BRANL GLM Manual

version 1.9E
BRSystems,Inc.
July 14,2023

update history

date	version	content
2021/11/16	1.0	First edition
2021/12/7	1.1	GLM modify sample fig.
2021/12/29	1.2	GLM add “3.2 configuration setting”
2022/1/31	1.3	GLM modify the table of β-value
2022/2/2	1.4	GLM add the procedure of consecutive calculation
2022/2/12	1.5	Add the explanation of input data
2022/3/9	1.6	Update GMF function、how to see the β-value in the case of FIR
2022/3/31	1.7	Add the average value of β-value in FIR_I/II
2022/11/7	1.8	Clarify the prerequisite of GLM and the “stats”
2023/7/14	1.9E	English Version

1. Start up

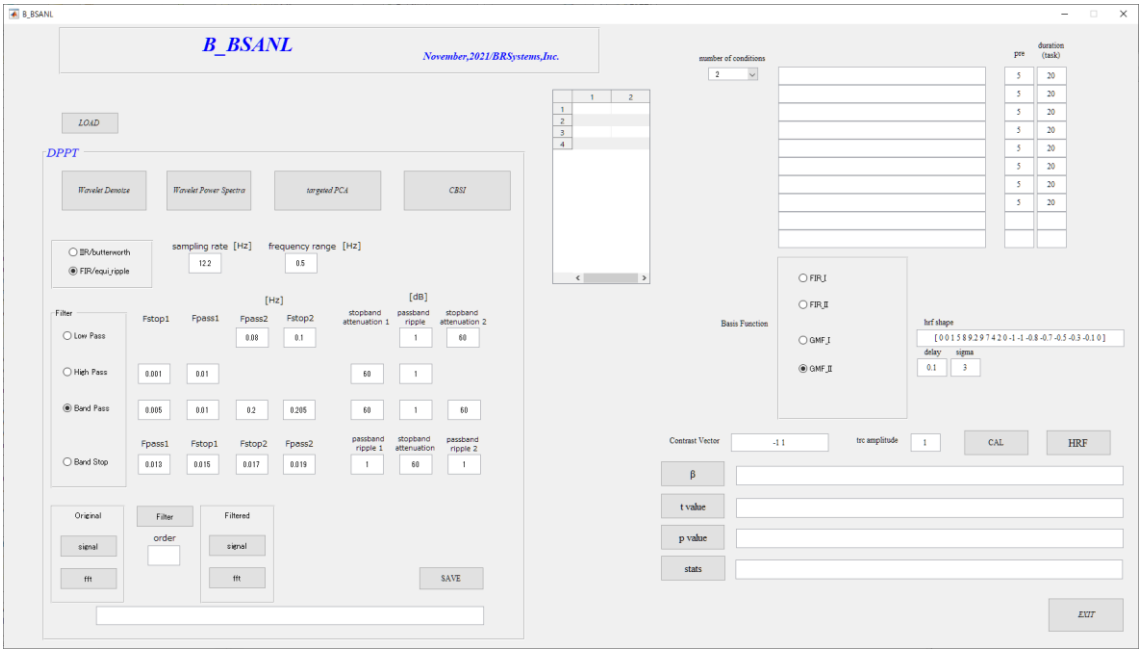
double click BRANL.exe

Next screen launches.

Three methods, WaveletDenoising, tPCA and pre-whitening are implemented for data pre-processing to reduce noise, MA.

Pre-whitening is calculated in the other tool.

Top View



2. GLM

The prerequisite of GLM are,

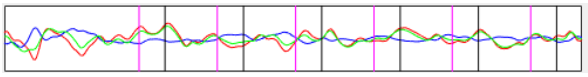
(1) signal is normal distribution.

(2) the effect of outliers on signal is negligible.

(3) the effect of serial correlation is negligible.

2.1 GLM Algorithm

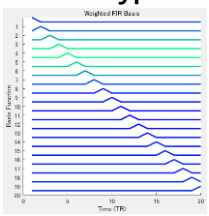
measured concentration data Y (HbO,HbR)



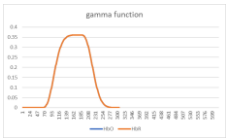
$$Y = X\beta + \varepsilon$$

basis function

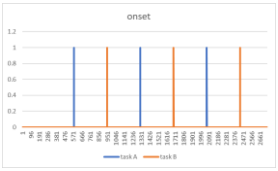
fir type



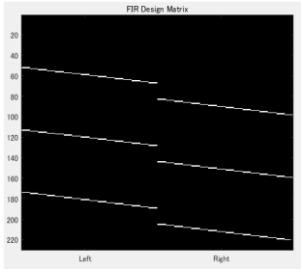
gamma function type



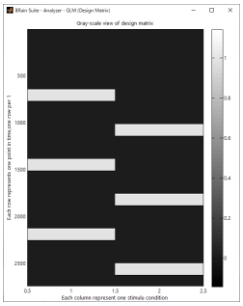
onset/duration



design matrix (convolution)



X

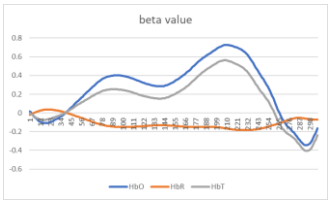


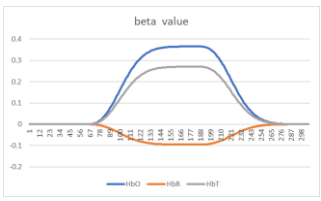
$$X^* = (X^T X)^{-1} X^T$$

β (based on OLS)

$$\beta = X^* Y$$ **(MATLAB/regress)**

HRF





t value

$$t = \frac{c^T \beta}{\sqrt{\varepsilon^2 c^2 (X^T X)^{-1} c}}$$

＊”regress” or ”robustfit” is used in GLM calculation.

＊stats information of regress function (Matlab) is available, so you can verify the R2 score.

＊Y:data　X:regressor　β:coefficient(weight)　e:error　c:contrast vector

2.2 HRF Basis Function

HRF basis function used in fNIRS software is listed the below table.

HRF Basis Function

	GAMMA		FIR	
"Functional Magnetic Response Imaging" second edition SA Huettel,AW Song, G McCarthy	Double gamma function,Gamma function, Gaussian function		Finite Impulse Response (FIR)	
SPM (NIRS_SPM)	Double gamma function spm_hrf.m, spm_Gpdf.m			
Homer3	Modified Gamma function convolved with square wave of duration T	Modified Gamma function and its derivative convolved with square wave of duration T	Consecutive sequence of gaussian function	
AnalyzIR(MDPI)	Canonical HRF Double gamma function	Gamma Function	FIR-Deconvolution	FIR-Impulse Response Deconvolution
BSANL	GMF_I: Double gamma function $gampdf(y,s1,r1) - k \times gampdf(y,s2,r2)$ $k: coefficient(ex. 0.5)$	GMF_II: Gamma Function (1) $gampdf(y,s,r) \cdots$ $p(y\|s,r) = \frac{r^s}{\Gamma(s)} y^{s-1} exp^{(-ry)}$ $y: time, s: shape(peak\ time),$ $r^{-1}: scale(dispersion\ time)$	FIR_I Consecutive 1[sec] BoxCar	FIR_II Consecutive gaussian function

(1) page138,「データ解析のための統計モデリング入門」、久保拓弥

＊Second term of Gamma function means the undershoot.

・Four Methods are provided as basis function.

（1）FIR_I

Flexible model

Multiple boxcar function duration 1[sec] are used as regressor.

（2）FIR_II

Flexible model

Consecutive Gaussian function is used as regressor.

（3）GLM_I

Fixed canonical shape

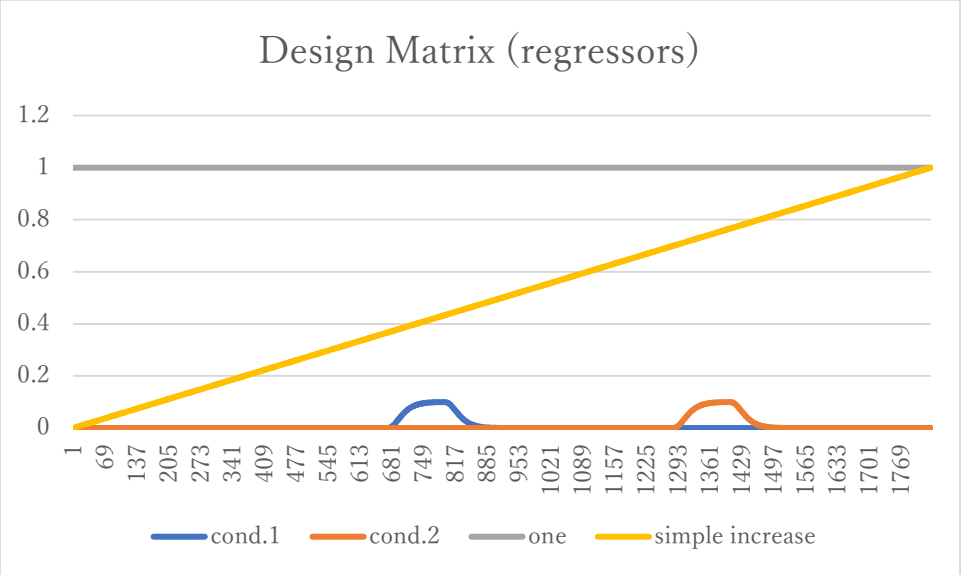
Double gampdf function (Matlab)

（4）GLM_II

Fixed canonical shape

Single gampdf function (Matlab)

・To compute coefficient estimates for a model with terms, include a column of ones and a column of simple increase drift [0,1] as regressors.



3. Configuration

Input data is limited to Concentration data (HbO,HbR).

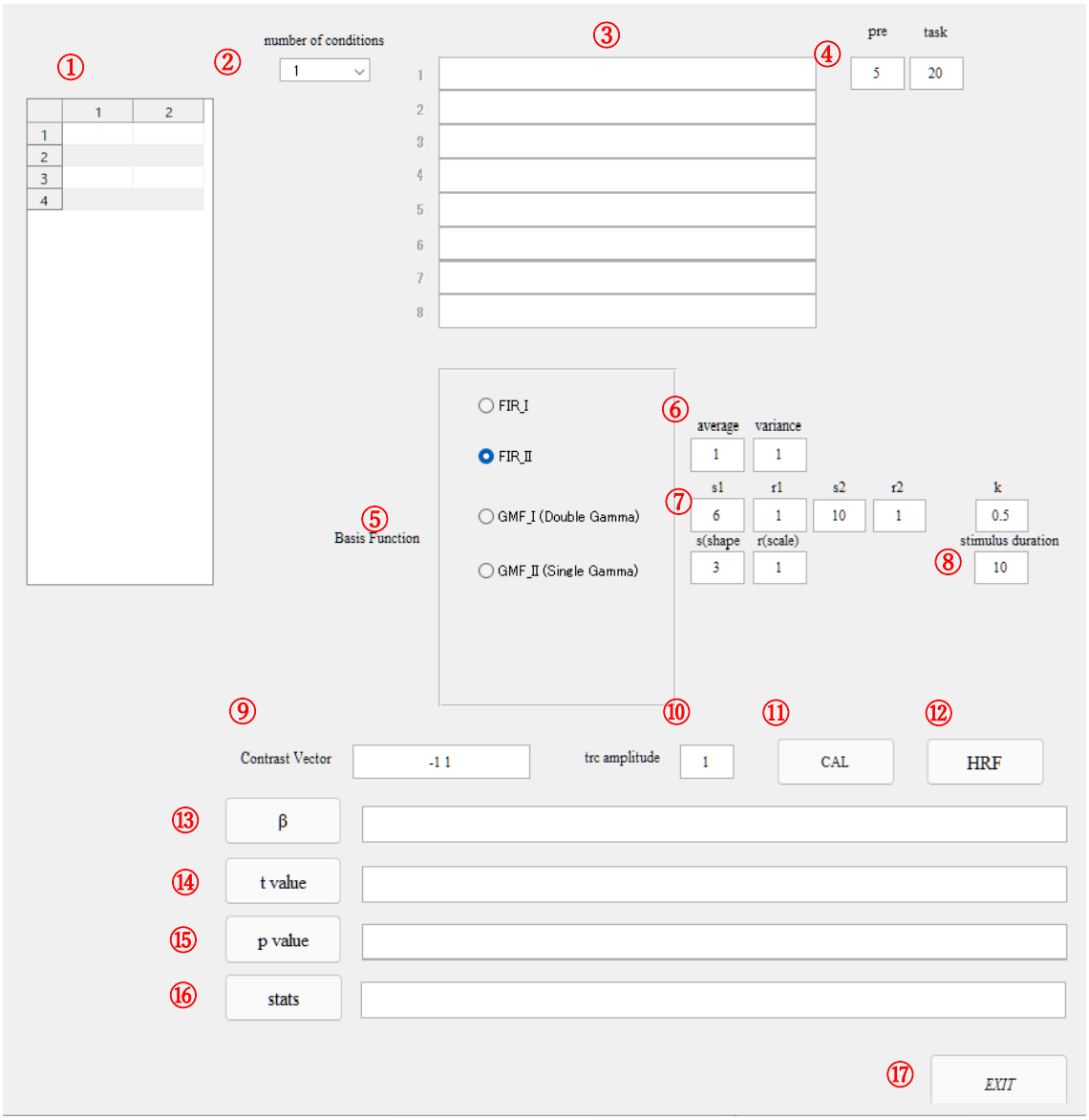
Data conversion. raw(electric signal) to OD, OD to Concentration is done by BRain Analyzer.

File format of input data is csv.

3.1 Configuration setting

*Load data(csv file)

[BRANL Configuration]



① start and end time of each task [sec]
this time is displayed for reference only.

② number of conditions

③ onset time of task
onset time is configured per each condition

④ pre-task range [sec], task duration range [sec]

⑤ select GLM method
◎FIR_I

◎FIR_II

◎GMF_I

canonical hrf, double gampdf function (MATLAB)

$hrf = gampdf(y, s1, r1) - k \times gampdf(y, s2, r2)$

$k: coefficient(ex.\ 0.5)$

$y: time,\ s: shape(peak\ time),\ r^{-1}: scale(dispersion\ time)$

Default value of s1,r1,s2,r2,k are set by reference to ”fMRI in Neuroscience: Modeling the HRF with FIR Basis Functions, The OG Clever Machine”

◎GMF_II

canonical hrf, single gampdf function (MATLAB)

$gampdf(y, s, r) \cdots$

$p(y|s, r) = \frac{r^s}{\Gamma(s)} y^{s-1} exp^{(-ry)} \quad (*)$

$y: time,\ s: shape(peak\ time),\ r^{-1}: scale(dispersion\ time)$

(*) page138,”Introduction to statistical modeling for data analysis”、T.Kubo, Iwanami Shoten,Publishers

Parameters are set depending on the measured data.

⑥ mean and variance of Gamma function, default is 1,1.ガンマ関数の係数

⑦ $s: shape(peak\ time),\ r^{-1}: scale(dispersion\ time)\ k: coefficient(ex.\ 0.5)$

⑧ stimulus duration time [sec]

⑨ contrast vector

⑩ amplitude factor of task related component

⑪ run GLM calculation

⑫ display HRF figure

⑬ save the result of β-value

⑭ save the result of t-value

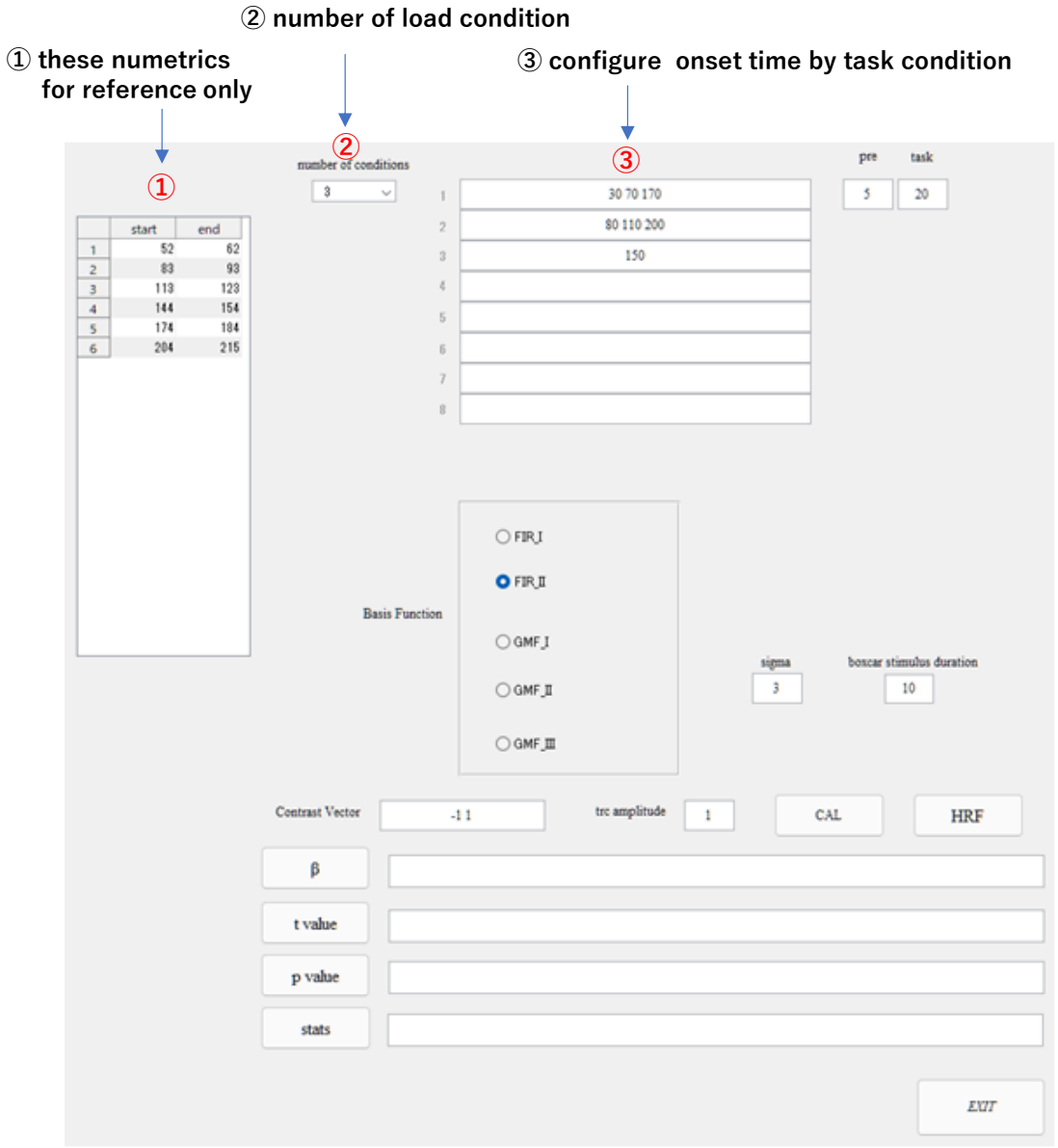
⑮ save the result of p-value

⑯ save the result of stats-value

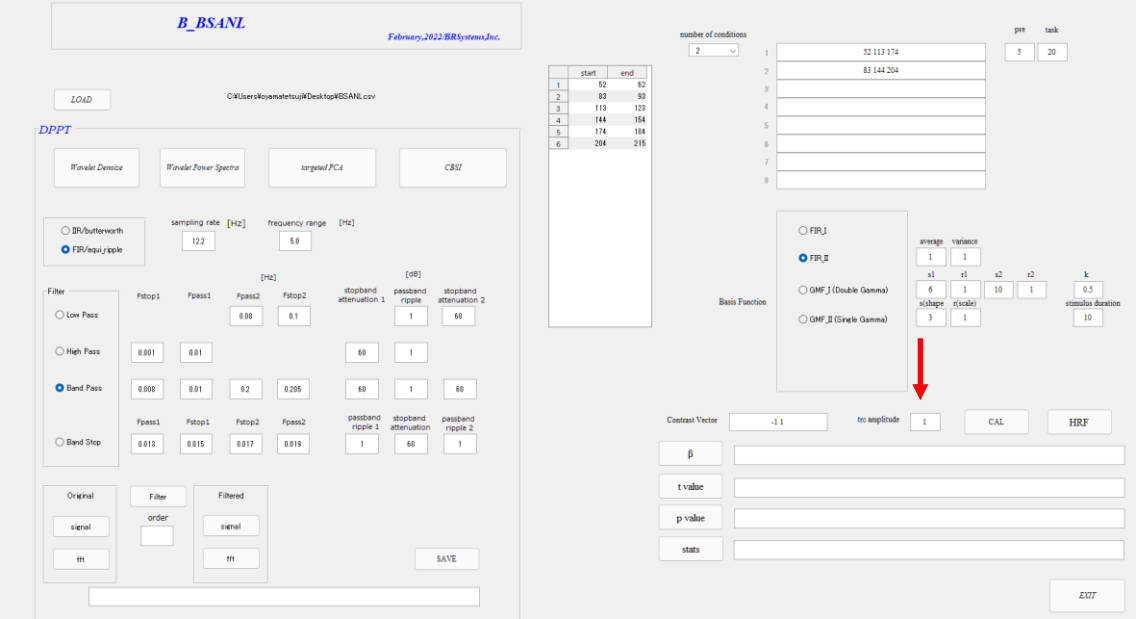
stats includes R^2statistic, F-statistic, p-value, an estimate of the error variance

⑰ Exit BRANL

[onset configuration]

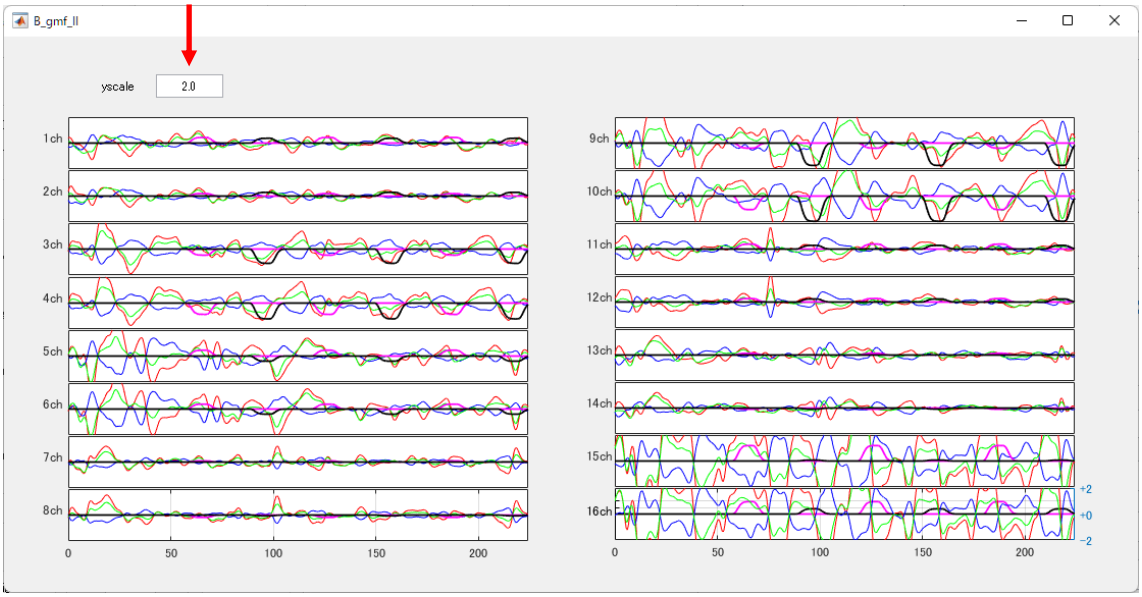


[ampliitude factor of task related component]



trc amplitude set 1, and click “CAL”, then figure below displayed.

data scale will be changed, according to the value “yscale”



The color of task related component

condition 1: magenta, condition 2: black, condition 3: cyan,

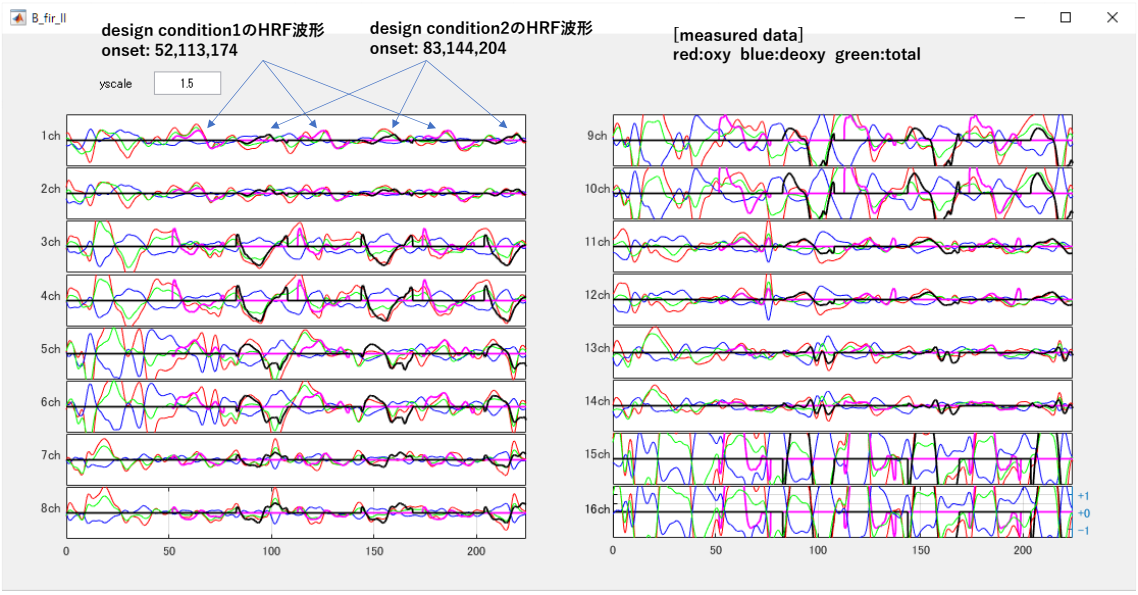
condition 4: magenta, condition 5: black, condition 6: cyan,

- - -

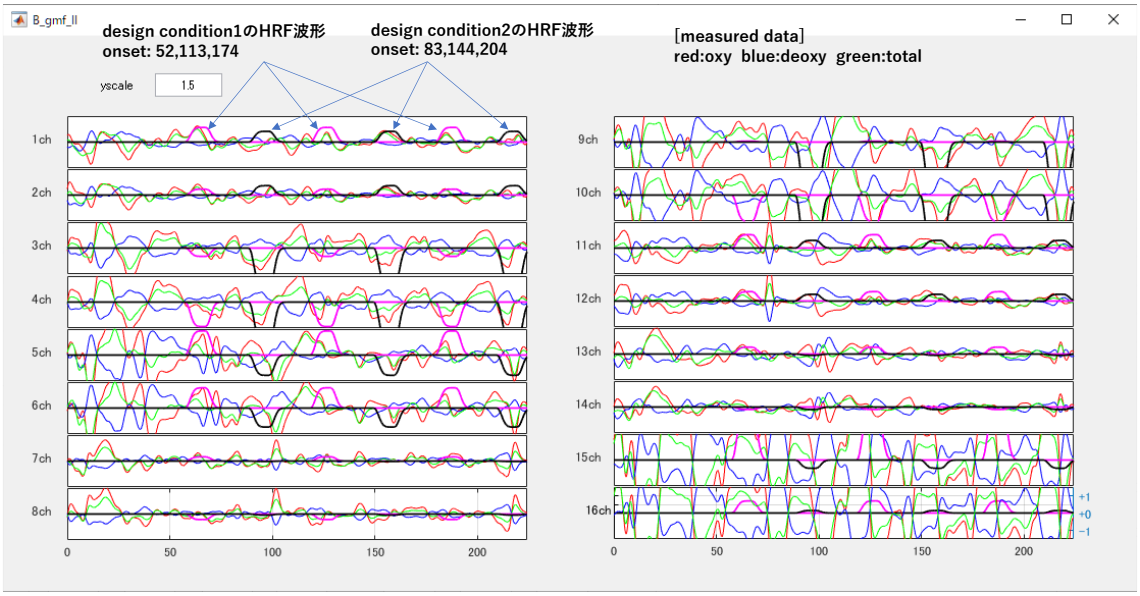
3.2 explanation of figure

concentration signal and task related component

FIR_II example



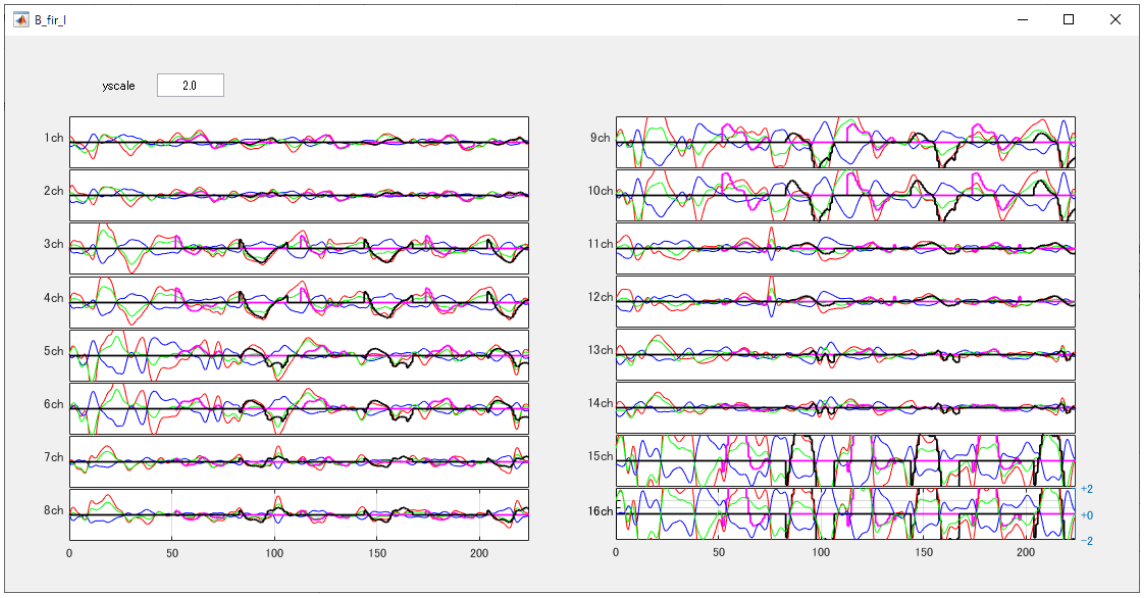
GMF_II example



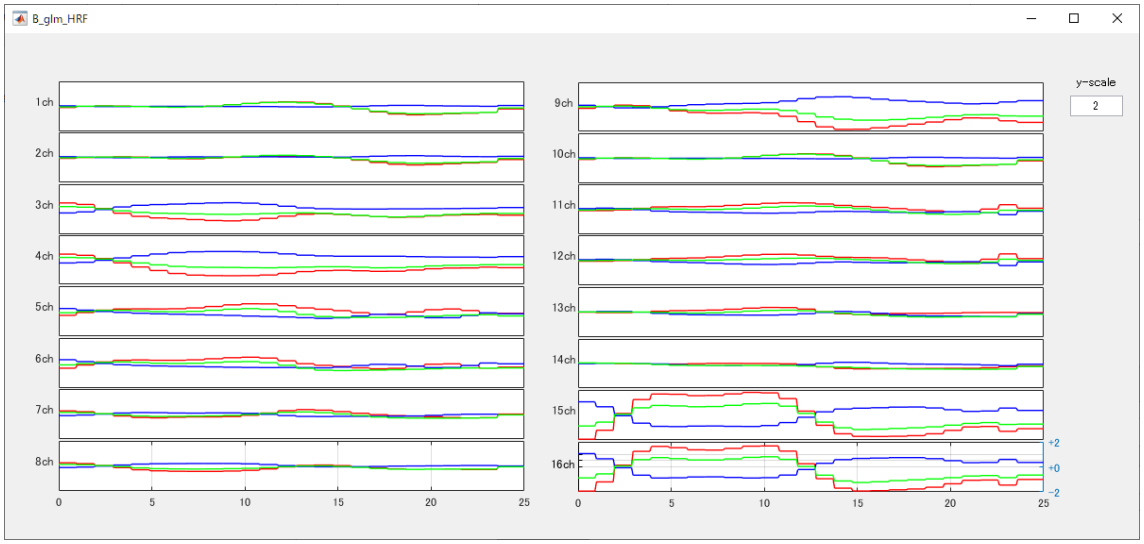
4　Figure for each GLM method

（1）FIR-I

HbO/R/T and task related component

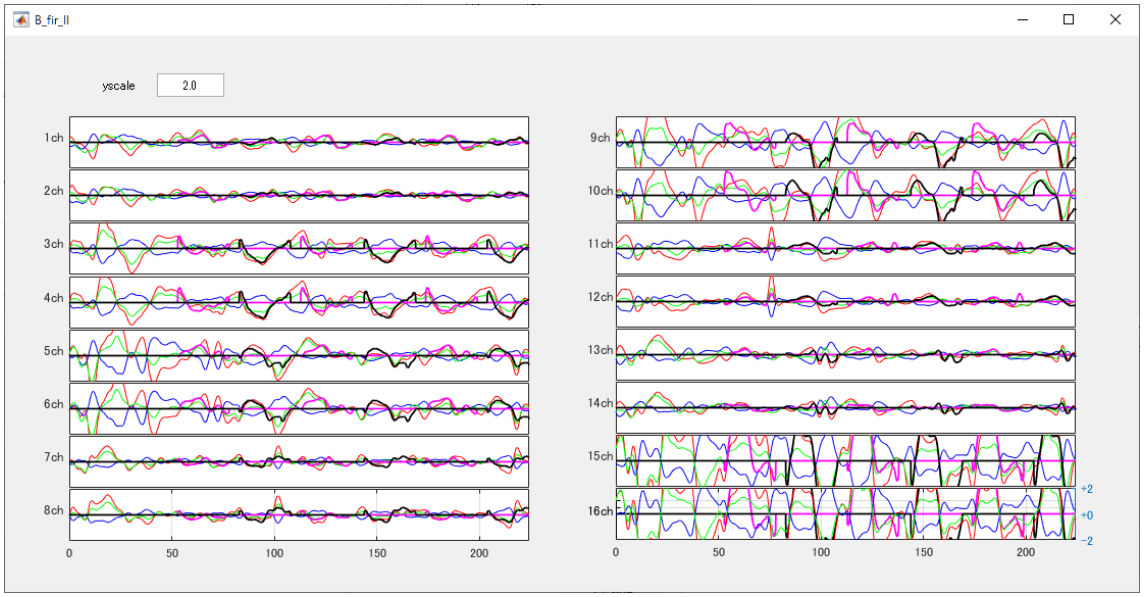


HRF figure

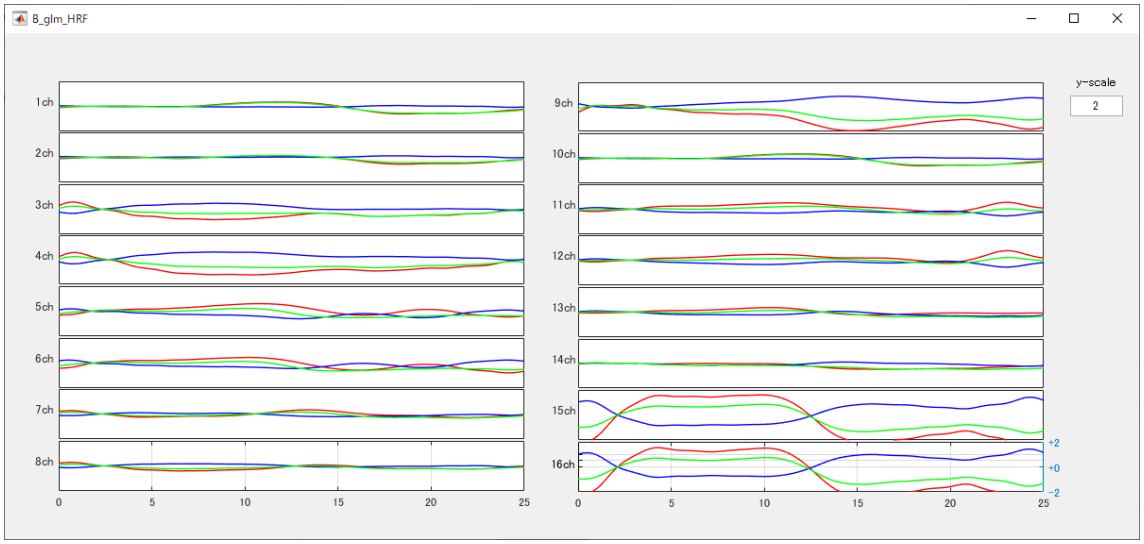


（2）FIR-II

HbO/R/T and task related component

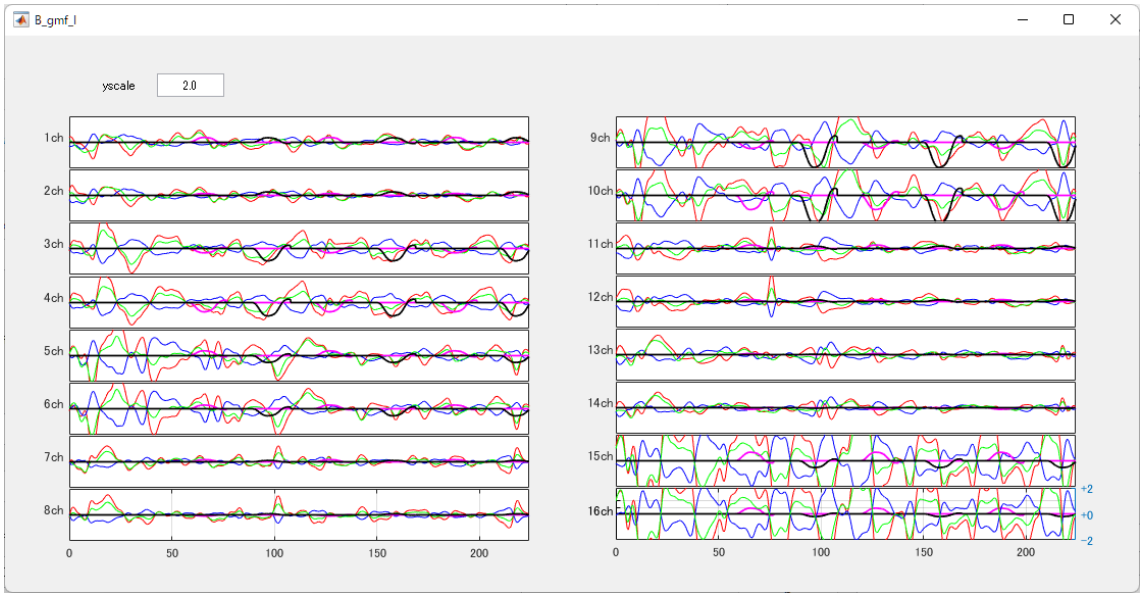


HRF figure

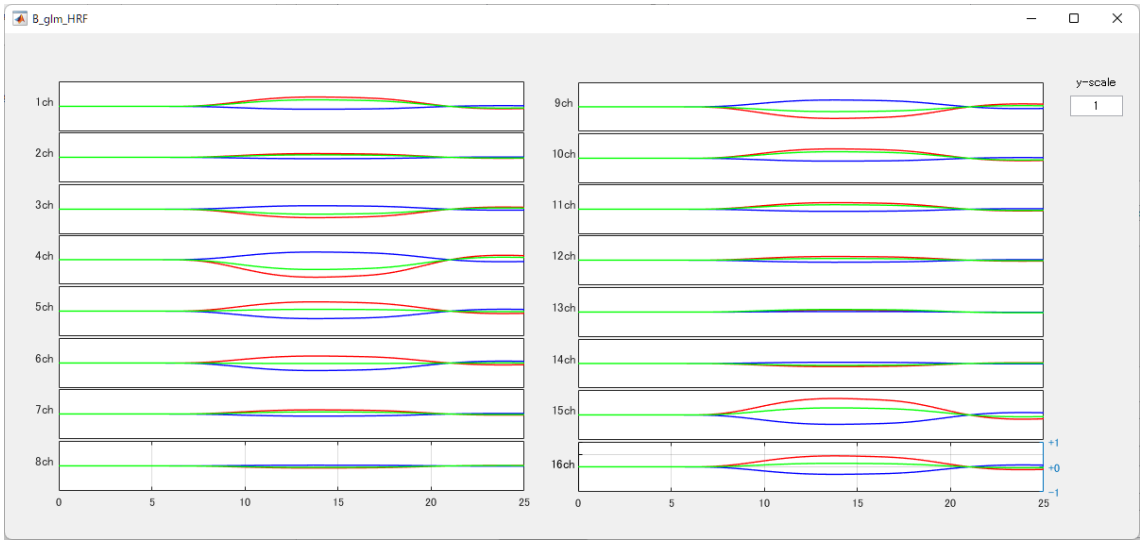


（3）GMF-I

HbO/R/T and task related component

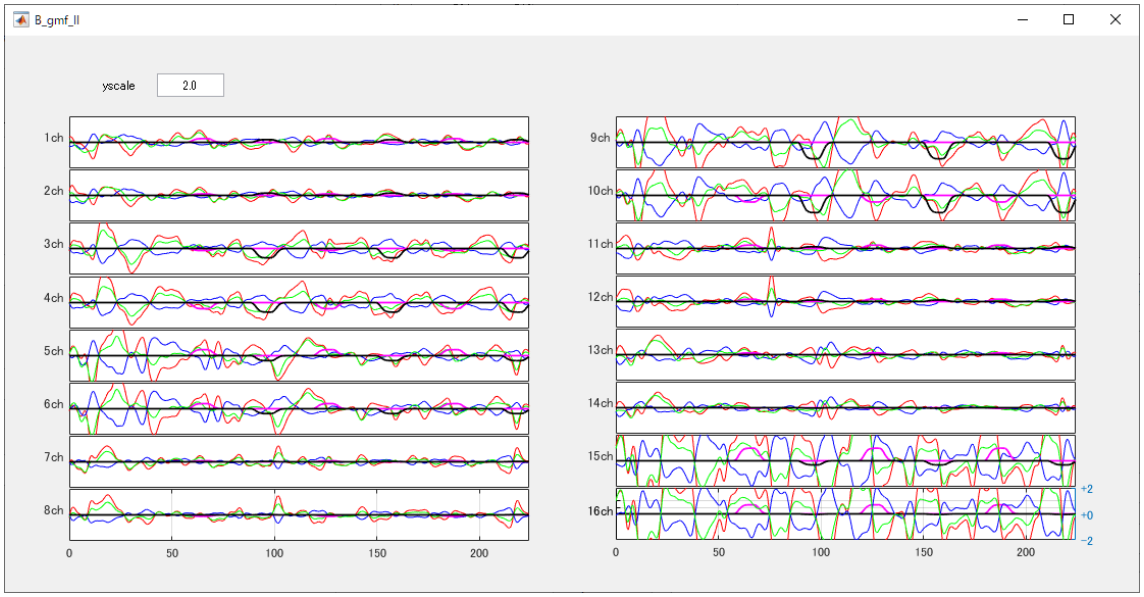


HRF figure

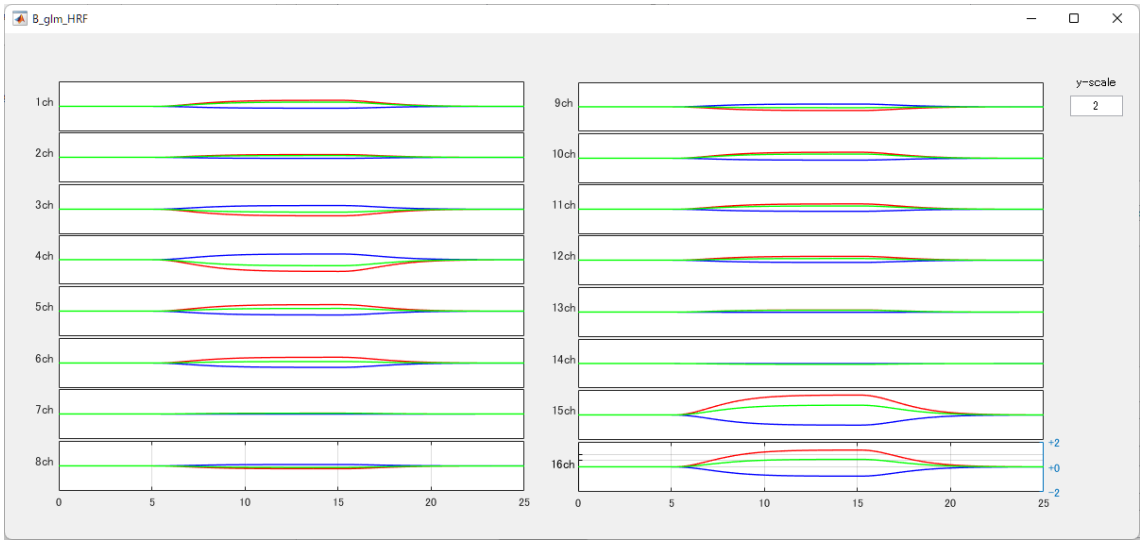


（4）GMF-II

HbO/R/T and task related component



HRF figure



5 Result (sample)

（1） β-value (GMF)

例：HbO/HbR β-value of load condition 1 and load condition 2

beta-value	ch1	ch2	ch3	ch4	ch5	ch6	ch7	ch8	ch9	ch10	ch11	ch12	ch13	ch14	ch15	ch16
1_HbO	0.813	0.339	-0.458	-1.326	1.312	1.114	0.219	-0.305	0.096	-1.354	0.73	0.517	0.387	-0.106	2.849	2.1
1_HbR	-0.247	-0.137	0.237	0.606	-0.692	-0.783	-0.096	0.12	0.169	0.743	-0.272	-0.312	-0.035	0.03	-1.262	-1.047
2_HbO	0.571	0.483	-2.037	-2.082	-1.016	-0.979	0.036	0.001	-3.435	-3.58	0.4	0.355	-0.028	-0.087	-0.638	0.131
2_HbR	-0.168	-0.136	1.121	1.094	0.053	0.262	0.03	0.039	1.309	1.511	-0.167	-0.137	-0.108	-0.158	-0.647	-0.759

β-value(FIR)

[sec] HbO HbR

	Cnd	ch1	ch2	ch3	ch4	ch5	ch6	ch7	ch8	ch9	ch10	ch11	ch12	ch13	ch14	ch15	ch16	ch1	ch2
condition one	1	0.25595	0.12409	0.63993	0.69447	-0.27415	-0.09553	0.2507	0.16634	1.1441	1.7563	0.044129	-0.04143	0.033447	0.21729	-0.17607	-0.23086	-0.0574	-0.0327
	2	0.052785	0.034659	-0.27287	-0.31243	0.44022	0.33892	-0.12538	-0.10055	-0.48197	-0.86224	-0.05849	-0.01954	-0.08542	-0.15483	0.11633	0.18082	-0.04096	-0.02373
	3	0.29775	0.17029	0.35694	0.49968	-0.11258	0.15365	0.12278	0.050535	1.4558	2.0505	0.077554	-0.01289	0.023451	0.22276	1.4447	1.3863	-0.07113	-0.05884
	4	0.052831	0.088236	-0.59828	-0.57579	0.46242	0.43203	-0.27368	-0.23479	-0.3461	-0.77207	0.077664	0.077711	-0.02568	-0.14139	1.3186	1.3839	-0.04056	-0.05862
	5	0.22061	0.12718	0.017751	0.10584	-0.02872	0.2047	-0.06134	-0.15287	0.97864	1.2506	0.20414	0.072109	0.076948	0.1463	1.7158	1.6378	-0.05711	-0.05055
	6	0.043863	0.02649	-0.55024	-0.68568	0.34535	0.34569	-0.25653	-0.28733	-0.31441	-0.68828	0.11057	0.080053	0.037349	-0.10096	1.2159	1.1678	-0.03963	-0.03139
	7	0.15784	0.046651	-0.12389	-0.25759	0.05154	0.22087	-0.01596	-0.16904	0.65423	0.7437	0.13097	0.065344	0.060129	0.13394	1.4907	1.3723	-0.04144	-0.01443
	8	0.095342	0.02125	-0.51142	-0.68805	0.3336	0.35136	-0.18524	-0.29097	-0.17712	-0.51652	0.15092	0.1543	0.054441	-0.01096	1.2842	1.1948	-0.05158	-0.02233
	9	0.20116	0.10549	-0.28665	-0.34782	0.20658	0.32688	-0.07353	-0.1925	0.50915	0.47035	0.18911	0.14825	0.11867	0.079814	1.5928	1.4899	-0.04658	-0.03182
	10	0.20805	0.095439	-0.51124	-0.63098	0.41116	0.4135	-0.17438	-0.24732	0.001515	-0.29095	0.25097	0.22204	0.14625	-0.00518	1.4594	1.4117	-0.06439	-0.03431
	11	0.27073	0.14081	-0.26436	-0.40367	0.3418	0.40574	0.002369	-0.1733	0.44736	0.35077	0.23368	0.17978	0.17676	0.085084	1.6645	1.6303	-0.02631	-0.0094
	12	0.29729	0.15135	-0.36561	-0.58341	0.40097	0.37188	0.000736	-0.16801	-0.12244	-0.3966	0.33378	0.27589	0.16292	0.005294	1.2097	1.2057	-0.07208	-0.03921
	13	0.31703	0.15425	-0.1169	-0.29531	0.22013	0.20789	0.18824	0.008731	-0.02951	-0.19128	0.21148	0.094023	0.069428	-0.00781	0.71236	0.68979	-0.04103	-0.007
	14	0.28263	0.13726	-0.18546	-0.41309	0.14907	0.055826	0.10545	-0.03968	-0.57259	-0.84163	0.25621	0.17857	-0.04361	-0.15318	-0.09262	-0.18942	-0.10316	-0.06068
	15	0.20027	0.11056	-0.10246	-0.25444	0.23174	0.20392	0.10677	0.020199	-0.12714	-0.35944	0.064199	-0.00488	-0.11291	-0.13251	0.31208	0.20699	-0.02094	-0.01137
	16	0.14048	0.054491	-0.28922	-0.399	0.061164	-0.01151	-0.03049	-0.11778	-0.57412	-0.87507	0.25799	0.24571	-0.09302	-0.16538	-0.18277	-0.28273	-0.10853	-0.07424
	17	-0.02763	-0.0477	-0.14841	-0.2777	0.077765	0.1104	0.022347	-0.02147	0.069453	-0.11687	-0.04366	-0.0707	-0.03248	-0.08939	0.47194	0.41655	0.037941	0.040013
	18	-0.0458	-0.11117	-0.40534	-0.50773	-0.12441	-0.16047	-0.15185	-0.25021	-0.55025	-0.71537	0.2406	0.25837	-0.01908	-0.17274	-0.33359	-0.3829	-0.11077	-0.05268
	19	-0.21654	-0.18752	-0.19331	-0.23331	0.14926	0.22304	-0.01065	-0.06189	0.33277	0.22502	-0.23279	-0.28321	-0.05219	-0.07886	0.67178	0.62896	0.11671	0.1083
	20	-0.04527	-0.13856	-0.38574	-0.44956	0.029786	-0.0407	-0.20828	-0.31435	-0.61078	-0.80263	0.32171	0.33929	-0.04252	-0.17273	-0.43395	-0.51914	-0.16455	-0.08847
	21	-0.16419	-0.12771	-0.04194	-0.05718	0.41624	0.49028	0.000673	0.047896	0.73919	0.52421	-0.46577	-0.53759	-0.00862	-0.05484	1.1951	1.1727	0.1356	0.11226
	22	0.035934	-0.0632	-0.39399	-0.47603	0.013488	-0.10904	-0.31632	-0.38505	-0.66521	-0.80909	0.4407	0.45606	-0.00042	-0.20874	-0.34447	-0.41271	-0.23909	-0.15621
	23	-0.17985	-0.09388	-0.00306	-0.06393	0.27071	0.35159	-0.02009	0.037012	0.84367	0.75052	-0.39048	-0.46954	-0.01338	-0.00667	1.3973	1.3614	0.17843	0.12714
	24	0.063193	-0.04924	-0.39321	-0.42004	-0.16846	-0.28229	-0.26654	-0.37046	-0.84681	-0.84217	0.92756	1.0722	-0.00526	-0.0985	-0.65175	-0.79211	-0.22884	-0.14264
condition two	1	0.30052	0.17544	0.34157	0.34719	-0.20273	-0.33209	0.35462	0.26702	-0.23195	0.10834	0.29355	0.20923	0.11778	0.071027	-1.783	-1.6316	0.005479	0.012497
	2	-0.19578	-0.10462	-0.44206	-0.30287	0.4614	0.60886	-0.29001	-0.27013	0.48972	0.38248	-0.08086	-0.02273	-0.12235	-0.08811	1.6883	1.6792	0.056144	0.031691
	3	0.27312	0.16141	0.026182	-0.02048	0.0049	-0.05478	0.22912	0.075073	-0.09722	0.34096	0.40105	0.27181	0.087767	-0.00465	-0.57554	-0.3137	0.013076	0.017247
	4	-0.22486	-0.14847	-0.70638	-0.68043	0.47182	0.65067	-0.36929	-0.44394	0.4467	0.39904	0.009218	0.001312	-0.14123	-0.15822	2.5264	2.6029	0.072414	0.059029
	5	0.14778	0.048825	-0.26384	-0.37107	0.086042	0.064357	0.02394	-0.11338	-0.0825	0.15755	0.36642	0.23017	0.040732	-0.06331	0.47864	0.6774	0.028631	0.046505
extra	0	-0.12381	0.019769	0.22341	0.26892	0.005066	-0.08776	0.05525	0.24084	0.054239	-0.03377	-0.0898	-0.03618	0.10629	0.077613	-0.45243	-0.49918	0.040767	-0.01419
	0	-0.08707	-0.15179	0.53703	0.62591	-0.22244	-0.1515	0.036554	-0.06093	0.32254	0.60729	-0.23953	-0.23787	-0.11774	0.050136	-0.76457	-0.80537	0.013415	0.052499
mean	t1_mean	0.086028	0.011845	-0.2775	-0.39182	0.17987	0.18289	-0.06754	-0.15661	-0.05227	-0.2306	0.15725	0.12653	0.021181	-0.06075	0.66519	0.59841	-0.04686	-0.02045
SD	t1_sd	0.16623	0.11106	0.16499	0.18244	0.17572	0.21984	0.13884	0.14085	0.51985	0.57405	0.30456	0.34523	0.08402	0.097306	0.79541	0.81107	0.10933	0.076152
	t2_mean	0.099904	0.06015	-0.39518	-0.43127	-0.06913	-0.04093	-0.01741	-0.05656	-0.43552	-0.45717	0.09201	0.083586	-0.07094	-0.09336	0.19624	0.3212	-0.01397	-0.00194
	t2_sd	0.10306	0.11356	0.23624	0.29745	0.4699	0.42767	0.22816	0.27565	0.73698	0.60375	0.30039	0.21424	0.26111	0.17252	1.2666	1.1633	0.087516	0.10436

- each row corresponds to 1[sec].
- In this case, as Pre=5[sec]、Task=20[sec]、first 5 rows is Pre parts, next 19 rows are Task parts.

（2） t-value

example of contrast vector [-1 1]

t test

t-value	ch1	ch2	ch3	ch4	ch5	ch6	ch7	ch8	ch9	ch10	ch11	ch12	ch13	ch14	ch15	ch16
HbO	-2.939	2.17	-10.023	-4.496	-12.29	-10.796	-2.097	3.027	-12.744	-7.854	-3.602	-1.846	-4.58	0.252	-7.101	-4.032
HbR	1.781	0.03	11.877	6.145	6.591	9.742	3.181	-1.675	7.604	5.234	1.6	2.845	-1.12	-3.417	2.526	1.196

（3） p-value

example of contrast vector [-1 1]

p-value

p-value	ch1	ch2	ch3	ch4	ch5	ch6	ch7	ch8	ch9	ch10	ch11	ch12	ch13	ch14	ch15	ch16
HbO	0.001661	0.015032	0	3.60E-06	0	0	0.018039	0.001246	0	2.89E-15	0.000161	0.032485	2.43E-06	0.40057	7.85E-13	2.84E-05
HbR	0.03751	0.48801	0	4.58E-10	2.61E-11	0	0.000742	0.047022	1.95E-14	8.91E-08	0.054858	0.002239	0.1314	0.000321	0.005804	0.11583

（4） stats-value (ref.8)

stats	ch1	ch2	ch3	ch4	ch5	ch6	ch7	ch8	ch9	ch10	ch11	ch12	ch13	ch14	ch15	ch16
1_R2	0.28594	0.24456	0.27783	0.33631	0.16254	0.19182	0.25582	0.27869	0.30366	0.34864	0.23257	0.19938	0.16804	0.22046	0.43985	0.4383
1_F	23.9348	18.3327	23.5886	30.8727	10.9906	13.5215	19.8776	24.9492	25.1723	30.6976	17.7358	14.2571	12.0596	16.8537	45.1314	45.0887
1_p(F)	5.39E-168	4.10E-128	1.34E-165	3.11E-214	2.19E-72	5.26E-92	2.40E-139	5.73E-175	1.72E-176	4.17E-213	1.00E-123	1.24E-97	1.02E-80	3.41E-117	1.23E-299	2.13E-299
1_ervar	0.10957	0.071773	0.41188	0.44255	0.64665	0.64602	0.11584	0.14927	1.2114	1.2087	0.13928	0.13062	0.14036	0.091862	2.8269	2.7689
2_R2	0.10556	0.078911	0.31822	0.35738	0.14523	0.19551	0.27626	0.27522	0.22685	0.30456	0.24276	0.22639	0.20272	0.21477	0.39029	0.42359
2_F	7.0252	4.8929	29.0418	34.287	9.4675	13.6547	23.1084	25.6012	17.1845	25.368	18.5259	16.7273	15.0333	15.9504	36.6452	42.5171
2_p(F)	3.60E-41	1.24E-24	2.35E-202	8.54E-236	1.99E-60	5.02E-93	2.93E-162	2.07E-179	1.19E-119	7.97E-178	1.58E-129	2.98E-116	1.57E-103	1.92E-110	2.94E-250	7.53E-285
2_ervar	0.037015	0.032997	0.090099	0.097522	0.22831	0.19717	0.023392	0.034632	0.3733	0.33431	0.067316	0.060732	0.070003	0.048399	0.7554	0.69201

・1_xx:HbO、2_xx:HbR

・R^2-statistics : coefficient of determination, The proportionate amount of variation in the response variable y explained by the independent variables X. $R2 = 1 - SSE/TSS$ SSE: error sum of squares

TSS: total sum of squares

・F-statistics :

$F = \big(RSS/(p-1)\big)/s2$

RSS: regression sum of squares

p:number of variables、s2: estimator of error variance

・p-value : the probability of observing R^2 value or larger

・ervar : the estimator of error variance as the square of the RMSE value

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