.01$, and $p<0.001$, respectively. Two-way ANOVA test with a post-hoc test with Bonferroni correction was used to analyze the significant difference.

TABLE S20. THE SIGNIFICANT DIFFERENCES (P-VALUE) OF PLI BETWEEN DIFFERENT AGE GROUPS IN THE CORTEX REGIONS OF FRONTAL, TEMPORAL, PARIETAL, AND OCCIPITAL CORTICES IN 0.01-0.1 HZ.

		Term	3-4 months	Children	Adults	Healthy elderlies
Frontal cortex	Early Preterm	o	o	***	o	***
	Term		o	***	o	*****
	3-4 months			***	o	***
	Children				***	***
	Adults					***
Left temporal cortex	Early Preterm	o	**	***	***	***
	Term		o	***	***	*****
	3-4 months			***	***	***
	Children				o	***
	Adults					***
Right temporal cortex	Early Preterm	o	o	***	***	***
	Term		o	***	***	*****
	3-4 months			***	***	***
	Children				o	***
	Adults					***

The symbols, "o", "*", "**" and "***" indicate the *p*-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, respectively. Two-way ANOVA test with a post-hoc test with Bonferroni correction was used to

analyze the significant difference.

Part V. The statistical analysis of the indices at the group level

The group-level analysis of Arg(Δ[Hb])-Arg(Δ[HbO]) and PLI based on the averaged indices of a subject in each cortical region were performed. Figs. S9-S11 are the box plots of Arg(Δ[Hb])-Arg(Δ[HbO]) and PLI in the frequency bands of 0.01-0.05 Hz, 0.05-0.1 Hz, and 0.01-0.1 Hz, respectively. The averaged values in each region are taken as the sample for statistical analysis. Similar to the statistical method used in the channel-based analysis, the parametric Watson-Williams multi-sample test and Kruskal-Wallis test were used for group-level analysis. Bonferroni correction was performed to determine significant differences between different age groups. A two-way repeated analysis of variance (two-way ANOVA) was applied to assess the interactions and the main effects on the two dependent variables (Arg(Δ[Hb])-Arg(Δ[HbO], and PLI) for the two conditions: age group and brain region. A post-hoc test with Bonferroni correction determined the significant difference of the phase difference (Arg(Δ[Hb])-Arg(Δ[HbO])) and PLI indices among various brain regions (i.e., frontal, left temporal, and right temporal regions) in each age group (i.e., preterm infants, term infants, 3-4-month-old infants, children, adults, and healthy elderly). Adjusted p-values below 0.05 were considered to indicate a statistically significant difference.

The results showed that the Arg(Δ[Hb])-Arg(Δ[HbO]) indices of the 3-4-month-olds infants, children, and adults tended toward anti-phase compared with the preterm, term infants and the healthy elderlies. The PLIs of children (6-11 years old.) are higher than the other age groups. The mean and SD of the Arg(Δ[Hb])-Arg(Δ[HbO]) and PLI indices are presented in tables S21 and S22. The significant differences of Arg(Δ[Hb])-Arg(Δ[HbO]) with different age groups in 0.01-0.05 Hz,0.05-0.1 Hz, and 0.01-0.1 Hz, are showed in tables S23-S25. The significant differences of PLI in these three frequency bands are shown in tables S26-S28. The significant tests showed that the significance with different age groups is variable in different frequency bands and cortical regions. These results of group-level analysis are similar to the channel-based statistics in some frequency bands and regions.

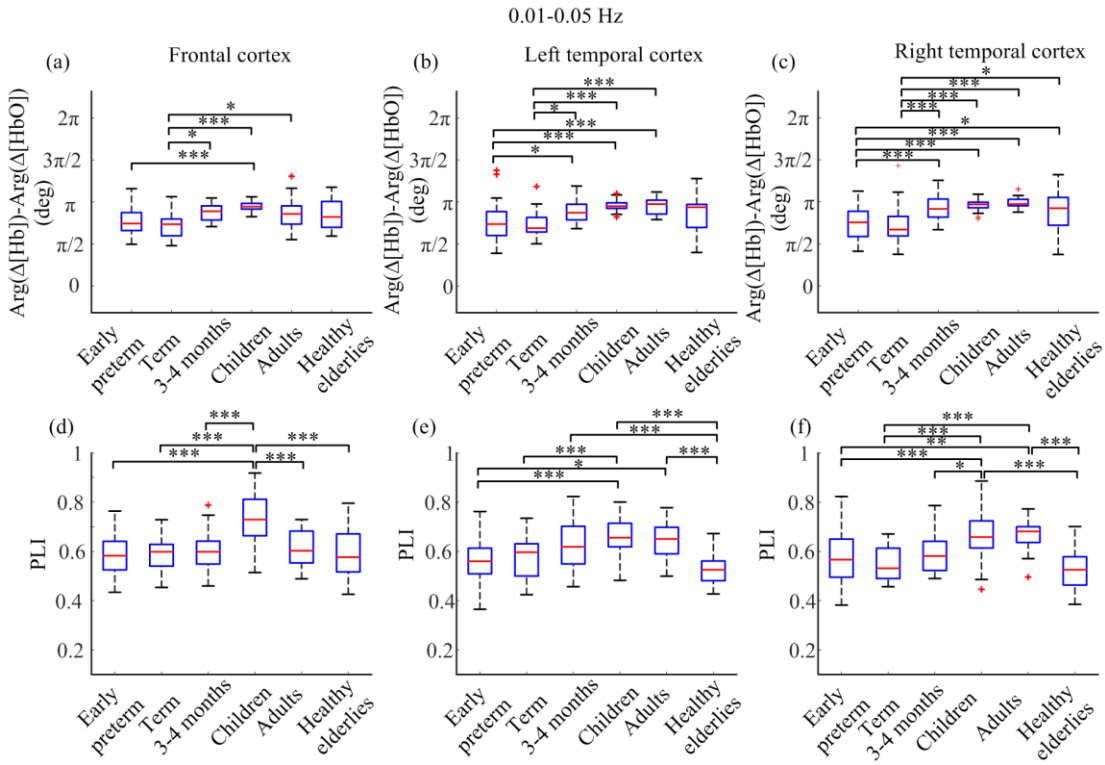

Fig. S9. The statistics of Arg(Δ[Hb])-Arg(Δ[HbO]) and PLI for the age groups of early preterm infants, term infants, 3-4-month-olds infant, children, adults, and healthy elderlies in the frequency band of 0.01-0.05 Hz. (a)-(c) The box plots of Arg(Δ[Hb])-Arg(Δ[HbO]) for six age groups in the cortical region of frontal, left temporal, and right temporal cortex, respectively. (d)-(f) The box plots of PLI indices for six age groups in the similar cortical regions with (a)-(c). The symbols, "o", "*", "**" and "***" indicate the p-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, respectively. Two-way ANOVA test with a post-hoc test with Bonferroni correction was used to analyze the significant difference.

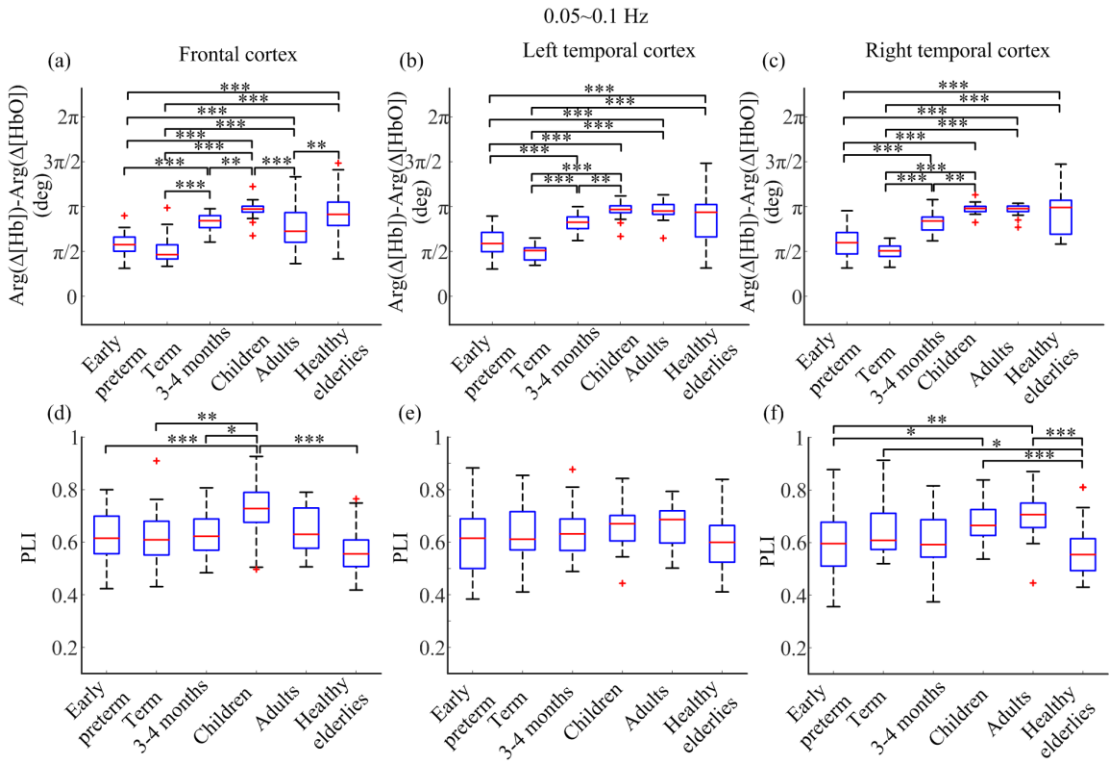

Fig. S10. The similar statistical analyses are shown in Fig. S9 for Arg(Δ[Hb])-Arg(Δ[HbO]) and PLI with the age groups of early preterm infants, term infants, 3-4-month-olds infant, children, adults, and healthy elderlies in the frequency band of 0.05-0.1 Hz.

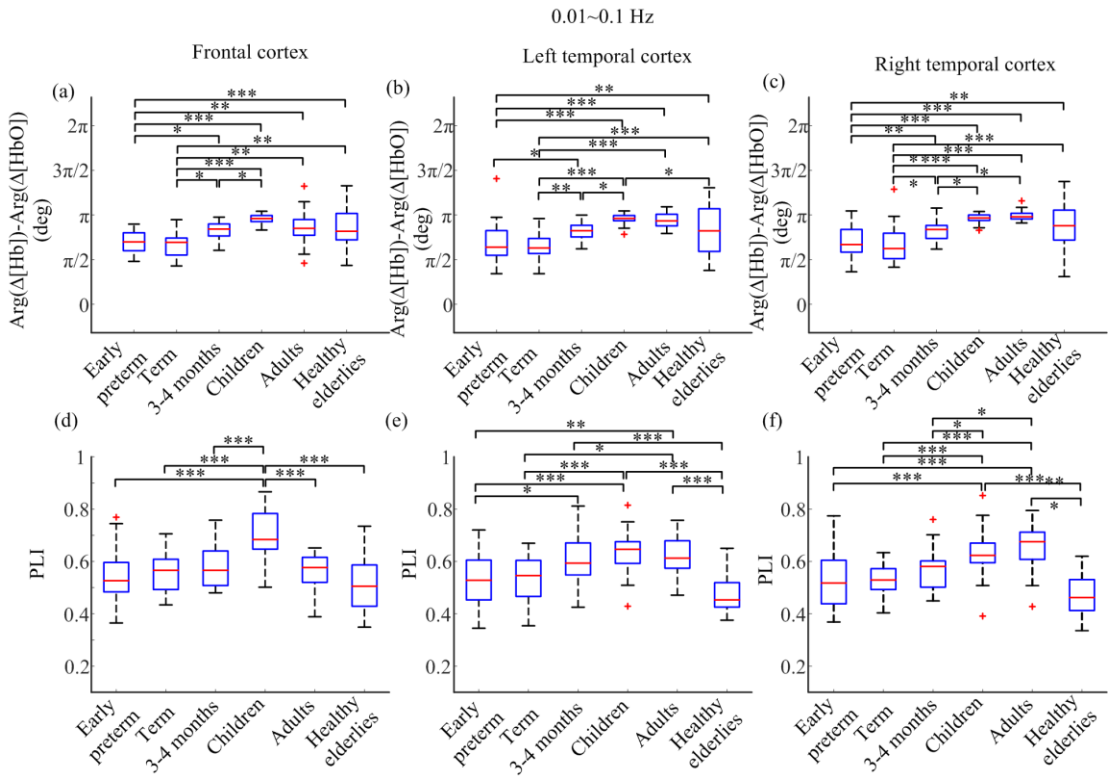

Fig. S11. The similar statistical analyses are shown in Fig S9 for Arg(Δ[Hb])-Arg(Δ[HbO]) and PLI with the age groups of early preterm infants, term infants, 3-4-month-olds infant, children, adults, and

healthy elderlies in the frequency band of 0.01-0.1 Hz.

TABLE S21. THE STATISTICS OF ARG(Δ[HB])-ARG(Δ[HBO]) WITH DIFFERENT AGE GROUPS (EARLY PRETERM, TERM, 3-4 MONTHS, CHILDREN, ADULTS, AND HEALTHY ELDERLIES) IN 0.01-0.05 HZ, 0.05-0.1 HZ AND 0.01-0.1 HZ

	0.01-0.05 Hz Mean ± SD	0.05-0.1 Hz Mean ± SD	0.01-0.1 Hz Mean ± SD
Early preterm	2.372±0.046	1.854±0.043	2.164±0.045
Term	2.297±0.059	1.571±0.056	2.092±0.058
3-4 months	2.811±0.059	2.602±0.056	2.602±0.058
children	2.998±0.045	3.044±0.042	3.014±0.044
Adults	2.952±0.067	2.805±0.063	2.925±0.066
Healthy elderlies	2.697±0.054	2.889±0.052	2.677±0.054

TABLE S22. THE STATISTICS OF PLI WITH DIFFERENT AGE GROUPS (EARLY PRETERM, TERM, 3-4 MONTHS, CHILDREN, ADULTS, AND THE HEALTHY ELDERLIES) IN 0.01-0.05 HZ, 0.05-0.1 HZ, AND 0.01-0.1 HZ

	0.01-0.05 Hz Mean ± SD	0.05-0.1 Hz Mean ± SD	0.01-0.1 Hz Mean ± SD
Early preterm	0.578±0.008	0.609±0.010	0.535±0.008
Term	0.572±0.010	0.631±0.012	0.541±0.010
3-4 months	0.609±0.010	0.631±0.012	0.584±0.010
Children	0.685±0.008	0.685±0.009	0.658±0.008
Adults	0.643±0.012	0.669±0.014	0.609±0.012
Healthy elderlies	0.545±0.009	0.578±0.011	0.491±0.010

TABLE S23. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF ARG(Δ[HB])-ARG(Δ[HBO]) WITH DIFFERENT AGE GROUPS IN 0.01-0.05 HZ.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		o	***	***	***	***
Term	o		***	***	***	***
3-4 months	***	***		o	o	o
Children	***	***	o		o	***
Adults	***	***	o	o		*
Healthy elderlies	***	***	o	***	*	

The symbols, “o”, “*”, “**” and “***” indicate the p-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, through Watson-Williams multi-sample test, respectively (adjusted by Bonferroni correction).

TABLE S24. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF ARG(Δ[HB])-ARG(Δ[HBO]) WITH DIFFERENT AGE GROUPS IN 0.05-0.1 HZ.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		**	***	***	***	***
Term	**		***	***	***	***
3-4 months	***	***		***	o	**
Children	***	***	***		*	o
Adults	***	***	o	*		o
Healthy elderlies	***	***	**	o	o	

The symbols, “o”, “*”, “**” and “***” indicate the p-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, through Watson-Williams multi-sample test, respectively (adjusted by Bonferroni correction).

TABLE S25. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF ARG(Δ[HB])-ARG(Δ[HBO]) WITH DIFFERENT AGE GROUPS IN 0.01-0.1 HZ.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		o	***	***	***	***
Term	o		***	***	***	***
3-4 months	***	***		***	**	o
Children	***	***	***		o	***
Adults	***	***	**	o		o
Healthy elderlies	***	***	o	***	o	

The symbols, “o”, “*”, “**” and “***” indicate the p-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, through Watson-Williams multi-sample test, respectively (adjusted by Bonferroni correction).

TABLE S26. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF PLI WITH DIFFERENT AGE GROUPS IN 0.01-0.05 HZ.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		o	o	***	***	o
Term	o		o	***	***	o
3-4 months	o	o		***	o	***
Children	***	***	***		*	***
Adults	***	***	o	*		***
Healthy elderlies	o	o	***	***	***	

The symbols, "o", “*”, “**” and “***” indicate the $p>0.05=0.0033$, $p<0.05$, $p<0.01$, and $p<0.001$, through Kruskal-Wallis multi-sample test, respectively (adjusted by Bonferroni correction).

TABLE S27. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF PLI WITH DIFFERENT AGE GROUPS IN 0.05-0.1 Hz.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		o	o	***	**	o
Term	o		o	**	o	*
3-4 months	o	o		**	o	*
Children	***	**	**		o	***
Adults	**	o	o	o		***
Healthy elderlies	o	*	*	***	***	

The symbols, "o", "*", "**" and "***" indicate the p-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, through Kruskal-Wallis multi-sample test, respectively (adjusted by Bonferroni correction).

TABLE S28. THE SIGNIFICANT DIFFERENCE (P-VALUES) OF PLI WITH DIFFERENT AGE GROUPS IN 0.01-0.1 Hz.

	Early Preterm	Term	3-4 months	Children	Adults	Healthy elderlies
Early Preterm		o	**	***	***	**
Term	o		o	***	***	**
3-4 months	**	o		***	o	***
Children	***	***	***		**	***
Adults	***	***	o	**		***
Healthy elderlies	**	**	***	***	***	

The symbols, "o", "*", "**" and "***" indicate the p-values $p>0.05$, $p<0.05$, $p<0.01$, and $p<0.001$, through Kruskal-Wallis multi-sample test, respectively (adjusted by Bonferroni correction).

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[2] N. Kollias, and W. B. Gratzer, "Tabulated molar extinction coefficient for hemoglobin in water," Wellman Laboratories, Harvard Medical School, Boston 5, 150–161 (1999).