

Original Paper**System analysis of physical abilities, social functioning and language proficiency**

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Abstract

The purpose of the present study was to investigate interrelationships among three different abilities—physical abilities, social functioning, and language proficiency. In this study, we attempted to quantify the relationships between physical abilities and the other types of abilities. Thirty Japanese college students served as subjects. There were three sessions in this study: physical ability measurement session, social functioning session, and language session. Regarding physical abilities, we measured quickness, strength, power, flexibility, and endurance, together with body mass index of the subjects. Correlation analysis was conducted for physical parameters, capacities of social cognition, and TOEIC scores together with reading rate, as well as vocabulary size. The results showed significant sex-related differences in the interrelationships among physical, social, and English parameters. A conspicuous difference in the effect on language proficiency between males and females was observed for one of the physical abilities; endurance. This physical ability showed a strong negative correlation with Empathy Quotient in the case of males, but not in the case of females. The results of this study indicated that the male-female differences in the interrelationships among the different types of abilities need to be taken into account in the design of physical exercise programs.

Keywords: Physical abilities, Social functioning, Language proficiency

1. Introduction

The relationship between physical abilities and social functioning and that between language proficiency and social functioning have been investigated in preceding studies; however, systematical investigation among all these three items is still lacking. Physical abilities and social functioning have been of interest with respect to their interrelationship in connection with common higher brain activities⁽¹²⁾⁽⁴¹⁾⁽²⁶⁾. Spatial cognition and memory play a crucial role in social communication⁽³⁸⁾⁽⁹⁾⁽¹⁵⁾. The usefulness of working memory, which is a major component of social communication, has been reported in various fields such as image training of physical exercises and rehabilitation training of cognitive and language disorders⁽¹¹⁾⁽³⁴⁾⁽³⁷⁾⁽³⁵⁾. Mochizuki and Kirino⁽¹⁹⁾ examined the effects of coordination exercises on brain activation measured by fMRI. The results of the study indicated that coordination exercises contribute to not only the improvement of motor activities but also cognitive control.

A few studies have dealt with the interrelationships between physical abilities and language proficiency through brain activities⁽²⁾. We have carried out a series of studies on interrelationships among physical abilities, language proficiency and brain activities. Sudo et al.⁽²⁸⁾ investigated interrelationships among these factors, especially from the viewpoint of social cognition. Furthermore, we attempted a preliminary system analysis of associations between spatial cognitive memory and performances of social communication as well as physical exercises⁽¹³⁾. Sudo et al.⁽²⁹⁾ examined the

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interrelationships between language proficiency and social cognition from the viewpoint of brain activation. In the study, we employed 3 parameters for the measurement of English proficiency of Japanese speakers: TOEIC scores, reading rate and vocabulary abilities. We applied the “Rauding Theory”³⁾, which claims that the same comprehension processes underlie both reading and listening, to second language acquisition and tested the hypothesis that the processing time for reading had an effect on that for listening. TOEIC scores showed a strong correlation with reading rate and some correlation with vocabulary, but showed no dependence on the Reading Span Test (RST) and empathizing parameters. Mochizuki et al.¹⁸⁾ suggested that there are significant sex differences in the relationships between some of the physical abilities and social cognitive abilities. One of the results of the above-mentioned study showed that quickness and Autism Spectrum Quotient (AQ) have a positive correlation in the female group, while the same parameters have a negative correlation in the male group. As reported in the above, a series of our studies indicated a strong possibility of different types of human abilities being closely interrelated. However, we have not dealt with the other physical abilities, except for quickness and endurance. Further study is needed to investigate the association system between different physical abilities and social communication. Spatial cognitive memory and performances are crucial factors in social functioning. These factors are also the components of physical abilities. Working memory—a dominant element in social functioning—plays an important role in image training, language acquisition, rehabilitation of language and cognitive impairment. We hypothesized that the three different types of abilities—physical abilities, social functioning and language proficiency—are closely interrelated, and that there exist sex-related differences in the interrelationships among the three different types of abilities.

The purpose of the present study was to investigate interrelationships among physical abilities, social functioning and language proficiency. We also attempted to carry out a gender-segregated analysis of these three different abilities. In the design of personalized physical exercise programs, individuality of personal abilities needs to be quantified. One major factor in individuality seems to be related to sex differences. In this study, we attempted to quantify the relationships between physical abilities and the other types of abilities.

2. Methods

2.1. Subjects

Thirty healthy college students (18 males and 12 females, 21.1 ± 1.6 years old) served as subjects. They were all Japanese undergraduate and graduate students who belonged to a School of Health and Sports Science. The study protocol, which is in accordance with the Declaration of Helsinki, was approved by the Teikyo Heisei University Research Ethics Committee and Juntendo University Research Ethics Committee. After a complete description of the study was given to all subjects, they gave informed consent for the protocol.

2.2. Procedures

There were three sessions in this study: a physical ability measurement session, a social functioning session and a language session. We held the two sessions, social functioning session and language session, on the same day for each subject. The physical ability measurement session was held within the range from one week to six weeks before/after the other sessions. To evaluate the associations among physical abilities, social functioning and language proficiency, following a normality test, correlation analysis was conducted for physical parameters, social parameters and language parameters.

2.2.1. Physical ability measurement session

In the physical ability measurement session, we used five tests to measure the physical abilities of the subjects. We employed a side-step test for the measurement of quickness, a vertical jump test for that of power, a grip test for that of strength, a sitting-and-bending-forward test for that of flexibility, and a

12-minute run test for that of endurance. In the side-step test, we used three lines with a width of one meter, and counted the number of steps within 20 seconds. In the vertical jump, we employed a digital meter installed on the wall, and in the grip test, a digital meter was used. In the 12-minute run test, we used an outdoor athletic track. In addition to the above-mentioned physical abilities, we obtained body mass index (BMI) of the subjects. The subjects were tested individually, except for a 12-minute run test in which the men and women ran in separate groups.

2.2.2. Social functioning session

We examined social functioning in terms of two specific components: memory span and empathizing. The Japanese version of the reading span test (RST) was employed to measure memory span as one of the quantified indices of working memory which fulfills a dominant role in social cognition. We obtained four parameters using the RST score: the total words, the proportion of words, the correct sets of words and the truncated span²⁰⁾. Empathizing—the ability to recognize other's emotions and mental states—was measured by self-reports on the Systemizing, Empathy, and Autism Spectrum Quotients (SQ, EQ and AQ)³⁹⁾.

2.2.3. Language session

In the language session, we used three tests to measure the English proficiency of the subjects. They took the official TOEIC test for the measurement of English proficiency. Regarding the measurement of English proficiency, TOEIC (Test of English for International Communication) is a widely-used standardized test, and it is recognized as providing a valid assessment of English-language reading and listening skills, especially for the workplace. It is a multiple-choice assessment consisting of Listening and Reading Sections. They also took the standardized tests, the "Rate Level Test"⁴⁾ and the "Accuracy Level Test"⁵⁾. The "Rate Level Test" was used to measure their reading rate in English. In the test, the subjects read English sentences for two minutes. The raw score was calculated from the number of words and the reading rate was interpreted by the conversion table. Two points were subtracted in cases of an incorrect answer. This reading rate was shown in terms of the number of words that one could read within one minute. The "Accuracy Level Test" was used to measure vocabulary abilities. The subjects answered 100 vocabulary questions within ten minutes. The raw score was calculated from the number of correct answers. 0.5 points were subtracted in cases of an incorrect answer. The vocabulary ability was interpreted by the conversion table.

3. Results

To evaluate the associations among physical abilities, social functioning and language proficiency, correlation analysis was conducted for physical parameters (quickness, power, strength, flexibility and endurance), social parameters (RST, SQ, EQ and AQ) and TOEIC scores (total, listening and reading scores) together with reading rate and vocabulary size, which reflect learning and performance abilities of English as a second language. The parameters, except the RST group, passed normative tests. Therefore, Spearman's and Pearson's correlation coefficients were calculated for non-normative parameters and others, respectively. Table 1 shows means and standard deviations as well as correlation coefficients for the above-mentioned parameters, and strong correlations ($r > 0.7$) are indicated in bold-faced fonts. In Table 1, Physical parameters showed no dependence on the social parameters, except for EQ, which negatively correlated with endurance. Flexibility showed correlation with one of the English parameters, vocabulary size. Regarding English parameters, TOEIC scores showed a strong correlation with reading rate and some correlation with vocabulary, but showed no dependence on the RST and empathizing parameters. Vocabulary ability showed a negative correlation with EQ.

It is noteworthy that gender-segregated analysis suggested that sex differences could affect the overall relationships among physical parameters, social parameters, and English-related parameters. Tables 2

Table 1. Correlation coefficients for physical parameters, English parameters and social parameters (male & female subjects)

	TOEIC total	TOEIC listening	TOEIC reading	Rate	Vocab	RST correct	RST rate	RST set	RST span	SQ	EQ	AQ	Quickness	Power	Strength	Flexibility	Endurance	BMI	
TOEIC total	1.000	0.917	0.927	0.803	0.494	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TOEIC listening	0.917	1.000	0.700	0.801	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TOEIC reading	0.927	0.700	1.000	0.683	0.592	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rate	0.803	0.801	0.683	1.000	0.421	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vocabulary	0.494	—	0.592	0.421	1.000	—	—	—	—	—	-0.367	—	—	—	—	0.388	—	—	—
RST correct	—	—	—	—	—	1.000	0.987	0.924	0.837	—	—	—	—	—	—	—	—	—	—
RST rate	—	—	—	—	—	0.987	1.000	0.912	0.830	—	—	—	—	—	—	—	—	—	—
RST set	—	—	—	—	—	0.924	0.912	1.000	0.929	—	—	—	—	—	—	—	—	—	—
RST span	—	—	—	—	—	0.837	0.830	0.929	1.000	—	0.363	—	—	—	—	—	—	—	—
SQ	—	—	—	—	—	—	—	—	1.000	—	—	—	—	—	—	—	—	—	—
EQ	—	—	—	—	-0.367	—	—	—	0.363	—	1.000	—	—	—	—	—	-0.491	—	—
AQ	—	—	—	—	—	—	—	—	—	—	—	1.000	—	—	—	—	—	—	—
Quickness	—	—	—	—	—	—	—	—	—	—	—	—	1.000	—	—	—	—	—	—
Power	—	—	—	—	—	—	—	—	—	—	—	—	—	1.000	0.647	—	0.512	—	—
Strength	—	—	—	—	—	—	—	—	—	—	—	—	—	0.647	1.000	-0.363	—	—	0.575
Flexibility	—	—	—	—	0.388	—	—	—	—	—	—	—	—	—	-0.363	1.000	—	—	—
Endurance	—	—	—	—	—	—	—	—	—	—	-0.491	—	—	—	—	—	1.000	—	—
BMI	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.575	—	—	—	1.000
[mean]	580.000	308.667	271.333	150.567	10800.000	46.167	0.702	19.400	3.883	26.067	41.500	18.767	55.133	53.300	39.523	52.333	2806.897	21.762	[mean]
[S.D.]	130.384	68.518	72.871	46.382	3576.383	8.945	0.112	13.037	3.131	12.817	12.544	6.118	7.771	9.777	10.469	10.965	442.373	1.710	[S.D.]

(— : p>0.05)

Table 2. Correlation coefficients for physical parameters, English parameters and social parameters (male subjects)

	TOEIC total	TOEIC listening	TOEIC reading	Rate	Vocab	RST correct	RST rate	RST set	RST span	SQ	EQ	AQ	Quickness	Power	Strength	Flexibility	Endurance	BMI	
TOEIC total	1.000	0.923	0.915	0.768	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TOEIC listening	0.923	1.000	0.688	0.837	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TOEIC reading	0.915	0.688	1.000	0.567	—	—	—	—	—	—	—	—	—	—	-0.507	—	0.631	—	—
Rate	0.768	0.837	0.567	1.000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vocabulary	—	—	—	—	1.000	—	—	—	—	—	-0.682	—	—	—	—	0.627	—	—	—
RST correct	—	—	—	—	—	1.000	0.985	0.909	0.790	—	—	—	—	—	—	—	—	—	—
RST rate	—	—	—	—	—	0.985	1.000	0.887	0.773	—	—	—	—	—	—	—	—	—	—
RST set	—	—	—	—	—	0.909	0.887	1.000	0.908	—	—	—	—	—	—	—	—	—	—
RST span	—	—	—	—	—	0.790	0.773	0.908	1.000	—	—	—	—	—	—	—	—	—	—
SQ	—	—	—	—	—	—	—	—	—	1.000	—	—	—	—	—	—	—	—	—
EQ	—	—	—	—	-0.682	—	—	—	—	—	1.000	—	—	—	0.643	—	-0.720	—	—
AQ	—	—	—	—	—	—	—	—	—	—	—	1.000	-0.590	—	—	—	—	—	—
Quickness	—	—	—	—	—	—	—	—	—	—	-0.590	—	1.000	—	—	-0.575	—	—	—
Power	—	—	—	—	—	—	—	—	—	—	—	—	—	1.000	—	—	—	—	—
Strength	—	—	-0.507	—	—	—	—	—	—	—	0.643	—	—	—	1.000	—	-0.701	—	—
Flexibility	—	—	—	—	0.627	—	—	—	—	—	—	—	-0.575	—	—	1.000	—	—	—
Endurance	0.720	0.662	0.631	—	—	—	—	—	—	—	-0.720	—	—	—	-0.701	—	1.000	—	—
BMI	—	—	—	—	—	—	—	—	—	0.547	—	—	—	—	0.701	—	-0.662	—	1.000
[mean]	575.278	304.444	270.833	154.111	11013.889	45.333	0.690	18.000	3.722	26.056	38.722	18.667	57.056	59.333	45.794	48.528	3046.111	22.210	[mean]
[S.D.]	133.323	74.318	70.799	51.950	3374.289	8.751	0.112	11.125	3.098	11.649	12.560	6.987	8.011	6.088	8.451	10.625	341.625	1.530	[S.D.]

(— : p>0.05)

Table 3. Correlation coefficients for physical parameters, English parameters and social parameters (female subjects)

	TOEIC total	TOEIC listening	TOEIC reading	Rate	Vocab	RST correct	RST rate	RST set	RST span	SQ	EQ	AQ	Quickness	Power	Strength	Flexibility	Endurance	BMI	
TOEIC total	1.000	0.916	0.950	0.930	0.789	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TOEIC listening	0.916	1.000	0.745	0.761	0.703	—	—	—	—	—	—	—	—	—	—	—	—	—	—
TOEIC reading	0.950	0.745	1.000	0.953	0.766	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rate	0.930	0.761	0.953	1.000	0.752	—	—	—	—	—	—	-0.596	—	—	—	—	—	—	—
Vocabulary	0.789	0.703	0.766	0.752	1.000	—	—	—	—	—	—	-0.680	—	—	—	—	—	—	—
RST correct	—	—	—	—	—	1.000	0.934	0.642	0.580	—	—	—	—	—	—	—	—	—	—
RST rate	—	—	—	—	—	0.934	1.000	0.832	0.715	—	—	—	—	—	—	—	—	—	—
RST set	—	—	—	—	—	0.642	0.832	1.000	0.946	—	—	—	—	—	—	—	—	—	—
RST span	—	—	—	—	—	0.580	0.715	0.946	1.000	—	—	—	—	—	0.626	—	—	—	—
SQ	—	—	—	—	—	—	—	—	—	1.000	—	—	—	—	—	—	—	—	—
EQ	—	—	—	—	—	—	—	—	—	—	1.000	—	—	—	—	—	—	—	—
AQ	—	—	—	-0.596	-0.680	—	—	—	—	—	—	1.000	—	—	—	—	—	—	—
Quickness	—	—	—	—	—	—	—	—	—	—	—	—	1.000	—	—	—	—	—	0.586
Power	—	—	—	—	—	—	—	—	—	—	—	—	—	1.000	—	—	—	—	—
Strength	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.000	—	—	—	—
Flexibility	—	—	—	—	—	—	—	—	—	0.626	—	—	—	—	—	1.000	—	—	—
Endurance	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.000	—	—
BMI	—	—	—	—	—	—	—	—	—	—	—	—	0.586	—	—	—	—	—	1.000
[mean]	587.083	315.000	272.083	145.250	10479.167	47.417	0.719	21.500	4.125	26.083	45.667	18.917	52.583	44.250	30.008	57.583	2415.455	21.089	[mean]
[S.D.]	131.364	61.386	79.070	38.070	3992.121	9.472	0.115	15.774	3.304	14.945	11.812	4.814	7.103	6.771	3.119	10.040	279.262	1.807	[S.D.]

(— : p > 0.05)

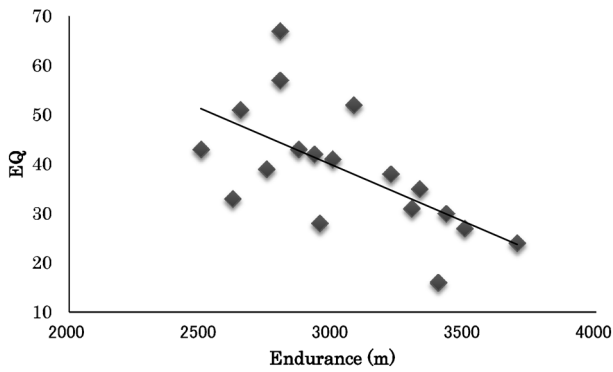


Figure 1. Scatter plot of Endurance Test and EQ (male subjects)

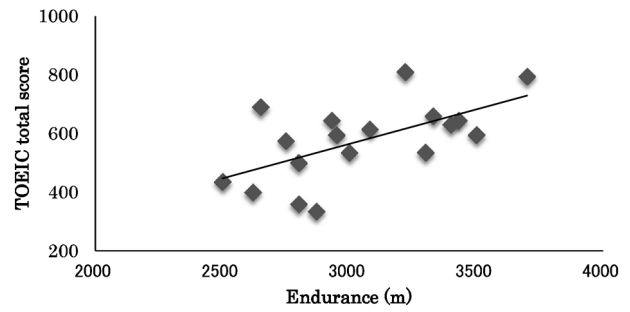


Figure 2. Scatter plot of Endurance Test and TOEIC total score (male subjects)

Table 4. Sex differences in physical, English and social parameters

	Quickness		Power		Strength		Flexibility		Endurance		BMI		RST		SQ		EQ		AQ	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
TOEIC total									+	ns										
TOEIC listening									+	ns										
TOEIC reading					-	ns			+	ns										
Rate																			ns	-
Vocabulary							+	ns											ns	-
RST correct																				
RST rate																				
RST set																				
RST span																				
SQ					ns	+	-	ns			+	ns							+	ns
EQ					+	ns			-	ns						+	ns			
AQ	-	ns																		
BMI	ns	+			+	ns			-	ns										

and 3 show significant sex-related differences in the interrelationships among these parameters. As in Table 1, strong correlations ($r > 0.7$) are indicated in bold-faced fonts. Regarding physical parameters, quickness showed a relatively negative correlation with AQ in the male group, but not in the female group. Endurance showed a negative strong correlation with EQ in the male group, but not in the female group (Figure 1). Strength showed a positive correlation with EQ in the male group, while strength correlated with SQ in the female group. Turning to the relationship between physical parameters and English parameters, we could also observe sex-related differences. Endurance showed a strong positive correlation with TOEIC scores in the male group, but not in the female group (Figure 2). Flexibility and vocabulary ability showed a relatively strong positive correlation in the male group, but not in the female group. Strength showed a negative correlation with the TOEIC reading score in the male group, but not in the female group. Vocabulary ability showed a positive correlation with flexibility and a strong negative correlation with EQ in the male group, but not in the female group. In addition, vocabulary ability showed a relatively strong negative correlation with AQ in the female group, but not in the male group. Table 4 summarizes the above-mentioned sex differences in physical, English and social parameters.

4. Discussion

The relationships between physical abilities and social functioning and that between language proficiency and social functioning have been previously studied³¹⁾²⁴⁾, but these studies have not investigated the interrelationships among these three different types of abilities⁸⁾¹⁾. In this study, language proficiency was taken up as one of the indices for learning ability. We carried out a quantitative analysis of three different types of abilities for the purpose of designing the personalized exercise program by which consolidated abilities are developed. The present study showed that there exist sex-related differences in the interrelationships among three different types of abilities—physical abilities, social functioning and language proficiency. Some sex differences have been reported in each field of language proficiency and social functioning³⁰⁾²⁵⁾¹⁴⁾¹⁶⁾³⁶⁾²¹⁾²²⁾⁴⁰⁾. When we look at the male-female pooled results of this study, the three different types of abilities were not closely interrelated, as suggested by the results of the correlation analysis. The present study revealed that the sex differences affected the overall relationships among the three types of abilities. Namely, the major finding of this study is that there exist male-female differences in the interrelationships among the three different abilities.

A novel aspect of this study is the findings about the interrelationships among physical abilities, social functioning and language proficiency. In case of males, one of the physical parameters, endurance, showed positive correlations with English parameters, which is in concordance with the study by Ratey²³⁾ that reported a positive correlation between physical abilities and academic abilities. This relationship between this physical ability and English ability was not found for females, which indicated notable sex differences. A conspicuous effect of physical ability on English ability was observed for endurance among five physical abilities—quickness, power, strength, flexibility and endurance—in the case of males. This finding suggested that male learners of second language need endurance in second language acquisition.

Another finding of the present study is that in the case of males, the physical parameter, endurance, showed negative correlations with one of social parameters, EQ, which was not found for females. Males with a high ability of endurance were found to be low in ability to empathize. This result might be interpreted as suggesting that a man with endurance becomes absorbed in what he does without paying attention to other people's states¹⁰⁾¹⁷⁾³²⁾. It is worth mentioning that there is an influence of sex hormones on the hemispheric differences of mental activities¹⁰⁾.

In the case of females, persons with less autistic traits had a high English ability, as suggested by the result of a relatively strong correlation between AQ and English abilities, especially reading rate and vocabulary ability. Also, females with high ability of strength were high in SQ. The personality trait of being extraverted might contribute to successful second language acquisition. This result is in accordance with the literature on second language acquisition²⁷⁾⁶⁾³³⁾⁷⁾ which reported on different personality types such as types of extroversion vs. introversion as one of the factors affecting the success in second language acquisition.

5. Conclusion

The gender-segregated analysis suggested several significant differences in the association of physical, social and linguistic parameters between men and women. The sex factor together with social factors should be taken into account in the design of personalized physical training programs. A personalized program which takes into account the individuality of personal abilities, including sex differences, is crucial for promoting consolidated ability development. The present study suggests that the research on the interrelationships among physical ability, social functioning and language proficiency can contribute to the design of the optimal exercise program and effective language acquisition. Among

physical abilities, conditional abilities were tested in the present study, but there was less information gathered about coordination motor abilities, which might be more related to social functioning and language proficiency. We are now carrying out research, focusing on the relations among coordination exercises, social functioning and language proficiency.

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