Music-experience-related and musical-error-dependent activations in the brain

Kuniyoshi L. Sakai[1], Yoshiaki Oshiba[1], Reiya Horisawa[1],

Takeaki Miyamae[2,3], Ryugo Hayano[3]

[1]Department of Basic Science, Graduate School of Arts and Sciences, The University of Tokyo, Japan

[2]University of Pittsburgh Medical Center Western Psychiatric Hospital, PA, USA

[3]Suzuki School of Music, The Talent Education Research Institute, Matsumoto-shi, Japan

Brain regions		S/E/L	S	S/E	E	E/L	L
IFG	L.	Art			Pit, Str		
LPMC	L.	Art		Pit		Str	
LPMC	R.	Str		Art			
SMA	M.		Tem	Pit			
PrCG/PoCG	R.	Str	Tem	Pit			
SMG	L.			Pit			
STG/HG	L.	Pit	Tem				
STG/HG	R.	Pit					
post-MTG	L.			Pit			Str
post-MTG	R.		Pit, Tem				Str
Insula	R.		Tem				
Putamen	R.		Tem				
Amyg./HC	R.		Tem				
MOG/Calc.	L.			Pit			
MOG/Calc.	R.		Pit, Tem		Str		

Supplementary Fig. 1 Summary of major activated regions for the multiple or single groups. The S, E, and L columns denote significant activations observed for all of Suzuki (in red), Early (in green), and Late (in blue) groups, respectively, under the indicated condition(s) within each cell (Pitch, Tempo, Stress, and Articulation conditions are abbreviated as Pit, Tem, Str, and Art here, respectively). See Fig. 4 for the activated regions in the same colors. The activated regions in the S/E/L and S/E columns are shown in Table 1; those in the S only column and others (E, E/L, and L) are shown in Supplementary Tables 1 and 2, respectively. L., left; R., right; M., medial.
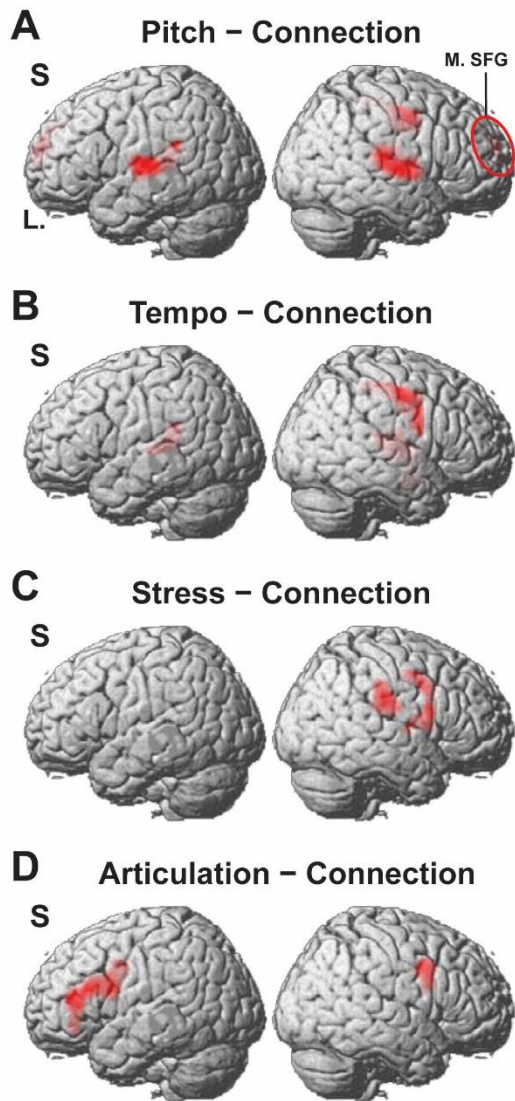
Supplementary Fig. 2 Activations reflecting musically valid judgement for the S group. Activated regions are shown for the S group, thereby restricting the runs with ≥ 75 % accuracy, in Pitch – Connection **(A)**, Tempo – Connection **(B)**, Stress – Connection **(C)**, and Articulation – Connection **(D)** (FWE-corrected $p < 0.05$). Note that the activations are basically consistent with those shown in Fig. 4. See Supplementary Table 3 for the activated regions.

Supplementary Table 1

Instruments	S group			E group			L group		
	N	AOA	DOE	N	AOA	DOE	N	AOA	DOE
Violin family	**33**	4.5 ± 0.3	10.2 ± 0.4	9	10.4 ± 0.9	3.6 ± 1.2	5	12.0 ± 0.6	2.9 ± 0.2
Other strings	–	–	–	1	14.0	1.0	–	–	–
Piano or keyboards	4	10.3 ± 2.2	3.1 ± 1.0	**35**	4.9 ± 0.3	6.7 ± 0.5	3	12.0 ± 1.2	1.5 ± 0.4
Flute	–	–	–	–	–	–	2	10.0 ± 0.0	3.6 ± 2.2
Other woodwinds	–	–	–	2	14.0 ± 2.8	2.7 ± 0.6	1	12.0	3.0
Brasses	–	–	–	7	10.9 ± 0.7	2.7 ± 0.6	3	10.0 ± 0.7	4.2 ± 1.7
Vocal	–	–	–	4	9.5 ± 2.3	4.2 ± 1.4	4	10.8 ± 0.9	2.3 ± 0.2
Percussion	–	–	–	1	11.0	6.2	1	9.0	6.0

Experiences of various musical instruments for each group. For the S group, all participants learned the violin, and four participants learned both the violin and piano. Data are shown with the mean ± standard error of the mean (SEM). AOA, age of acquisition; DOE, duration of exposure.

Supplementary Table 2

Brain region	BA	Side	x	y	z	Z
				S group		
Tempo – Connection						
HG	41/42	L	–42	–37	20	4.0
STG/HG	22/42	L	–42	–34	8	4.0
			–51	–22	5	3.7
LPMC	6	R	54	–1	47	4.1
PrCG	4	R	42	–13	47	4.7
			60	–1	20	3.5
SMA	6	R	12	–22	50	3.7
Insula		R	36	–13	17	3.9
PoCG	3	R	24	–34	50	3.8
HG	41/42	R	42	–31	14	3.4
MTG	37	R	42	–61	5	4.7
Putamen		R	36	–4	2	4.2
Amygdala		R	33	–1	–16	4.5
HC		R	24	–10	–19	4.4
Cuneus	18/19	R	18	–85	26	4.9
			18	–91	11	3.8
MOG	18/19	R	33	–85	14	4.9
			45	–76	2	3.4
Calc.	17	R	24	–91	–1	3.4
Pitch – Connection						
MTG	37	R	45	–58	–4	4.0
			48	–73	–1	3.6
Cuneus	18	R	18	–91	11	3.5
Calc.	17/18	R	21	–79	14	3.9
LiG	19	R	27	–73	2	3.9

Activated regions specialized for the S group. Stereotactic coordinates (x, y, z) in the MNI space are shown for activation peaks of Z values (see Fig. 4, 5). Uncorrected $p < 0.001$ for the voxel level, FDR corrected $p < 0.05$ for the cluster level. BA: Brodmann's area, L: left, M: medial, R: right, Calc.: calcarine sulcus, HC: hippocampus, HG: Heschl's gyrus, LiG: lingual gyrus, LPMC: lateral premotor cortex, MOG: middle occipital gyrus, PoCG: postcentral gyrus, PrCG: precentral gyrus, SMA: supplementary motor area, STG/MTG: superior/middle temporal gyrus.

Supplementary Table 3

Brain region	BA	Side	x	y	z	Z	x	y	z	Z
			E group				**L group**			
Stress – Connection										
LPMC	6	L					–54	–4	44	4.2
			–54	5	14	3.4	–57	5	20	4.9
F3op	44	L	–42	5	26	4.1				
F3t	45	L	–51	32	11	4.6				
PoCG	43	L					–63	–7	23	4.5
MTG	37	L					–54	–61	2	4.5
ITG	20/37	L					–42	–58	–7	4.7
							–45	–43	–16	4.1
MTG	37	R					42	–58	2	4.1
SOG	19	R	21	–85	26	4.6				
FuG	19	R	24	–64	–1	4.0	36	–76	–7	3.5
Pitch – Connection										
F3t	45	L	–45	29	5	4.6				

Activated regions specialized for the E group and/or L group. Stereotactic coordinates (x, y, z) in the MNI space are shown for activation peaks of Z values (see Fig. 4, 5). Uncorrected $p < 0.001$ for the voxel level, FDR corrected $p < 0.05$ for the cluster level. BA: Brodmann's area, L: left, M: medial, R: right, F3op/F3t: opercular/triangular parts of the inferior frontal gyrus, FuG: fusiform gyrus, LPMC: lateral premotor cortex, SOG: superior occipital gyrus, PoCG: postcentral gyrus, MTG/ITG: middle/inferior temporal gyrus.

Supplementary Table 4

Brain region	BA	Side	x	y	z	Z
				S group		
Articulation – Connection						
LPMC	6	L	–48	–4	35	3.8
F3op	44	L	–48	8	26	4.4
F3t	45	L	–54	23	26	5.0
			–51	35	14	4.5
F3O	47	L	–42	35	–4	4.1
LPMC	6	R	51	5	32	4.8
Stress – Connection						
LPMC	6	R	57	8	38	4.4
F3op	44	R	57	8	17	4.2
PrCG	4	R	48	–4	47	4.1
PoCG	2	R	63	–22	26	4.8
HG	41/42	R	54	–10	5	3.4
Tempo – Connection						
HG	41/42	L	–39	–40	17	4.4
			–39	–31	8	4.1
STG	22	L	–54	–25	2	3.6
LPMC	6	R	54	–1	47	4.2
			60	2	26	3.8
PrCG	4	R	42	–13	47	4.7
PoCG	3	R	24	–37	53	4.1
HG	41/42	R	48	–31	17	3.5
			36	–25	8	4.5
Putamen		R	36	–7	2	4.7
Amygdala		R	30	–4	–19	4.2
Pitch – Connection						
SFG	8/9	L	–18	35	41	3.2
		M	–9	50	38	3.4
			–6	59	26	4.8
SMG	40	L	–54	–43	23	4.2
HG	41/42	L	–36	–37	14	5.5
			–48	–19	5	7.4
PrCG	4	R	33	–19	53	5.0
			45	–7	47	4.9
PoCG	1/2/3	M	12	–37	56	3.9
SPL	7	R	30	–37	56	3.4
Insula		R	36	–13	20	3.5
HG	41/42	R	45	–25	8	6.5
			54	–13	5	6.9

Activations reflecting musically valid judgement for the S group. Stereotactic coordinates (*x*, *y*, *z*) in the MNI space are shown for activation peaks of Z values (see Supplementary Fig. 2). Uncorrected $p < 0.001$ for the voxel level, FDR corrected $p < 0.05$ for the cluster level. BA: Brodmann's area, L: left, M: medial, R: right, F3op/F3t/F3O: opercular/triangular/orbital parts of inferior frontal gyrus, HG: Heschl's gyrus, LPMC: lateral premotor cortex, PoCG: postcentral gyrus, PrCG: precentral gyrus, SFG: superior frontal gyrus, SMG: supramarginal gyrus, SPL: superior parietal lobule, STG: superior temporal gyrus.