Research Report

The Characteristics of Five Higher Brain Function Types as Assessed with a go/no-go Task in Japanese Children

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Background: Childcare and education professionals in Japan have increasingly complained that growing numbers of children "tire instantly," "constantly fidget," or "are unable to sit still during childcare or class." Against this backdrop, there is a belief that contemporary Japanese children exhibit underdeveloped or distorted higher brain functions related to satisfaction or feelings of fulfillment.

Objective: We aimed to ascertain the characteristics of five higher brain function types in contemporary Japanese children with a focus on reaction times and reaction magnitudes to positive conditional stimuli.

Methods: We recruited 301 boys and 300 girls in elementary school grades 1-6 in October 2012. We collected data on grasp motor responses to light stimuli go/ no-go tasks that have long been used in Japan.

Results: The no task errors in the differentiation experiment and the go and no task errors in the reverse differentiation experiment exhibited a significant interaction between sex and grade level (no task errors: p=0.043, go errors: p=0.008, no task errors: p=0.006), whereas other indicators did not. In addition, melancholic type was better represented among boys than among girls, with the type becoming less common among girls in higher grades. Analysis of task parameters for different types in the differentiation experiment revealed that response times (RTs) were significantly shorter for the choleric type than for other types and longer for the inhibitory type, whereas the coefficients of variation in RT (RT-CVs) were significantly greater for the melancholic type than for other types. Analysis of response parameters for the phlegmatic and sanguine types in the reverse differentiation experiment revealed significant difference in the RT-CVs and the coefficients of variation in peak response magnitude (Peak-CVs) of the two groups.

Conclusion: The type frequencies of higher brain function in contemporary Japanese children may vary by sex and grade. Our results may provide an important guide in the reformation of daycare and educational practices to address the changing higher brain function profiles of contemporary children.

Keywords: Pavlovian theory, type classification, excitation process, suppression process

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I. Introduction

Among Japanese childcare and education professionals, there is a growing sense that contemporary Japanese children are more likely than earlier cohorts to quickly become tired, slump over, and fidget in daycare or school[1]. These observations have fueled speculation that these children may express delayed or irregular development of higher brain functions related to satisfaction, fulfillment, motivation, willpower, and concentration, which are governed by the cerebral neocortex and prefrontal cortex[2-3].

According to Pavlov[4], higher brain functions, which are manifestations of neural processing in the cerebral neocortex, can be classified by i) intensity, ii) equilibrium, and iii) lability, all of which are properties of nervous excitation and inhibition. Researchers in the so-called neo-Pavlovian school of thought, which systematized Pavlovian theory, later advanced research on different individual nervous system activity types[5-7]. Eysenck[8] also hypothesized that individuals with weak types exhibit introverted tendencies, whereas individuals with strong types are more extroverted. This hypothesis was verified by two subsequent studies[9-10].

Based on this Pavlovian theory, Luria[11] devised a go/no-go task that involves determining whether to perform a grasping motion based on a preceding language instruction. Many reports have examined brain activity during such go/no-go tasks. Sasaki and Gemba[12] and Sasaki et al.[13] used cortical electrodes and magnetoencephalography to examine activity enhancement in the cerebellum, basal nucleus, and motor region during a go task and in the prefrontal area during a no-go task. Studies examining event-related potentials have also shown that no-go stimuli evoke potentials primarily in the frontal area[14-15], whereas other such studies have assessed how the magnitudes of the N2 and P3 components elicited in a no-go task are reduced in association with age-related loss of reaction inhibition[16-17].

In a 1969 investigation conducted in Japan, Masaki and Moriyama[18] used Luria's go/no-go task to create five classifications of higher brain function in children (i.e., melancholic, choleric, inhibitory, phlegmatic, and sanguine) based on Pavlovian theory[4]. These classifications reflect different developmental stages. For instance, the melancholic type is typical of infants, whereas the sanguine type reflects a more adult developmental stage. Their study has been followed in Japan by extensive investigations of nervous system types using similar procedures[19-22].

Many studies involving go/no-go tasks have also been conducted outside Japan. For example, Casey et al.[23] conducted an experiment with subjects aged 4–18 years to investigate cognitive function development, and Durston et al.[24] investigated nervous system defects related to cognitive function in children with attention deficit hyperactivity disorder (ADHD). Several other studies[25-27] have used reaction time and the correct stimulus response rates in go/no-go tasks for further explorations, but few international studies have examined higher brain function types with such tasks. However, type results were the key focus in the Japanese studies cited above, which limits comparisons between Japanese and international studies.

Of course, one effective method for assessing contemporary children is to compare them to past cohorts, such as by comparing the type assessments of contemporary Japanese children to those recorded in Japanese studies conducted roughly 50 years ago. Type assessments are also potentially valuable because their results are often consistent with the opinions that teachers and guardians hold towards the child, which makes the results highly understandable indicators. However, the type classifications used in the above-cited Japanese studies have not been theorized. Given that higher brain function in children is an important topic that merits further investigation, this theorization must be attempted.

We therefore aimed to assess higher brain functions in contemporary Japanese children with the go/no-go task and to determine the characteristics of five higher brain function types, with a focus on the timing and magnitude of reactions to positive conditional stimuli.

II. Methods

1. Subjects and duration

We recruited 601 children enrolled in grades 1-6 (ages 6 to 12 years; 301 boys and 300 girls) at two public elementary schools in the Tokyo metropolitan area (**Table 1**). The children had no medical or psychological illnesses. The surveys were conducted in October 2012 on days when there were no special school events. All subjects and their guardians received prior written descriptions of the study's procedures and purpose, and we obtained consent to participate from all guardians and assent to participate from all subjects.

Our study protocols were approved by the Ethics Review Committee for human subjects research at Nippon Sport Science University (approval no.: 012-H14).

Table 1 Numbers of subjects

School grade	boys	girls	Total
1st grade	33	47	80
2nd grade	52	34	86
3rd grade	54	50	104
4th grade	57	48	105
5th grade	49	53	102
6th grade	56	68	124
Total	301	300	601

2. Procedure

We examined grasp motor responses in go/no-go tasks with a light stimulus. We used a brain activity measurement program (Tecno Muscat Co., Ltd., Nagano, Japan) to collect data in sessions each containing no more than 12 children in a quiet classroom within the subjects' school. A single experimenter conducted all sessions. Seated subjects were instructed to grasp a rubber ball with their dominant hand in response to a light stimulus projected onto a rectangle (2.5 cm long × 4 cm wide) in front of a box (4.5 cm long × 10.5 cm wide) placed approximately 50 cm in front of them. The subjects participated in a formation experiment, a differentiation experiment, and a reverse differentiation experiment, in that order.

For the formation experiment, the subjects were introduced to the go task, which involved quickly grasping their rubber balls once a red light started shining and quickly releasing the balls when the light stopped shining. After ten training rounds, the light stimulus was presented five times for 0.5- to 1.5-s periods at 3- to 6-s intervals.

For the differentiation experiment, the subjects were introduced to the no-go task, which involved refraining from grasping their rubber balls when a yellow light started shining. After training with two go task rounds and two no-go task rounds, the subjects were randomly presented with 11 go trials and 11 no-go trials. The light stimulus intervals and durations in this experiment were identical to those in the formation experiment.

For the reverse differentiation experiment, the color cues for the go and no-go tasks were reversed. After training with two go task rounds and two no-go task rounds, the subjects were randomly presented with 11 go trials and 11 no-go trials. The light stimulus intervals and durations were identical to those of the earlier experiments.

3. Data analysis

We calculated the numbers of commission errors (no-go errors) in the no-go trials, omission errors (go errors) in the go trials, and incorrect responses between stimuli (no-task errors). We consulted prior studies[18-19] to determine the error rates that corresponded to the five classification types. For each type, **Table 2** shows the interpretation, the corresponding incorrect response rates, and the related criteria.

We first examined sex- and grade-dependent

Table 2 The interpretations of each of the types, the number of incorrect responses, and the related criteria for each

Types	Interpretations [a]	Criteria [b]
Melancholic[c]	This type do not have a fully developed excitation process and inhibition process.	(the differentiation experiment・incorrect response number) The commission errors (no-go errors) of the no-go task is 3 or more and the omission errors (go errors) for the go task is 1 or more.
Choleric[c]	This type has a developed excitation process and inhibition process. However, their equilibrium is imbalanced. Their excitation is stronger than inhibition.	(the differentiation experiment・incorrect response number) The commission errors (no-go errors) of the no-go task is 3 or more and the omission errors (go errors) for the go task is 0.
Inhibitory[c]	This type has a developed excitation process and inhibition process. However, their equilibrium is imbalanced. Their excitation is stronger than inhibition.	(the differentiation experiment・incorrect response number) The commission errors (no-go errors) of the no-go task is less than 3 and the omission errors (go errors) for the go task is 1 or more.
Phlegmatic	This type has a developed excitation process and inhibition process. Also their equilibrium is good. However, their mobility is not good.	(the differentiation experiment・incorrect response number) The commission errors (no-go errors) of the no-go task is less than 3 and the omission errors (go errors) for the go task is 0. (the reverse differentiation experiment・incorrect response number) The commission errors (no-go errors) of the no-go task is 3 or more and the omission errors (go errors) for the go task is 1 or more.
Sanguine	This type has a developed both their excitation process and inhibition process. Moreover, their equilibrium and mobility also are good.	(the differentiation experiment・incorrect response number) The commission errors (no-go errors) of the no-go task is less than 3 and the omission errors (go errors) for the go task is 0. (the reverse differentiation experiment・incorrect response number) The commission errors (no-go errors) of the no-go task is less than 3 and the omission errors (go errors) for the go task is 0.

[a] Interpretation of each of the types based on the characteristics of the two nerve processes (the excitation process and suppression process) in the cerebral neocortex

[b] Number of incorrect response of no task errors are aggregated by adding to no-go errors and go errors basically

[c] For inhibitory and choleric and melancholic type, it is determined only by the number of incorrect response in the differentiation experiment

differences in indicators such as numbers of no-go errors, go errors, and no task errors in the differentiation and reverse differentiation experiments. We also compared grades and sexes on go task parameters including response time (RT), the coefficient of variation in RT (RT-CV), peak response magnitude (Peak), and the coefficient of variation in Peak (Peak-CV). We excluded responses occurring within 150 ms of the start of the go task from analysis because these were probably not true responses to stimuli. For RT and Peak, we used each participant's mean values. These comparisons were conducted with a two-way non-repeated-measures analysis of variance with sex and grade taken into consideration. Next, a one-way non-repeated-measures analysis of variance was used to compare grade differences for each indicator, differentiated by sex, with Bonferroni multiple comparison corrections applied to any significant differences. We then analyzed the incidence of each classification type by sex, with differentiation by grade level.

Lastly, we examined how the five types differed in RT, RT-CV, Peak, and Peak-CV. We conducted an independent one-way analysis of variance with subsequent Bonferroni multiple comparison corrections to assess these differences. We also performed independent t-tests to compare the phlegmatic and sanguine types for RT, RT-CV, Peak, and Peak-CV in the reverse differentiation experiment.

We used SPSS version 20 (IBM, Armonk, NY) for statistical analyses. We defined statistical significance as $p < 0.05$

III. Results

1. Effects of sex and grade on errors and response parameters

Among boys and girls, we found no between-grade differences in the number of no-go errors or go errors in the differentiation experiment. Among girls, we also found no between-grade differences in the number of go errors in the reverse differentiation experiment. However, we observed between-grade differences in the number of no task errors and go errors in the reverse differentiation experiment among boys with numerous errors observed among grade 1 students and a decrease in number of errors starting from grade 2 or 3; in the number of no task errors and no-go errors in the reverse differentiation experiment among girls with numerous errors observed among lower grade students and a decrease in number of errors starting from upper grade (**Table 3**). We observed no between-grade differences in RT-CV among boys or girls in the differentiation experiment or in Peak among girls in the reverse differentiation experiment. However, we observed between-grade differences in RT among boys, with RTs being significantly shorter in grade 2 than for those in grade 1 and significantly shorter in grades 4-6 than in grade 3; among girls, with RTs being significantly shorter in grades 4-6 than for those in grades 1-2 (**Table 4**).

As shown in **Tables 5** and **6**, the no task errors in the differentiation experiment and the go and no task errors in the reverse differentiation experiment exhibited a sex × grade interaction, whereas the other indicators did not. The boys exhibited more no-go and no task errors and

Table 3 No-go errors, go errors, no task errors differentiated by sex within the differentiation experiment and reverse differentiation experiment, broken down by grade[a]

		1st grade	2nd grade	3rd grade	4th grade	5th grade	6th grade	F value [c] (degrees of freedom)	multiple comparison [d]
boys		n=33	n=52	n=54	n=57	n=49	n=56		
the differentiation experiment	no-go errors[b]	5.0±2.5	4.9±2.8	4.7±2.6	5.6±2.6	4.9±2.4	4.8±2.3	0.830 (5, 295)	
	go errors[b]	0.5±1.2	0.3±0.8	0.2±0.4	0.1±0.3	0.1±0.3	0.1±0.4	1.786 (5, 295)	
	no task errors[b]	2.5±3.7	1.7±1.9	1.0±1.3	1.0±1.4	0.6±1.1	1.1±2.1	4.940* (5, 295)	1＞3・4・5・6
the reverse differentiation experiment	no-go errors[b]	4.8±3.3	4.5±2.8	4.0±2.5	4.0±2.3	3.8±2.1	4.0±2.5	0.913 (5, 295)	
	go errors[b]	0.8±1.1	0.3±0.6	0.4±0.7	0.2±0.4	0.1±0.3	0.2±0.4	6.971* (5, 295)	1＞2・3・4・5・6
	no task errors[b]	3.3±3.6	2.2±2.4	1.1±1.7	1.0±1.8	1.0±1.3	1.0±1.6	8.672* (5, 295)	1＞3・4・5・6, 2＞4・6,
girls		n=47	n=34	n=50	n=48	n=53	n=68		
the differentiation experiment	no-go errors[b]	4.3±2.3	4.4±2.8	4.5±2.4	4.0±2.5	3.6±2.4	3.6±2.3	1.446 (5, 294)	
	go errors[b]	0.3±0.6	0.0±0.2	0.1±0.3	0.3±1.1	0.1±0.3	0.1±0.4	1.579 (5, 294)	
	no task errors[b]	1.0±1.5	0.9±2.0	1.0±1.4	0.5±1.0	0.4±0.8	0.3±0.7	3.801* (5, 294)	1・3＞6
the reverse differentiation experiment	no-go errors[b]	3.8±2.3	3.9±2.6	3.5±2.6	3.0±2.2	2.6±2.1	2.5±1.6	3.698* (5, 294)	1・2＞6
	go errors[b]	0.3±0.8	0.2±0.8	0.2±0.6	0.3±0.5	0.3±0.6	0.2±0.5	0.365 (5, 294)	
	no task errors[b]	1.6±2.3	0.9±1.4	1.2±1.9	0.7±1.3	0.6±1.0	0.3±0.8	5.057* (5, 294)	1＞5・6, 3＞6

[a] Data was analyzed by one-way analysis of variance without repetition.

[b] Values indicate the mean ± S.D.. Unit is msec.

[c] *: p<0.05

[d] Result of multiple comparison by Bonferroni's method, *: p<0.05

Table 4 Response time, coefficient of variation in response time, peak response magnitude and coefficient of variation in the peak differentiated by sex within the differentiation experiment and reverse differentiation experiment, broken down by grade[a]

		1st grade	2nd grade	3rd grade	4th grade	5th grade	6th grade	F value [e] (degrees of freedom)	multiple comparison [f]
boys		n=33	n=52	n=54	n=57	n=49	n=56		
the differentiation experiment	response time[b]	476.3±93.3	412.1±88.0	386.6±69.3	338.0±52.2	335.0±46.7	324.3±80.0	27.390* (5, 295)	1＞2・3＞4・5・6
	coefficient of variation in response time[c]	30.0±8.8	31.2±10.6	30.8±8.1	29.7±7.7	32.4±11.0	29.9±10.3	0.577 (5, 295)	
	peak response magnitude[d]	1458.4±824.2	2038.4±1030.9	2086.6±994.5	2227.5±1020.7	2498.5±1291.3	2555.±1330.7	5.130* (5, 295)	1＜4・5・6
	coefficient of variation in the peak[c]	31.1±20.6	25.7±14.9	26.0±14.1	22.6±18.2	30.7±23.9	18.4±16.5	3.433* (5, 295)	1・5＞6
the reverse differentiation experiment	response time[b]	527.1±98.6	465.3±105.4	427.5±81.9	369.1±58.7	376.2±62.5	359.1±69.5	28.957* (5, 295)	1＞2・3＞4・5・6
	coefficient of variation in response time[c]	34.8±14.0	34.4±16.2	33.4±12.0	28.4±9.9	31.1±12.1	28.8±7.5	2.704* (5, 295)	
	peak response magnitud[d]	1443.0±811.2	2125.7±1040.8	2247.9±1112.3	2396.2±1260.7	2588.1±1360.9	2664.4±1363.0	5.312* (5, 295)	1＜3・4・5・6
	coefficient of variation in the peak[c]	34.6±20.3	28.0±17.1	25.6±15.5	23.5±16.9	37.7±21.0	19.2±14.7	5.064* (5, 295)	1・5＞6
girls		n=47	n=34	n=50	n=48	n=53	n=68		
the differentiation experiment	response time[b]	472.3±92.5	430.2±81.3	376.8±74.5	374.9±73.3	364.2±62.0	343.4±54.6	21.974* (5, 294)	1・2＞3・4・5・6
	coefficient of variation in response time[c]	30.3±10.6	27.6±9.7	30.0±11.0	28.0±8.4	29.7±8.0	26.9±7.4	1.298 (5, 294)	
	peak response magnitud[d]	1804.8±1040.1	1834.6±688.6	2137.2±1144.9	2211.7±1039.5	2308.0±1120.0	2384.6±1230.0	2.413* (5, 294)	
	coefficient of variation in the peak[c]	28.9±14.5	21.7±10.5	24.6±14.2	18.7±12.5	24.5±20.0	15.1±11.7	6.455* (5, 294)	1＜4・6, 3＜6, 5＜6
the reverse differentiation experiment	response time[b]	528.7±100.8	475.8±87.6	422.8±93.2	406.2±90.3	399.8±86.9	387.2±83.1	18.043* (5, 294)	1＞3・4・5・6, 2＞4・5・6
	coefficient of variation in response time[c]	33.3±14.8	29.7±11.7	30.6±10.9	27.9±8.2	26.4±9.3	27.0±11.6	2.653* (5, 294)	1＞5
	peak response magnitud[d]	1931.5±1235.2	1918.6±738.5	2132.3±1055.7	2315.2±1080.4	2264.1±1126.4	2430.3±1318.9	1.665 (5, 294)	
	coefficient of variation in the peak[c]	29.6±15.1	24.3±14.2	26.3±15.0	18.8±14.1	22.9±19.1	16.6±12.0	5.469* (5, 294)	1＞4・6, 3＞6

[a] Data was analyzed by one-way analysis of variance without repetition. [b] Values indicate the mean ± S.D.. Unit is msec. [c] Values indicate the mean ± S.D.. Unit is % [d] Values indicate the mean ± S.D.. Unit is mV [e] *: $p<0.05$ [f] Result of multiple comparison by Bonferroni's method, *: $p<0.05$

Table 5 No-go errors, go errors, no task errors classified by sex and grade[a]

		factor	degree of freedom	sum of squares	mean square	F value [b]
the differentiation experiment	no-go errors	sex	1	121.077	121.077	19.617*
		grade	5	29.779	5.956	0.965
		sex × grade	5	37.041	7.408	1.200
		residual	589	3635.404	6.172	
	go errors	sex	1	0.362	0.362	1.076
		grade	5	3.930	0.786	2.336*
		sex × grade	5	2.150	0.430	1.272
		residual	589	198.132	0.336	
	no task errors	sex	1	50.423	50.423	18.867*
		grade	5	97.745	19.549	7.315*
		sex × grade	5	30.796	6.159	2.305*
		residual	589	1574.112	2.673	
the reverse differentiation experiment	no-go errors	sex	1	133.966	133.966	23.526*
		grade	5	100.721	20.144	3.538*
		sex × grade	5	16.700	3.340	0.587
		residual	589	3354.018	5.694	
	go errors	sex	1	0.680	0.680	1.792
		grade	5	8.992	1.798	4.736*
		sex × grade	5	5.977	1.195	3.149*
		residual	589	223.629	0.380	
	no task errors	sex	1	67.770	67.770	20.581*
		grade	5	198.732	39.746	12.071*
		sex × grade	5	54.484	10.897	3.309*
		residual	589	1939.461	3.293	

[a] Data was analyzed by two-way analysis of variance without repetition.
[b] *: $p<0.05$

Table 6 Response time, coefficient of variation in response time, peak response magnitude and coefficient of variation in the peak classified by sex and grade[a]

		factor	degree of freedom	sum of squares	mean square	F value [b]
the differentiation experiment	response time	sex	1	32181.094	32181.094	6.617*
		grade	5	1241671.805	248334.361	47.586*
		sex × grade	5	41181.844	8236.369	1.578
		residual	589	3073754.486	5218.598	
	coefficient of variation in response time	sex	1	541.436	541.436	6.246*
		grade	5	538.146	107.629	1.242
		sex × grade	5	235.607	47.121	0.544
		residual	589	51059.349	86.688	
	peak response magnitude	sex	1	136069.843	136069.843	0.113
		grade	5	44168603.524	8833720.705	7.316*
		sex × grade	5	4773631.612	954726.322	0.557
		residual	589	711156705.814	1207396.784	
	coefficient of variation in the peak	sex	1	1776.492	1776.492	6.673*
		grade	5	11716.507	2343.301	8.802*
		sex × grade	5	328.421	65.684	0.247
		residual	589	156802.927	266.219	
the reverse differentiation experiment	response time	sex	1	37295.271	37295.271	5.153*
		grade	5	1597742.574	319548.515	44.150*
		sex × grade	5	33166.070	6633.214	0.916
		residual	589	4263102.051	7237.864	
	coefficient of variation in response time	sex	1	1060.037	1060.037	7.797*
		grade	5	3054.335	610.867	4.493*
		sex × grade	5	366.180	73.236	0.539
		residual	589	80072.811	135.947	
	peak response magnitude	sex	1	899956.488	899956.488	0.661
		grade	5	44365682.812	8873136.562	6.515*
		sex × grade	5	8794961.886	1758992.377	1.292
		residual	589	802141643.755	1361870.363	
	coefficient of variation in the peak	sex	1	2580.302	2580.302	9.747*
		grade	5	12469.405	2493.881	9.421*
		sex × grade	5	1528.287	305.657	1.155
		residual	589	155921.739	264.723	

[a] Data was analyzed by two-way analysis of variance without repetition.
[b] *: $p<0.05$

greater RT-CVs and Peak-CVs than the girls did, whereas the girls exhibited longer RTs than the boys did.

2. Higher brain function type results

In examining the by-grade and by-sex breakdown of higher brain function types (**Figure 1**), we found that the melancholic type was better represented among boys than among girls, with the type become less common among girls in higher grades.

In analyzing the task parameters for different types in the differentiation experiment (**Figure 2**), we found that RTs were significantly shorter for the choleric type than for the other types and longer for the inhibitory type, whereas RT-CVs were significantly greater for the melancholic type than for the other types. In analyzing response parameters for the phlegmatic and sanguine types in the reverse differentiation experiment (**Figure 3**), we found that the two groups differed significantly in RT-CVs and Peak-CVs.

In analyzing the error rates and response parameters for each type (**Table 7**), we found that children with the melancholic type exhibited the most no-go errors in the differentiation experiment, more go errors than children with any other type except for the inhibitory type did, and high RT-CVs in the differentiation experiment. The choleric group exhibited the second most no-go errors in the differentiation experiment but shorter RTs than the other type groups did. The inhibitory group exhibited the most go errors in the differentiation experiment and especially long RTs. Finally, the phlegmatic group exhibited more no-go, go, and no task errors and greater RT-CVs and Peak-CVs in the reverse differentiation experiment than the sanguine group did.

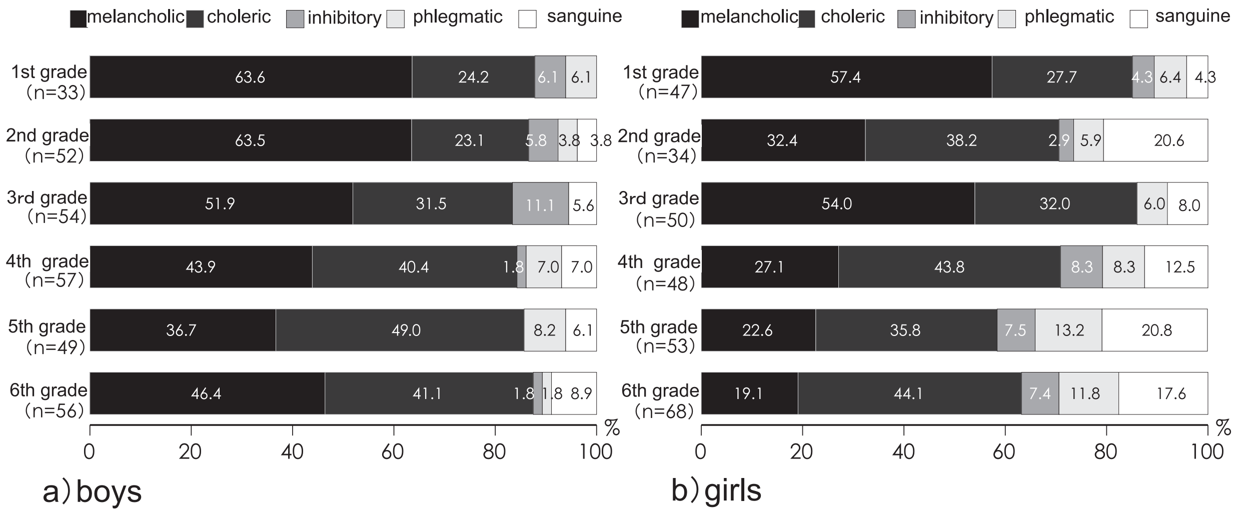

Figure 1 Frequencies of the types of higher brain function according to school grade.

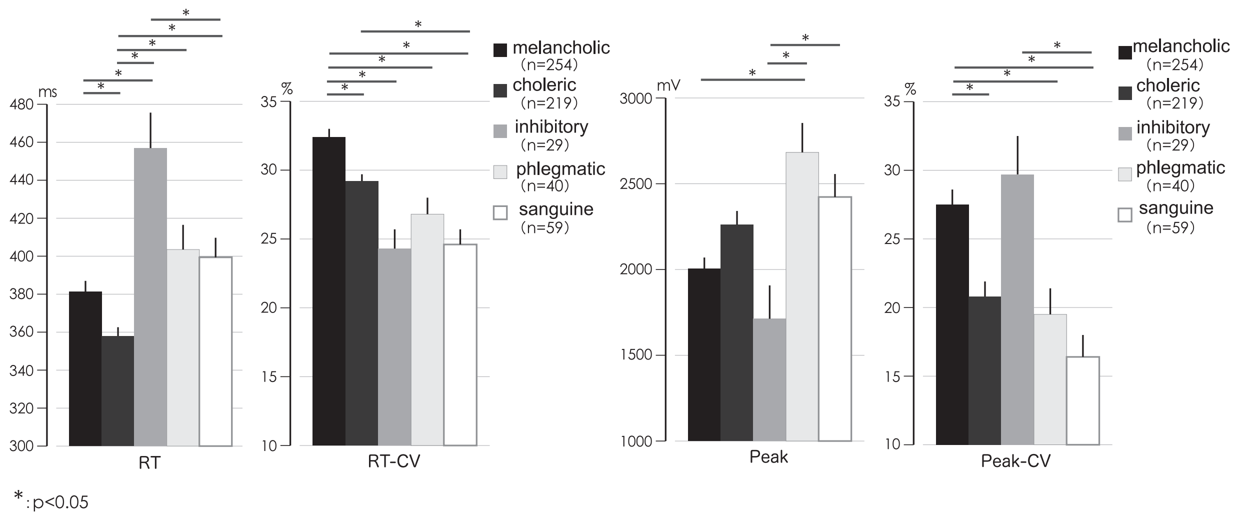

Figure 2 The response time (RT), coefficient of variation in response time (RT-CV), peak response magnitude (Peak) and coefficient of variation in the peak differentiated (Peak-CV) for each of the types in the differentiation experiment

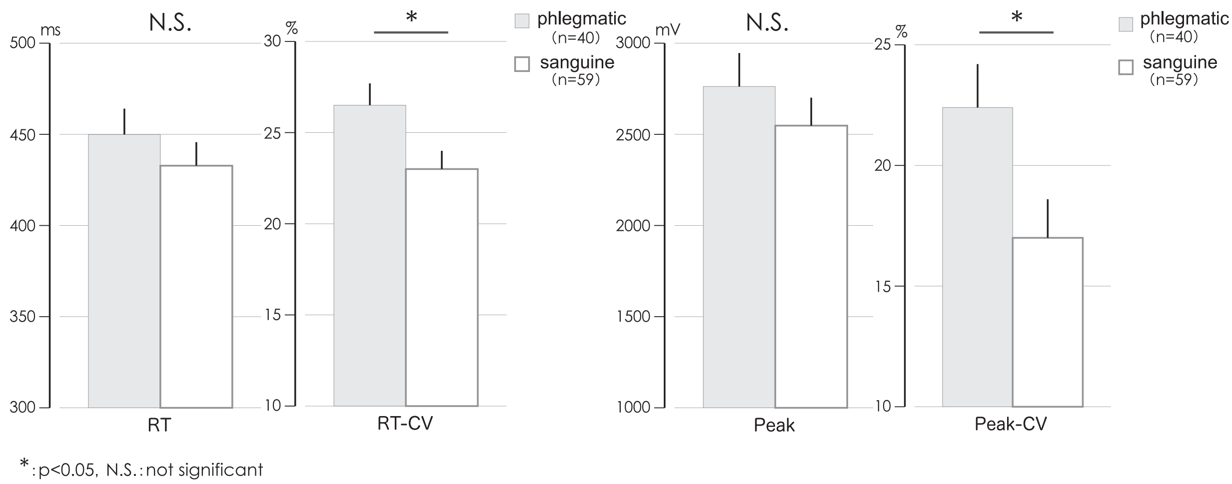

Figure 3 The response time (RT), coefficient of variation in response time (RT-CV), peak response magnitude (Peak) and coefficient of variation in the peak differentiated (Peak-CV) in the phlegmatic type and the sanguine type in the reverse differentiation experiment

Table 7 The characteristics of no-go errors, go errors, no task errors, response time, coefficient of variation in response time, peak response magnitude and coefficient of variation in the peak in each of the types

	the differentiation experiment							the reverse differentiation experiment						
	no-go errors	go task errors	no task errors	response time	coefficient of variation in response time	peak response magnitude	coefficient of variation in the peak	no-go errors	go task errors	no task errors	response time	coefficient of variation in response time	peak response magnitude	coefficient of variation in the peak
melancholic	most	more [b]	most		high									
choleric	more [a]			short										
inhibitory		most		long										
phlegmatic								more	more	more		higher		higher
sanguine								fewer	fewer	fewer		smaller		smaller

[a] melancholic＞choleric＞inhibitory・phlegmatic・sanguine

[b] inhibitory＞melancholic＞choleric・phlegmatic・sanguine

IV. Discussion

1. Recent findings concerning higher brain function in Japanese children

Our primary aim was to assess higher brain function types in contemporary Japanese children with go/no-go tasks, which have long been used in Japanese research. In comparing our findings about the grade- and sex-specific frequencies of the melancholic type to those that Noi et al.[22] obtained from 2007 to 2009, we found that the frequencies among boys were similar but that our observed frequencies among girls were higher. Many of our subjects exhibited this type, which has become common since the beginning of the 2000s.

Saijo et al.[19] reported that in comparison to the children in a 1969 survey, those in a 1979 survey more frequently exhibited the melancholic and inhibitory types and less frequently exhibited the choleric type. Changes in children's growth environments have been proposed as a cause. Terasawa et al.[20] added the results of a 1998 survey to Saijo et al.'s data and found that the 1998 survey showed results similar to those of the 1979 survey, which suggests that the major changes in higher brain function patterns in Japanese children occurred between 1969 and 1979. The notion that Japanese children are less physically active, owing to a transition towards non-social recreation, has been proposed as a reason for these changes.

Individuals exhibit extremely high plasticity in their higher brain functions. Individuals normally start with the puerile melancholic type, progress through the choleric stage more characteristic of older children, and gradually develop the more adult sanguine type. Most individuals can be expected to express the sanguine type after reaching adulthood[18-19]. However, the results of a 1998 survey showed that as late as their elementary school enrolment, 50–60% of children were expressing the melancholic type. Analyses of subsequent trends show that the frequency of this type among children has not decreased. Researchers have noted that this naturally increases the occurrence of issues such as "the first-grade problem" or "classroom dysfunction," in which it is nearly impossible to hold a class because children are standing up or acting out[3]. Our findings indicate that these issues of problematic development in boys have not been resolved. Ways of addressing these issues should be examined in future studies.

In summary, we confirmed that contemporary Japanese children's higher brain functions present a developmental profile different from that of past cohorts. Our results therefore have important implications for how school education should henceforth be conducted.

2. Grade and sex in error numbers and response parameters

As shown in **Tables 3** and **4**, we found that compared to girls, boys exhibited greater reductions in error numbers with grade progression, but other indicators did not show sex × grade interactions. Furthermore, error numbers and most response parameters were reduced with grade progression, whereas Peak values increased. Casey et al.[23] had 4- to 18-year-old subjects perform go/no-go tasks with auditory stimuli and observed age-dependent RT reductions until approximately 12 years of age. Iida et al.[27] had 6- to 12-year-old subjects perform go/no-go tasks with visual stimuli and reported that age negatively correlated with RT and incorrect response numbers. Our results are consistent with these earlier results.

3. Response characteristics of each type

Our secondary aim was to examine the response characteristics of different higher brain function types. We found that the melancholic group exhibited considerable RT variance. Our results support the contention that individuals with the melancholic type exhibit downregulated neural excitation and inhibition processes, which makes it difficult to maintain concentration. Individuals of the choleric and inhibitory types also exhibit a poor excitation-inhibition balance, with the choleric and inhibitory types being associated with excitation dominance and inhibition dominance, respectively. These imbalances might have affected RTs during the differentiation experiment. Individuals of the phlegmatic type exhibit strong and well-balanced excitation and inhibition, but they are deficient in lability and were probably unable to adapt when the tasks switched from differentiation to reverse differentiation. The CVs observed for the phlegmatic group in the reverse differentiation experiment may be a manifestation of these characteristics.

Our results suggest that the type classifications used in Japan may adequately reflect Pavlovian theory. Importantly, the individuals with the melancholic type, which has been garnering attention in Japan in recent years, exhibited go/no-go task performance that closely resembled that of children with ADHD. Rubia et al.[28] reported diminished inhibition in go/no-go tasks and Stroop tasks among children with ADHD, which may reflect a congenital frontal lobe defect compromising executive functions, including inhibitory functions. Banaschewski et al.[29] and Negoro et al.[30] reported similar results. Vaurio et al.[31] reported that children with ADHD exhibited increased RT variance in go/no-go tasks. Such results are consistent with those that we observed for the melancholic group.

By describing the characteristics of each type, including the melancholic type that has attracted much recent concern, our study elucidates the higher brain function properties of children and ways of address concerns related to each type.

4. Study limitations and future challenges

Our study has some limitations. We examined the characteristics of different types, but we did not examine the children's individual backgrounds, which would certainly influence their type classifications. For type information to be effectively used in childcare and education, future research is needed to assess how children's types relate to their relationships with teachers, including the teachers' evaluations of them. We believe that such research questions are important, particularly for developing remedial approaches for misbehaving children.

5. Conclusion

In conclusion, we found that the type frequencies varied by sex and grade. Our results may provide important guidance in reforming daycare and educational practices to address the changing higher brain function profiles of contemporary children.

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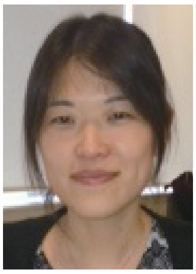

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