The development of brain systems supporting handwriting and letter perception

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1 Project Description

1.1 background

Handwriting ability which is displayed by producing letters by hand a very complex behavior for human . The principal idea is that act of handwriting is generated from something about the visual and motor coordination spontaneously, and this stuff integrates visual and motor brain systems, which is significant to develop letter perceptual abilities. There are two visual stream can effect about our perceptual ability.The dual streams hypothesis of version, which high relates to visual processing, is one of most distinguished ideas about how the brain functions. Ventral stream objects recognition and identification, and dorsal stream reaches to grasp, hand position and unconscious. There are a lot of the early work on visual processing began with investigating responses in the ventral visual stream. Scientists found that selective responses for various object domains, for example faces and places, but also for learned object, such as words. In this case, we want to explore how brain supports perceptual processes by considering the ventral visual stream as major effect with some influence from dorsal visual stream in order to better understand how people start to know the meaning of object.

The data is collected by looking at how letter is produced by brain support at three different levels of ages. The experiment asked early-literate children, literate children, and literate adults to write and perceive individual letters in an fMRI scanner. To look at how the brain supports letter production at these different levels of experience, we asked early-literate children, literate children, and literate adults to write and perceive individual letters in an fMRI scanner. There are 6 areas (LaIPS, RaIPS, LmUPS, RmUPS, LpIPS and RpIPS) to indicate 6 part in our brain and 4 conditions (WatchDynamic_ other, WatchDynamic_ own, WatchStatic_ own, and WatchStatic_ typed) to show 4 designed situations; each area have every condition. To be specific, we collected 4 conditions data in each 6 area from 38 people divided into three different age levels, so each person have 24 response

variable in this experiment.

1.2 Research Questions

1.2.1 RQ1

The five guiding research questions for the present analysis are the following: (1)Does there is any relationship between different areas? (2) Does there is any relationship between different conditions? (3) Does there is any relationship between areas within each condition? (4) Does there is any relationship between conditions within each area? and, finally, (5) Is there a relationship between each group?

1.2.2 RQ2

In second part, we need to build a model for each area according to fixed and random effect.

1.3 Variables

The fixed effects in the first analysis are area, condition, and age; the random effect is student ID. The area indicates six different in our brain. Condition indicates four methods which scientists apply to people in different age level. Age indicates three different age level in this experiment. In this case, area, condition and age are all categorical variables. Area =1,2,3,4,5 and 6 respectively indicates LaPIS, LmIPS, LpIPS, RaIPS, RmIPS and RpIPS. Condition=1 indicates people....., condition=2 indicates people....., condition=3 indicates people....., and condition=4 indicates..... Age=1 indicates people are from 5 to 6 years old called early-literate children, age=2 indicates people are from 7 to 8 years old called literate children, and age=3 indicates people are from 19 to 25 years old called literate adults. In the second analysis, the fixed effects are Age, VMI, VP, MC, WJIV Letter Word Reading, WJIV Spelling, WJIV Word Attack and WJIV Spelling of Sounds and the random effect is student ID. Age is a categorical variable which is same as in the first analysis. VMI indicates Beery Visual Motor Integration. VP indicates Beery Visual Perception. MC indicates Beery Motor Coordination.

2 Methods

3 Pairwise Comparisons

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	34.000	137.664	.000
area	5	812.000	2.538	.027
Group	2	34.000	1.009	.375
condition	3	812	6.133	.000
Group * area	10	812.000	.690	.734
Group * condition	6	812.000	2.695	.013
area * condition	15	812.000	.285	.997

a. Dependent Variable: action.

Figure 1: table of fixed effect

As can be noted in the table above, base on the p value, area with $p = 0.027$, condition with $p < 0.001$ and Group* condition with $p = 0.013$ contain in the model.

3.0.1 Area

The below table shows the interrelationships between different areas in brains of people. According to the significant value of each pair, there is an interrelationship between LmIPS and RmIPS, and the P-value is 0.021, which is smaller than the significant level, p = 0:05.The P-value of the intersection term between LmIPS and RpIPS equals to 0.01, which means there is a relationship between RpIPS and LmIPS. The intersection between RaIPS and RpIPS is significant, p = 0:02. However, all the other pairs do not have interactions between them.

Pairwise Comparisons[a]

(I) area	(J) area	Mean Difference (I-J)	Std. Error	df	Sig.[c]	95% Confidence Interval for Difference[c] Lower Bound	Upper Bound
LaPIS	LmIPS	.126	.071	812	.075	-.013	.266
	LpIPS	.009	.071	812	.894	-.130	.149
	RaIPS	.060	.071	812	.400	-.079	.199
	RmIPS	-.038	.071	812	.593	-.177	.101
	RpIPS	-.106	.071	812	.135	-.245	.033
LmIPS	LaPIS	-.126	.071	812	.075	-.266	.013
	LpIPS	-.117	.071	812	.099	-.256	.022
	RaIPS	-.067	.071	812	.347	-.206	.072
	RmIPS	-.164*	.071	812	.021	-.304	-.025
	RpIPS	-.233*	.071	812	.001	-.372	-.093
LpIPS	LaPIS	-.009	.071	812	.894	-.149	.130
	LmIPS	.117	.071	812	.099	-.022	.256
	RaIPS	.050	.071	812	.479	-.089	.189
	RmIPS	-.047	.071	812	.504	-.187	.092
	RpIPS	-.116	.071	812	.103	-.255	.024
RaIPS	LaPIS	-.060	.071	812	.400	-.199	.079
	LmIPS	.067	.071	812	.347	-.072	.206
	LpIPS	-.050	.071	812	.479	-.189	.089
	RmIPS	-.098	.071	812	.169	-.237	.042
	RpIPS	-.166*	.071	812	.020	-.305	-.027
RmIPS	LaPIS	.038	.071	812	.593	-.101	.177
	LmIPS	.164*	.071	812	.021	.025	.304
	LpIPS	.047	.071	812	.504	-.092	.187
	RaIPS	.098	.071	812	.169	-.042	.237
	RpIPS	-.068	.071	812	.336	-.207	.071
RpIPS	LaPIS	.106	.071	812	.135	-.033	.245
	LmIPS	.233*	.071	812	.001	.093	.372
	LpIPS	.116	.071	812	.103	-.024	.255
	RaIPS	.166*	.071	812	.020	.027	.305
	RmIPS	.068	.071	812	.336	-.071	.207

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: action.

c. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Figure 2: pairwise comparisons between six areas

The univariate tests of area shows p = 0:027, so the area is significant in the model.

Univariate Tests[a]

Numerator df	Denominator df	F	Sig.
5	812.000	2.538	.027

The F tests the effect of area. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Dependent Variable: action.

Figure 3: Univariate Tests of area

3.0.2 Condition

Pairwise Comparisons[a]

(I) condition	(J) condition	Mean Difference (I–J)	Std. Error	df	Sig.[c]	95% Confidence Interval for Difference[c] Lower Bound	Upper Bound
WatchStatic_other	WatchStatic_own	.191*	.058	812.000	.001	.078	.305
	WatchDynamic_own	-.011	.058	812	.849	-.125	.103
	WatchTyped	.142*	.058	812	.015	.028	.255
WatchStatic_own	WatchStatic_other	-.191*	.058	812.000	.001	-.305	-.078
	WatchDynamic_own	-.202*	.058	812	.001	-.316	-.089
	WatchTyped	-.050	.058	812	.392	-.163	.064
WatchDynamic_own	WatchStatic_other	.011	.058	812	.849	-.103	.125
	WatchStatic_own	.202*	.058	812	.001	.089	.316
	WatchTyped	.153*	.058	812	.009	.039	.266
WatchTyped	WatchStatic_other	-.142*	.058	812	.015	-.255	-.028
	WatchStatic_own	.050	.058	812	.392	-.064	.163
	WatchDynamic_own	-.153*	.058	812	.009	-.266	-.039

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: action.

c. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Figure 4: pairwise comparisons between four conditions

Following across the rows for "Sig_c" in the above table of tests for the within subject effects, the relationship between WatchStatic_own and WatchStatic_other is significant, $p = 0.001$, and the relationship between WatchStatic_other and WatchTyped is also significant, $p = 0.015$. In addition, significant interactions betweenWatchStatic own andWatchDynamic own, $p = 0.001$, and between WatchDynamic own and WatchTyped, $p = 0.09$,were noted.

Univariate Tests[a]

Numerator df	Denominator df	F	Sig.
3	812	6.133	.000

The F tests the effect of condition. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Dependent Variable: action.

Figure 5: Univariate Tests of condition

The univariate tests of area shows $p = 0.027$, so the area is significant in the model.

3.0.3 Areas within each condition

The table in the below shows the inter area effects within each condition. There are significant interaction between LmIPS and LpIPS ($p = 0.042$), between LmIPS and RmIPS ($p = 0.031$), and between LmIPS and RpIPS ($p = 0.018$) in the first condition, WatchStatic_other. None of interrelationship is in the second condition, WatchStatic_own, and all the P-value is larger than the significant level, ($p = 0 : 05$). The interaction between LmIPS and RpIPS is significant in the third condition, WatchDynamic_own, and there is no interaction between areas in the fourth condition, WatchTyped.

condition	(I) area	(J) area	JJ	Std. Error	df	Sig.`	Lower Bound	Upper Bound
WatchStatic_other	LaPIS	LmIPS	.222	.141	812	.117	-.056	.499
		LpIPS	-.066	.141	812	.639	-.344	.211
		RaIPS	.114	.141	812	.418	-.163	.392
		RmIPS	-.084	.141	812	.551	-.362	.193
		RpIPS	-.112	.141	812	.427	-.390	.165
	LmIPS	LaPIS	-.222	.141	812	.117	-.499	.056
		LpIPS	-.288*	.141	812	.042	-.565	-.011
		RaIPS	-.107	.141	812	.449	-.384	.170
		RmIPS	-.306*	.141	812	.031	-.583	-.028
		RpIPS	-.334*	.141	812	.018	-.611	-.056
	LpIPS	LaPIS	.066	.141	812	.639	-.211	.344
		LmIPS	.288*	.141	812	.042	.011	.565
		RaIPS	.181	.141	812	.201	-.097	.458
		RmIPS	-.018	.141	812	.899	-.295	.259
		RpIPS	-.046	.141	812	.746	-.323	.231
	RaIPS	LaPIS	-.114	.141	812	.418	-.392	.163
		LmIPS	.107	.141	812	.449	-.170	.384
		LpIPS	-.181	.141	812	.201	-.458	.097
		RmIPS	-.199	.141	812	.160	-.476	.079
		RpIPS	-.227	.141	812	.109	-.504	.051
	RmIPS	LaPIS	.084	.141	812	.551	-.193	.362
		LmIPS	.306*	.141	812	.031	.028	.583
		LpIPS	.018	.141	812	.899	-.259	.295
		RaIPS	.199	.141	812	.160	-.079	.476
		RpIPS	-.028	.141	812	.843	-.305	.249
	RpIPS	LaPIS	.112	.141	812	.427	-.165	.390
		LmIPS	.334*	.141	812	.018	.056	.611
		LpIPS	.046	.141	812	.746	-.231	.323

		RaIPS	.227	.141	812	.109	−.051	.504
		RmIPS	.028	.141	812	.843	−.249	.305
WatchStatic_own	LaPIS	LmIPS	.121	.141	812	.391	−.156	.399
		LpIPS	.081	.141	812	.569	−.197	.358
		RaIPS	.065	.141	812	.646	−.212	.342
		RmIPS	−.004	.141	812	.979	−.281	.274
		RpIPS	−.072	.141	812	.608	−.350	.205
	LmIPS	LaPIS	−.121	.141	812	.391	−.399	.156
		LpIPS	−.041	.141	812	.774	−.318	.237
		RaIPS	−.056	.141	812	.691	−.334	.221
		RmIPS	−.125	.141	812	.377	−.402	.152
		RpIPS	−.194	.141	812	.171	−.471	.084
	LpIPS	LaPIS	−.081	.141	812	.569	−.358	.197
		LmIPS	.041	.141	812	.774	−.237	.318
		RaIPS	−.016	.141	812	.912	−.293	.262
		RmIPS	−.084	.141	812	.551	−.362	.193
		RpIPS	−.153	.141	812	.279	−.430	.124
	RaIPS	LaPIS	−.065	.141	812	.646	−.342	.212
		LmIPS	.056	.141	812	.691	−.221	.334
		LpIPS	.016	.141	812	.912	−.262	.293
		RmIPS	−.069	.141	812	.627	−.346	.209
		RpIPS	−.137	.141	812	.331	−.415	.140
	RmIPS	LaPIS	.004	.141	812	.979	−.274	.281
		LmIPS	.125	.141	812	.377	−.152	.402
		LpIPS	.084	.141	812	.551	−.193	.362
		RaIPS	.069	.141	812	.627	−.209	.346
		RpIPS	−.069	.141	812	.627	−.346	.209
	RpIPS	LaPIS	.072	.141	812	.608	−.205	.350
		LmIPS	.194	.141	812	.171	−.084	.471
		LpIPS	.153	.141	812	.279	−.124	.430
		RaIPS	.137	.141	812	.331	−.140	.415
		RmIPS	.069	.141	812	.627	−.209	.346
WatchDynamic_own	LaPIS	LmIPS	.064	.141	812	.651	−.213	.341
		LpIPS	−.003	.141	812	.984	−.280	.274
		RaIPS	.042	.141	812	.764	−.235	.320
		RmIPS	−.072	.141	812	.611	−.349	.205
		RpIPS	−.214	.141	812	.130	−.491	.063
	LmIPS	LaPIS	−.064	.141	812	.651	−.341	.213
		LpIPS	−.067	.141	812	.636	−.344	.211
		RaIPS	−.022	.141	812	.879	−.299	.256
		RmIPS	−.136	.141	812	.336	−.413	.141
		RpIPS	−.278*	.141	812	.049	−.555	−.001
	LpIPS	LaPIS	.003	.141	812	.984	−.274	.280
		LmIPS	.067	.141	812	.636	−.211	.344
		RaIPS	.045	.141	812	.749	−.232	.323
		RmIPS	−.069	.141	812	.625	−.346	.208
		RpIPS	−.211	.141	812	.135	−.489	.066
	RaIPS	LaPIS	−.042	.141	812	.764	−.320	.235
		LmIPS	.022	.141	812	.879	−.256	.299
		LpIPS	−.045	.141	812	.749	−.323	.232
		RmIPS	−.114	.141	812	.419	−.392	.163
		RpIPS	−.256	.141	812	.070	−.534	.021
	RmIPS	LaPIS	.072	.141	812	.611	−.205	.349
		LmIPS	.136	.141	812	.336	−.141	.413

		LpIPS	.069	.141	812	.625	−.208	.346
		RaIPS	.114	.141	812	.419	−.163	.392
		RpIPS	−.142	.141	812	.315	−.419	.135
	RpIPS	LaPIS	.214	.141	812	.130	−.063	.491
		LmIPS	.278*	.141	812	.049	.001	.555
		LpIPS	.211	.141	812	.135	−.066	.489
		RaIPS	.256	.141	812	.070	−.021	.534
		RmIPS	.142	.141	812	.315	−.135	.419
WatchTyped	LaPIS	LmIPS	.099	.141	812	.483	−.178	.376
		LpIPS	.027	.141	812	.851	−.251	.304
		RaIPS	.017	.141	812	.903	−.260	.295
		RmIPS	.008	.141	812	.953	−.269	.286
		RpIPS	−.026	.141	812	.855	−.303	.252
	LmIPS	LaPIS	−.099	.141	812	.483	−.376	.178
		LpIPS	−.073	.141	812	.608	−.350	.205
		RaIPS	−.082	.141	812	.562	−.359	.195
		RmIPS	−.091	.141	812	.520	−.368	.187
		RpIPS	−.125	.141	812.000	.377	−.402	.152
	LpIPS	LaPIS	−.027	.141	812	.851	−.304	.251
		LmIPS	.073	.141	812	.608	−.205	.350
		RaIPS	−.009	.141	812	.947	−.287	.268
		RmIPS	−.018	.141	812	.897	−.296	.259
		RpIPS	−.052	.141	812.000	.711	−.330	.225
	RaIPS	LaPIS	−.017	.141	812	.903	−.295	.260
		LmIPS	.082	.141	812	.562	−.195	.359
		LpIPS	.009	.141	812	.947	−.268	.287
		RmIPS	−.009	.141	812	.950	−.286	.268
		RpIPS	−.043	.141	812.000	.761	−.320	.234
	RmIPS	LaPIS	−.008	.141	812	.953	−.286	.269
		LmIPS	.091	.141	812	.520	−.187	.368
		LpIPS	.018	.141	812	.897	−.259	.296
		RaIPS	.009	.141	812	.950	−.268	.286
		RpIPS	−.034	.141	812.000	.810	−.311	.243
	RpIPS	LaPIS	.026	.141	812	.855	−.252	.303
		LmIPS	.125	.141	812.000	.377	−.152	.402
		LpIPS	.052	.141	812.000	.711	−.225	.330
		RaIPS	.043	.141	812.000	.761	−.234	.320
		RmIPS	.034	.141	812.000	.810	−.243	.311

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: action.

c. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Figure 6: pairwise comparisons between six areas within each condition

3.0.4 Conditions within each area

Following across the rows in the below table of tests for the within- subject effects in six different areas in brains of people, significant interactions between WatchStatic_other and-WatchStatic_own in LpIPS, $p = 0.24$, between WatchStaticown and WatchDynamic_own in RpIPS, p = 0:046, and between WatchDynamic own and WatchTyped in RpIPS, $p = 0.041$, were noted.

Pairwise Comparisons[a]

area	(I) condition	(J) condition	Mean Difference (I-J)	Std. Error	df	Sig.[c]	95% Confidence Interval for Difference[c]	
							Lower Bound	Upper Bound
LaPIS	WatchStatic_other	WatchStatic_own	.172	.141	812	.225	−.106	.449
		WatchDynamic_own	.032	.141	812	.823	−.246	.309
		WatchTyped	.133	.141	812	.347	−.144	.410

	WatchStatic_own	WatchStatic_other	-.172	.141	812	.225	-.449	.106
		WatchDynamic_own	-.140	.141	812	.322	-.417	.137
		WatchTyped	-.039	.141	812	.784	-.316	.239
	WatchDynamic_own	WatchStatic_other	-.032	.141	812	.823	-.309	.246
		WatchStatic_own	.140	.141	812	.322	-.137	.417
		WatchTyped	.101	.141	812	.473	-.176	.379
	WatchTyped	WatchStatic_other	-.133	.141	812	.347	-.410	.144
		WatchStatic_own	.039	.141	812	.784	-.239	.316
		WatchDynamic_own	-.101	.141	812	.473	-.379	.176
LmIPS	WatchStatic_other	WatchStatic_own	.071	.141	812	.614	-.206	.349
		WatchDynamic_own	-.126	.141	812	.373	-.403	.151
		WatchTyped	.010	.141	812	.941	-.267	.288
	WatchStatic_own	WatchStatic_other	-.071	.141	812	.614	-.349	.206
		WatchDynamic_own	-.197	.141	812	.163	-.474	.080
		WatchTyped	-.061	.141	812	.667	-.338	.216
	WatchDynamic_own	WatchStatic_other	.126	.141	812	.373	-.151	.403
		WatchStatic_own	.197	.141	812	.163	-.080	.474
		WatchTyped	.136	.141	812	.334	-.141	.414
	WatchTyped	WatchStatic_other	-.010	.141	812	.941	-.288	.267
		WatchStatic_own	.061	.141	812	.667	-.216	.338
		WatchDynamic_own	-.136	.141	812	.334	-.414	.141
LpIPS	WatchStatic_other	WatchStatic_own	.318*	.141	812	.024	.041	.596
		WatchDynamic_own	.095	.141	812	.501	-.182	.372
		WatchTyped	.226	.141	812	.110	-.051	.503
	WatchStatic_own	WatchStatic_other	-.318*	.141	812	.024	-.596	-.041
		WatchDynamic_own	-.223	.141	812	.114	-.501	.054
		WatchTyped	-.093	.141	812	.512	-.370	.185
	WatchDynamic_own	WatchStatic_other	-.095	.141	812	.501	-.372	.182
		WatchStatic_own	.223	.141	812	.114	-.054	.501
		WatchTyped	.131	.141	812	.355	-.146	.408
	WatchTyped	WatchStatic_other	-.226	.141	812	.110	-.503	.051
		WatchStatic_own	.093	.141	812	.512	-.185	.370
		WatchDynamic_own	-.131	.141	812	.355	-.408	.146
RaIPS	WatchStatic_other	WatchStatic_own	.122	.141	812	.387	-.155	.399
		WatchDynamic_own	-.040	.141	812	.775	-.318	.237
		WatchTyped	.036	.141	812	.801	-.242	.313
	WatchStatic_own	WatchStatic_other	-.122	.141	812	.387	-.399	.155
		WatchDynamic_own	-.163	.141	812	.250	-.440	.115
		WatchTyped	-.086	.141	812	.540	-.364	.191
	WatchDynamic_own	WatchStatic_other	.040	.141	812	.775	-.237	.318
		WatchStatic_own	.163	.141	812	.250	-.115	.440
		WatchTyped	.076	.141	812	.590	-.201	.353
	WatchTyped	WatchStatic_other	-.036	.141	812	.801	-.313	.242
		WatchStatic_own	.086	.141	812	.540	-.191	.364
		WatchDynamic_own	-.076	.141	812	.590	-.353	.201
RmIPS	WatchStatic_other	WatchStatic_own	.252	.141	812	.075	-.025	.529
		WatchDynamic_own	.044	.141	812	.756	-.233	.321
		WatchTyped	.225	.141	812	.111	-.052	.503
	WatchStatic_own	WatchStatic_other	-.252	.141	812	.075	-.529	.025
		WatchDynamic_own	-.208	.141	812	.141	-.486	.069
		WatchTyped	-.027	.141	812	.850	-.304	.250
	WatchDynamic_own	WatchStatic_other	-.044	.141	812	.756	-.321	.233
		WatchStatic_own	.208	.141	812	.141	-.069	.486
		WatchTyped	.182	.141	812	.199	-.096	.459
	WatchTyped	WatchStatic_other	-.225	.141	812	.111	-.503	.052
		WatchStatic_own	.027	.141	812	.850	-.250	.304
		WatchDynamic_own	-.182	.141	812	.199	-.459	.096
RpIPS	WatchStatic_other	WatchStatic_own	.211	.141	812	.135	-.066	.489
		WatchDynamic_own	-.070	.141	812	.619	-.348	.207
		WatchTyped	.219	.141	812.000	.121	-.058	.497
	WatchStatic_own	WatchStatic_other	-.211	.141	812	.135	-.489	.066
		WatchDynamic_own	-.282*	.141	812	.046	-.559	-.004
		WatchTyped	.008	.141	812.000	.955	-.269	.285
	WatchDynamic_own	WatchStatic_other	.070	.141	812	.619	-.207	.348
		WatchStatic_own	.282*	.141	812	.046	.004	.559
		WatchTyped	.290*	.141	812.000	.041	.012	.567
	WatchTyped	WatchStatic_other	-.219	.141	812.000	.121	-.497	.058
		WatchStatic_own	-.008	.141	812.000	.955	-.285	.269
		WatchDynamic_own	-.290*	.141	812.000	.041	-.567	-.012

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: action.

c. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Figure 7: pairwise comparisons between four conditions within each area

3.0.5 Group

Pairwise Comparisons[a]

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	df	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Early-literate children	Literate children	.135	.137	34.000	.332	-.143	.412
	Literate adults	.184	.132	34.000	.172	-.084	.452
Literate children	Early-literate children	-.135	.137	34.000	.332	-.412	.143
	Literate adults	.049	.129	34.000	.704	-.213	.311
Literate adults	Early-literate children	-.184	.132	34.000	.172	-.452	.084
	Literate children	-.049	.129	34.000	.704	-.311	.213

Based on estimated marginal means

a. Dependent Variable: action.

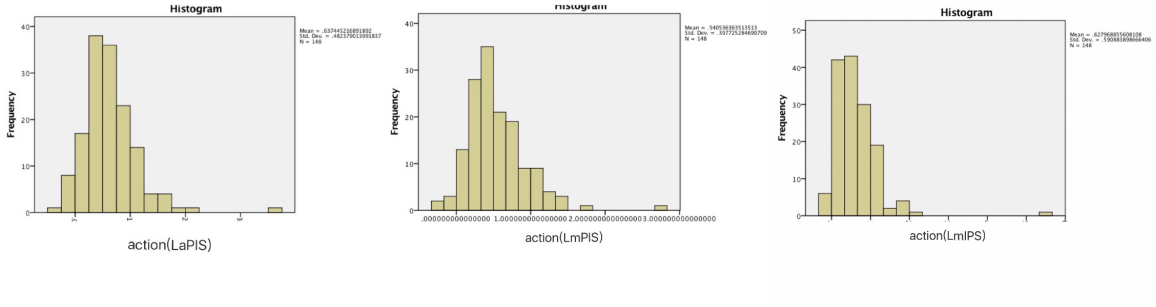
b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Figure 8: pairwise comparisons between age groups

According the pairwise comparisons table in the above, all the p values of interaction between each groups are larger than significant level $p = 0.05$. The result shows that there is no interrelationship between each age group. It also explains the group is not significant in the model (Figure 1).

4 Exploratory Data Analysis

4.1 Normality



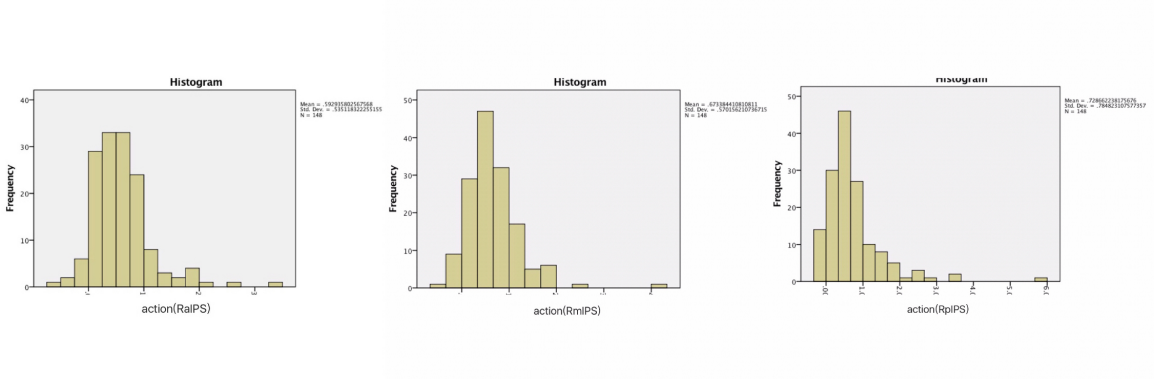
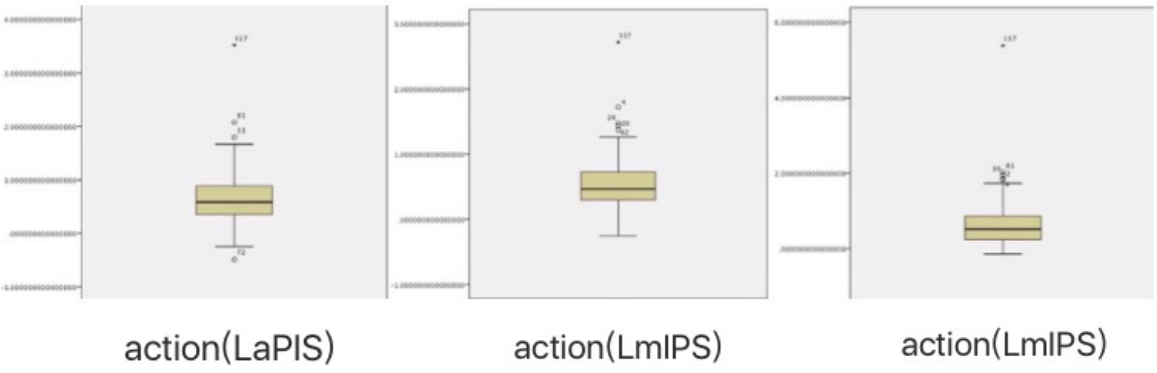


Figure 9: Histograms of action in 6 areas

According the six histograms of each area, all the value are skew to right, so we cannot say the data is normality in each area.

4.2 Outliers

To see the six boxplots of each area, there are some outliers in each boxplot and all the boxplots show that data are skew to right.



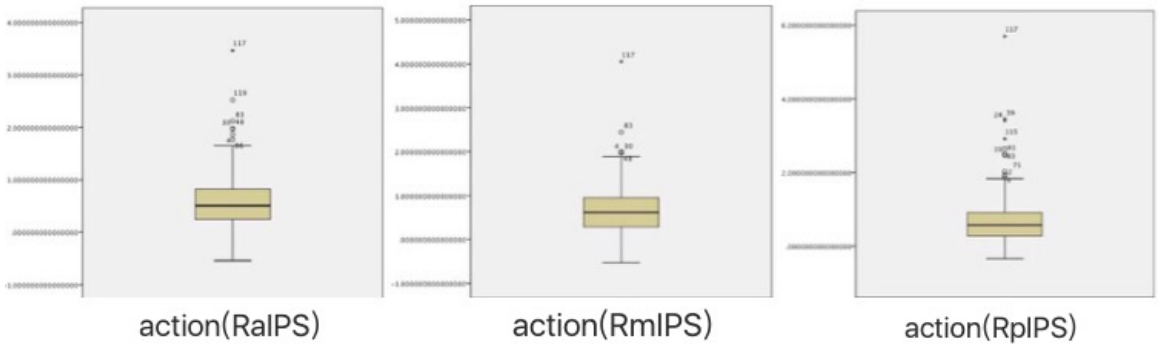


Figure 10: boxplots of action in 6 areas

Because of the out of normality and some outliers, we try to transform the dependent variable y (action) to $log(y + 1)$.

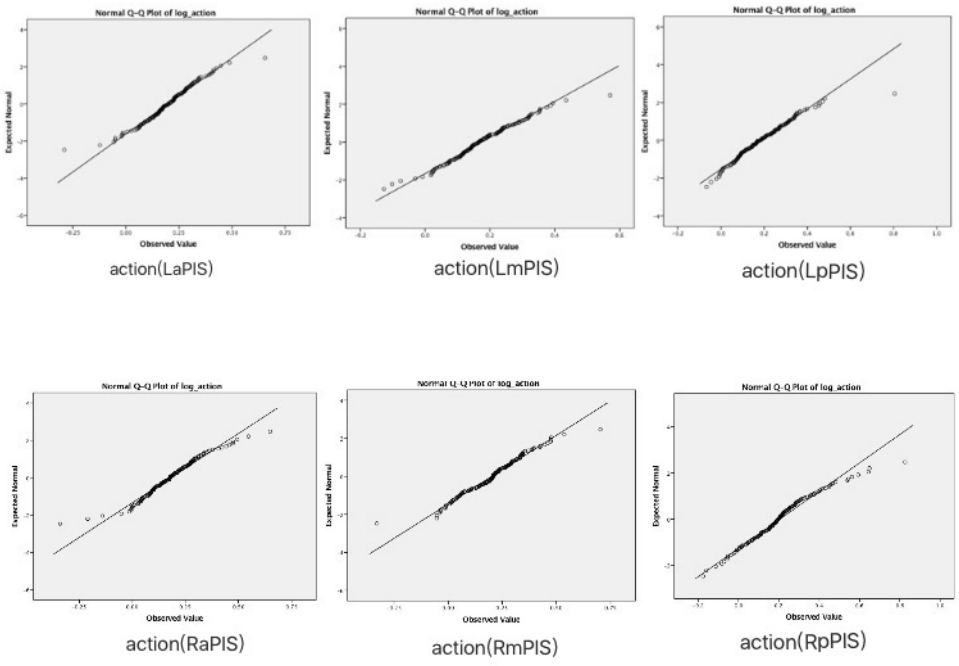


Figure 11: qq plots of log_action in 6 areas

Following the qq plots in the above, all the data of log_action in each area is normality,

even though the plots have few outliers. Because of the normality test, we change the dependent variable from action to log_action.

4.3 Equal Variance

According to the residual plots in 6 areas with dependent variable y=log_action, all the residual points in each plot are randomly distributed and fall in a symmetrical pattern around $residual = 0$, which means residuals normal distributed.

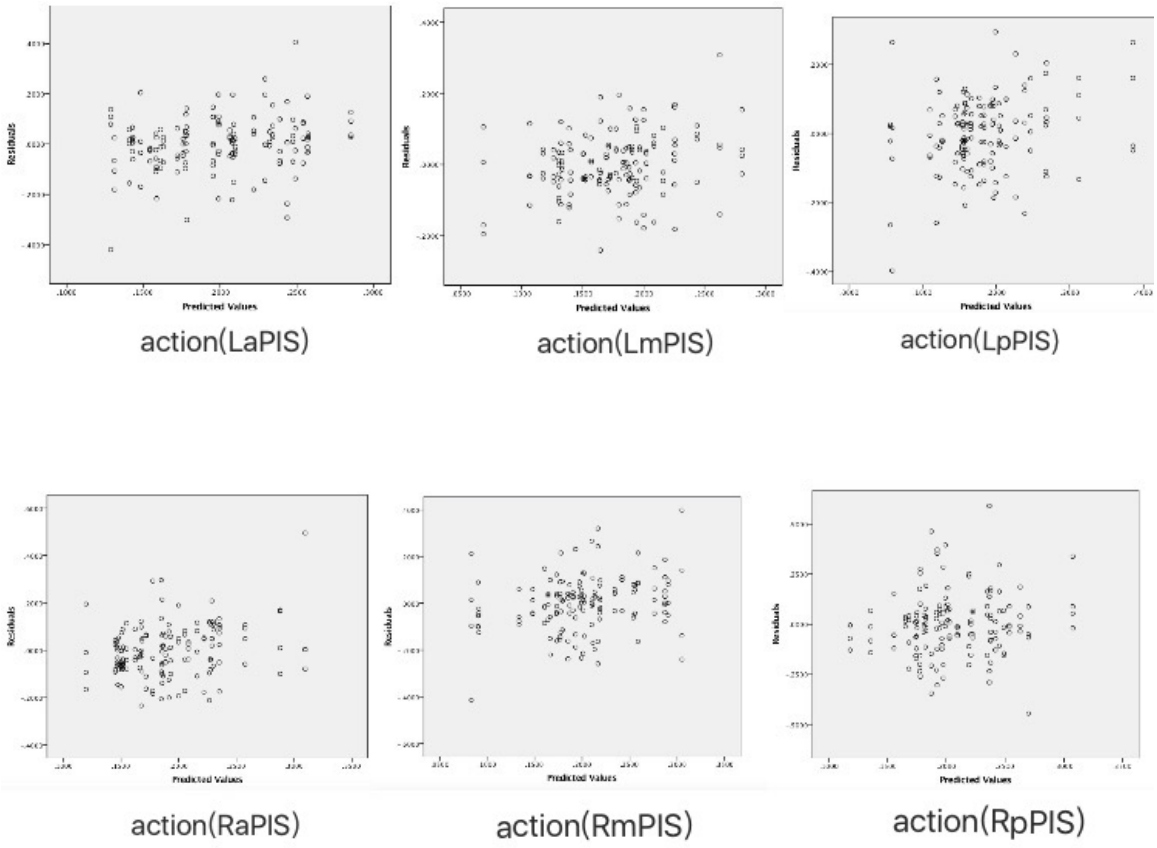


Figure 12: residual plots in 6 areas

4.4 Correlation Analyses

Correlations

		Age	VMI	VP	MC	WJIV_LW	WJIV_Spelling	WJIV_WordAttack	WJIV_SpellSounds
Age	Pearson Correlation	1	.890**	.800**	.738**	.770**	.930**	.758**	.882**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000
	N	148	148	148	148	148	148	148	148
VMI	Pearson Correlation	.890**	1	.774**	.857**	.765**	.853**	.794**	.852**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000
	N	148	148	148	148	148	148	148	148
VP	Pearson Correlation	.800**	.774**	1	.674**	.700**	.792**	.715**	.761**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000
	N	148	148	148	148	148	148	148	148
MC	Pearson Correlation	.738**	.857**	.674**	1	.584**	.683**	.606**	.701**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000
	N	148	148	148	148	148	148	148	148
WJIV_LW	Pearson Correlation	.770**	.765**	.700**	.584**	1	.891**	.956**	.902**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000
	N	148	148	148	148	148	148	148	148
WJIV_Spelling	Pearson Correlation	.930**	.853**	.792**	.683**	.891**	1	.875**	.951**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000
	N	148	148	148	148	148	148	148	148
WJIV_WordAttack	Pearson Correlation	.758**	.794**	.715**	.606**	.956**	.875**	1	.925**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000
	N	148	148	148	148	148	148	148	148
WJIV_SpellSounds	Pearson Correlation	.882**	.852**	.761**	.701**	.902**	.951**	.925**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	
	N	148	148	148	148	148	148	148	148

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 13: Correlation

The above table shows some high correlated variables in the model in every area. From example, the Pearson correlation between Age and WJIV_Spelling is 0.930, between WJIV_LW and WJIV_WordAttack is 0.956, and between WJIV_Spelling and WJIV_SpellSounds is 0.951.In addition, the correlation between WJIV_SpellSounds and WJIV_LW is 0.902, and between WJIV_WordAttack and WJIV_SpellSounds is 0.925.

5 Building model

5.1 LaPIS

According to the table in the below, most of variables (age, VIP, MC, WJIV_LW, WJIV_WordAttack, WJIV_Spelling and WJIV_SpellSounds) are not significant, In other words, only the variable VMI is significant in the linear mixed effect model in LaPIS.

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	28	278.151	.000
Age	1	28	.229	.636
VP	1	28	.061	.806
VMI	1	28	4.224	.049
MC	1	28	1.859	.184
WJIV_LW	1	28	1.360	.253
WJIV_WordAttack	1	28	.004	.952
WJIV_Spelling	1	28	.798	.379
WJIV_SpellSounds	1	28	.218	.644

a. Dependent Variable: log_action.

Figure 14: Coefficients table of original model

Following Statistics VIF values in the below table, only the value of VP and MC is smaller than 10, which the variable with highest VIF value need to be removed until all the VIF values are lower than 10.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	.637	.039		16.414	.000		
	Age	.124	.148	.255	.841	.402	.071	14.120
	VMI	-.331	.131	-.678	-2.534	.012	.091	10.989
	VP	-.050	.071	-.104	-.715	.476	.311	3.217
	MC	.147	.082	.301	1.788	.076	.230	4.340
	WJIV_LW	.147	.153	.301	.960	.339	.066	15.059
	WJIV_Spelling	-.216	.188	-.444	-1.148	.253	.044	22.898
	WJIV_WordAttack	.085	.182	.174	.465	.643	.047	21.488
	WJIV_SpellSounds	.059	.177	.121	.335	.738	.050	20.159

a. Dependent Variable: action

Figure 15: original LMM

After comparing VIF values several times, the final model contains variables in the below table.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	.637	.039		16.487	.000		
	Age	-.001	.096	-.001	-.007	.995	.167	6.004
	VMI	-.291	.120	-.597	-2.420	.017	.106	9.395
	VP	-.054	.069	-.110	-.781	.436	.327	3.057
	MC	.146	.078	.300	1.863	.065	.250	4.007
	WJIV_LW	.157	.066	.322	2.365	.019	.349	2.864

a. Dependent Variable: action

Figure 16: Coefficients table of changed model

The below table shows that the variables VMI and WJIV_ are significant in the changed linear mixed effect model in LaPIS.

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	31	299.262	.000
Age	1	31	.000	.995
VMI	1	31	4.924	.034
VP	1	31	.144	.707
MC	1	31	2.468	.126
WJIV_LW	1	31	4.772	.037

a. Dependent Variable: log_action.

Figure 17: changed LMM

5.2 LmPIS

To look at the below table, non of variable in the original linear mixed effect model in the LmIPS is significant.

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	28	248.625	.000
Age	1	28	.009	.925
VP	1	28	.009	.925
VMI	1	28	1.973	.171
MC	1	28	.007	.935
WJIV_LW	1	28	.126	.725
WJIV_WordAttack	1	28	.001	.976
WJIV_Spelling	1	28	.000	.986
WJIV_SpellSounds	1	28	.474	.497

a. Dependent Variable: log_action.

Figure 18: iCoefficients table of original mode

Following Statistics VIF values in the below table, only the value of VP and MC is smaller than 10.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	.541	.032		16.832	.000		
	Age	.080	.122	.199	.653	.515	.071	14.120
	VMI	-.207	.108	-.515	-1.918	.057	.091	10.989
	VP	-.008	.058	-.019	-.129	.898	.311	3.217
	MC	-.004	.068	-.011	-.066	.947	.230	4.340
	WJIV_LW	-.076	.126	-.189	-.602	.548	.066	15.059
	WJIV_Spelling	-.056	.156	-.139	-.359	.720	.044	22.898
	WJIV_WordAttack	.051	.151	.128	.340	.735	.047	21.488
	WJIV_SpellSounds	.126	.146	.314	.863	.390	.050	20.159

a. Dependent Variable: action

Figure 19: original LMM

After changing the model by comparing VIF values, the final model of LmPIS contains variables in the below table.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	.541	.032		16.901	.000		
	Age	.084	.079	.209	1.057	.292	.167	6.004
	VMI	-.183	.099	-.455	-1.838	.068	.106	9.395
	VP	-.006	.057	-.015	-.103	.918	.327	3.057
	MC	.001	.065	.003	.020	.984	.250	4.007
	WJIV_LW	.011	.055	.026	.193	.848	.349	2.864

a. Dependent Variable: action

Figure 20: Coefficients table of changed model

Then here is the linear mixed effect model after changing.

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	31	266.254	.000
Age	1	31	.365	.550
VMI	1	31	2.265	.142
VP	1	31	.012	.912
MC	1	31	.039	.844
WJIV_LW	1	31	.048	.829

a. Dependent Variable: log_action.

Figure 21: changed LMM