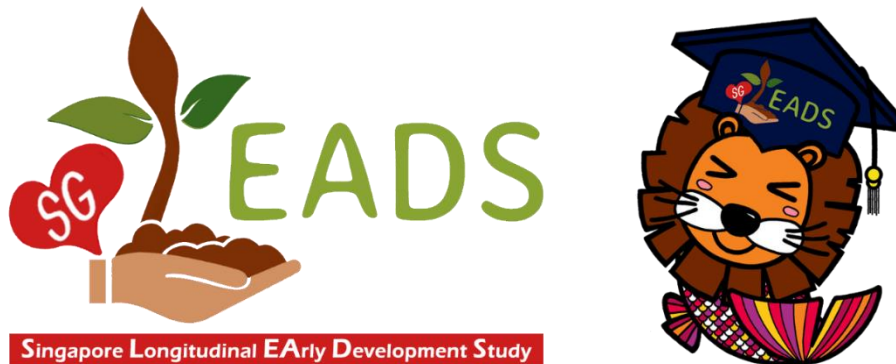


# Singapore Longitudinal Early Development Study (SG LEADS)



## Panel Survey Wave 1

### Technical Report 5

#### Norming of Woodcock-Johnson Test of Achievement IV in SG LEADS Wave 1

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This technical manual contains the procedure of norm development for the Woodcock-Johnson Test of Achievement fourth edition (WJ ACH IV, Form C) for a nationally representative sample of children in Singapore included in the Singapore Longitudinal and EARly Development Study (SG LEADS) conducted in 2018-2019 (Yeung et al, 2020). The current norm of WJ ACH IV is based on the US population, which may not be appropriate for Singaporean children. A Singapore norm based on the children of SG LEADS is constructed following the Woodcock-Johnson IV technical Manual (McGrew, LaForte and Schrank, 2014). This manual introduces the norming study sample and its representativeness, the processes of data collection and statistical methods used to develop the norm-based scores. A comparison of the Singapore norm and US norm is also provided.

### Demographic characteristics of the norming sample

The norming sample is the 3- to 6-year-olds who participated in the SG LEADS Wave 1 survey. SG LEADS is a nationally representative survey conducted in Singapore between November 2018 to September 2019. The survey adopted a multi-stage probability sampling — clustered and stratified sampling strategy. Data were collected from Singaporean children aged 7 and below across three broad dwelling types in 45 planning areas across five planning regions in Singapore. Sample weights are used to adjust the sampling distribution. The weighted distribution of the housing type, education, and ethnicity of the head of the household is close to the national statistics (refer to technical report 2 for details of sampling strategies and weighted distribution of the abovementioned demographic characteristics). Thus, the SG LEADS sample is an ample representation of the Singapore population aged under 7 across different groups.

The WJ Test was administered among 3- to 6- year-olds who could either speak or understand English. Four subsets have been administrated among the SG LEADS children: (1) Letter-Word Identification, (2) Passage Comprehension, (3) Applied Problems, and (4) Calculation. In total, 2,947 SG LEADS children participated in the WJ assessment. Table 1 shows the weighted distribution of the sample by gender, age and grade.

Table 1. Weighted distribution of the norming sample by gender, age and grade

	Unweighted n	Weighted %
<b>Gender</b>	2,947	
Boy	1,490	52.0%
Girl	1457	48.0%
<b>Age</b>	2,947	
3	785	26.6%
4	706	24.0%
5	723	24.5%
6	733	24.9%
<b>Child's grade</b>	2,946 <sup>a</sup>	
Nursery 1 (N1)	321	11.5%
Nursery 2 (N2)	690	24.1%
Kindergarten 1(K1)	684	23.0%
Kindergarten 2 (K2)	700	23.1%
Primary 1 (P1)	418	14.3%
Not in school	133	3.9%

<sup>a</sup> One missing value for the child’s grade

The WJ test was administered by trained professional interviewers. A weeklong in-person training was conducted for the interviewers with ample practice interviews simulating various interview scenarios. Interviewers who were assessed to be qualified for the fieldwork were deployed to participate in the SG LEADS survey (refer to the SG LEADS Panel Survey Wave 1 User Guide for a detailed description of interviewer recruitment and training). An assessment of the interviewer effect in the WJ assessment in SG LEADS reveals a small and acceptable interviewer effect (mostly lower than 10%) for each of the subtest (refer to technical report 11 for details).

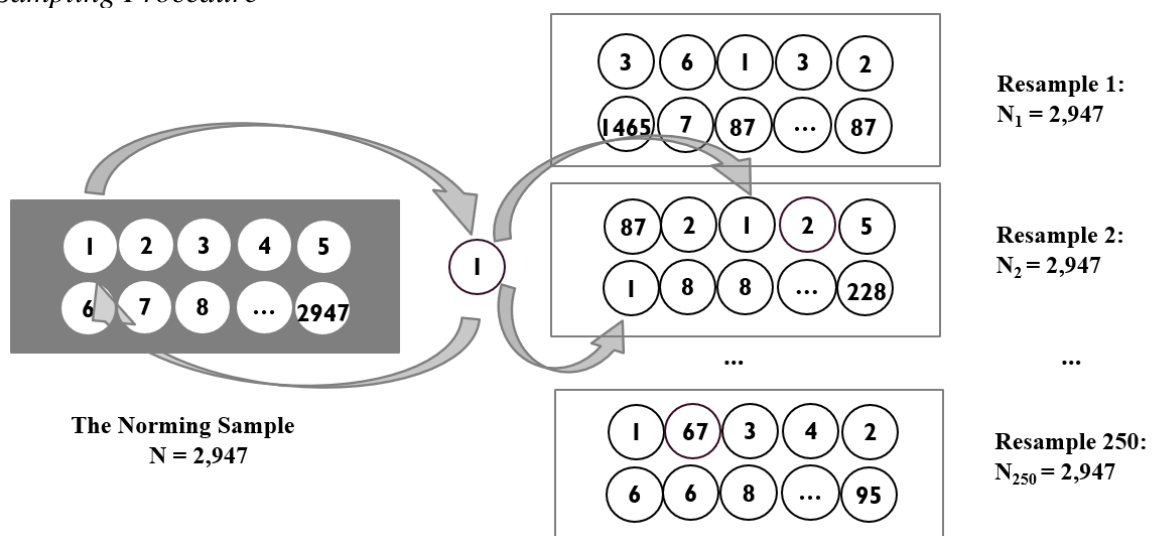
### Construction of the WJ IV Norms and Derived Scores

This section provides a step-by-step procedure of the construction of the WJ IV norms and the derivation of the norm-referenced test scores (e.g., standardized scores and percentile ranks), which allows for inferring the examinee’s relative standing in a representative sample of Singaporean children. We adopted the bootstrap-based procedure of norm construction used by McGrew, Dailey, and Schrank (2007) in constructing the norms for WJ III in the US.

#### Step 1 Bootstrap Sampling

The norming sample comprises 2,947 children in total. Their W-scores generated through the WJ Offline Solution were used. Two hundred and fifty resamples with the same number of children (i.e.,  $N = 2,947$ ) were selected with replacement from the norming sample. In the figure illustration, each child was represented as a ping-pong ball and was randomly selected from the box representing the norming sample (see Figure 1). Then the selected child’s age and test scores were recorded before being put back into the norming sample box. The selecting process was repeated for 2,947 times to produce a resample of the same size as the norming sample. The sampling procedure was repeated for 250 times to produce 250 resamples. Importantly, individual weights were incorporated in the sampling procedure in order to produce nationally representative resamples. The bootstrap-based sampling procedure was performed in R version 4.0.4 using the ‘boot’ package version 1.3.26.

**Figure 1**  
*Sampling Procedure*

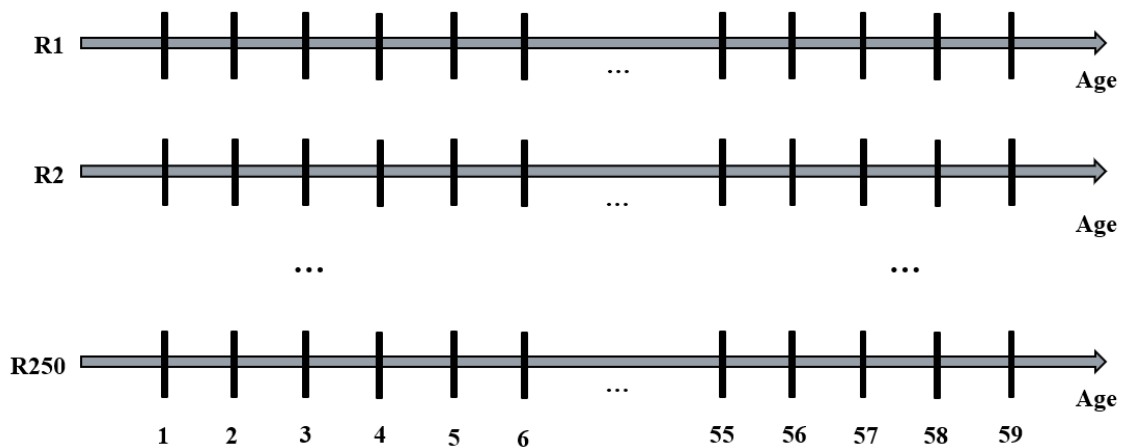


### Step 2 Retrieving Median Ages and Median Test Scores

At this step, the resamples were rearranged by the child's age in months from the youngest to the oldest for each of the 250 resamples. Each resample was separated into blocks of 50 subjects. This process is illustrated in Figure 2. The long arrows represent the age-sorted resamples and the sticks cut the 2,947 children into blocks of 50 subjects for the first 58 blocks and 47 subjects for the 59th block. Medians of the ages and the test scores for the blocks were retrieved, which resulted in 250 medians of the ages and 250 medians of the test scores for block 1 to block 59. Next, the first quartile and the third quartile of the medians for each block were retrieved, which generated the 50% confidence intervals for the median ages and median scores of each block.

**Figure 2**

*Constructing Age-Sorted Blocks for Each Bootstrap Resample*



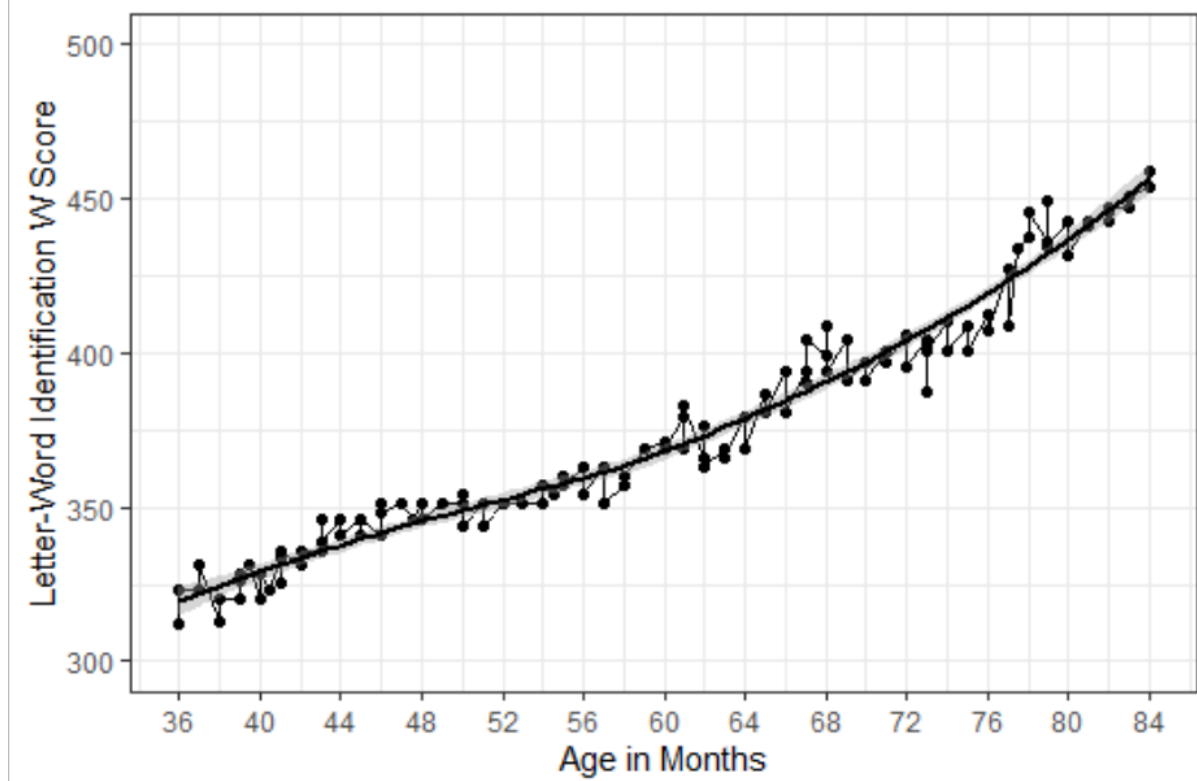
### Step 3 Fitting Norm Curves

The data points representing the first quartile and third quartile of the median age and test score were connected to constitute a confidence band. Then the confidence bands for each of the 59 blocks were connected and a smoothed curve was fitted to the connected bands using the loess curve fitting procedure. The norm curves for the WJ IV achievement tests were shown below (Figure 3 to Figure 8).

In our analysis, we found a floor effect for children aged 53 months and below in the Passage Comprehension Test and children aged 59 months and below in the Calculation Test. Therefore, we applied the norming procedure for Passage Comprehension Test for the sample of children of 54 months and above ( $n = 1,804$ ) and the norming for the Calculation Test to children of 60 months and above ( $n = 1,473$ ). The norming table and curve of the broad Reading score (a composite score of Letter-word Identification and Passage comprehension) and Mathematics score (a composite score of Applied problems and Calculation) generated by the WJ offline solution were created using the same process. While constructing the norms for the two broad Reading and Mathematics Tests, we only used the Reading score for children aged 54 months above and Mathematics score for those aged 60 months and above.

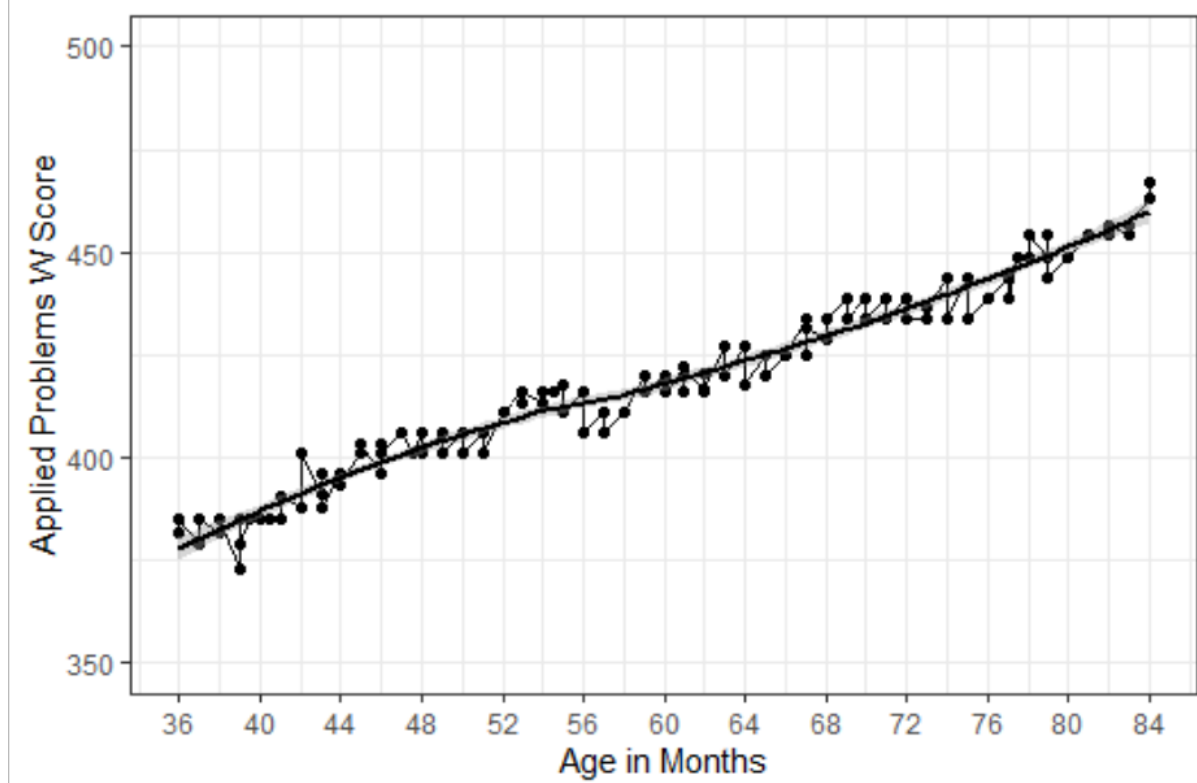
**Figure 3**

*Norm Curve for the WJ IV Achievement Test of Letter-Word Identification (36 – 84 Months)*

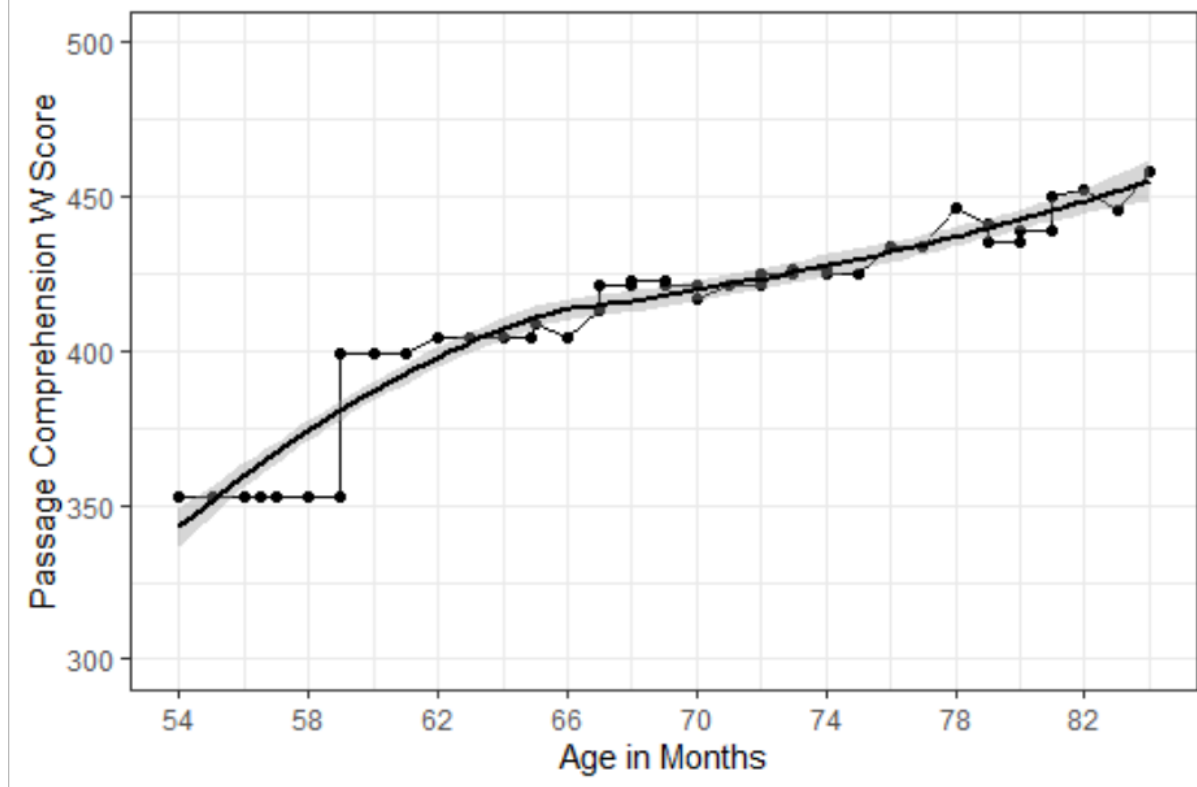


**Figure 4**

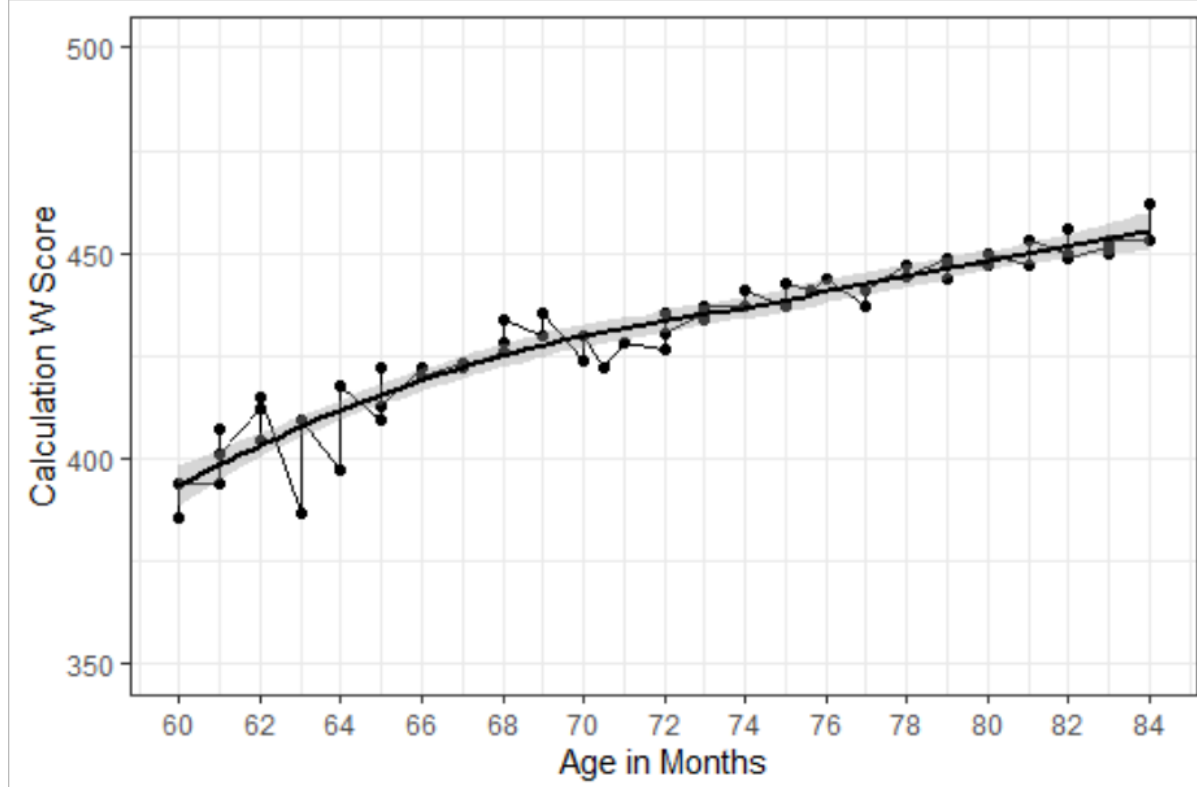
*Norm Curve for the WJ IV Achievement Test of Applied Problems (36 – 84 Months)*



**Figure 5**  
*Norm Curve for the WJ IV Achievement Test of Passage Comprehension (54 – 84 Months)*

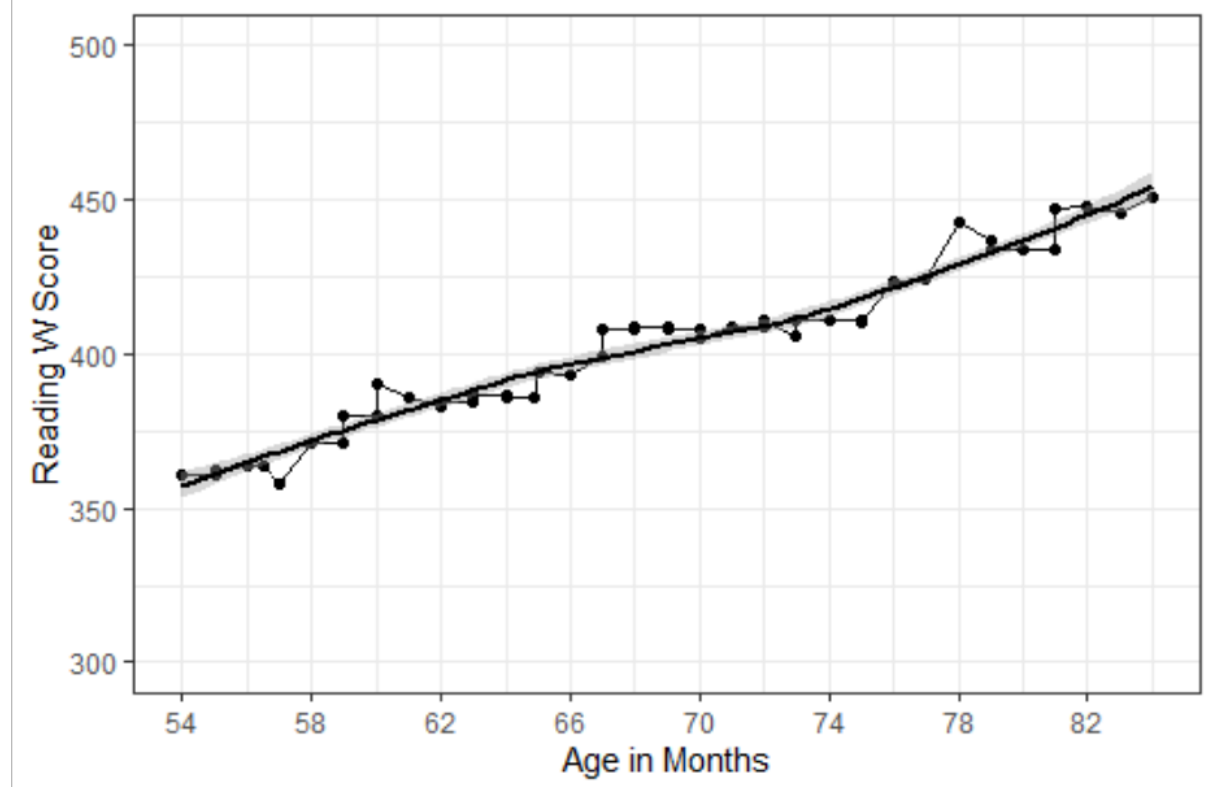


**Figure 6**  
*Norm Curve for the WJ IV Achievement Test of Calculation (60 – 84 Months)*



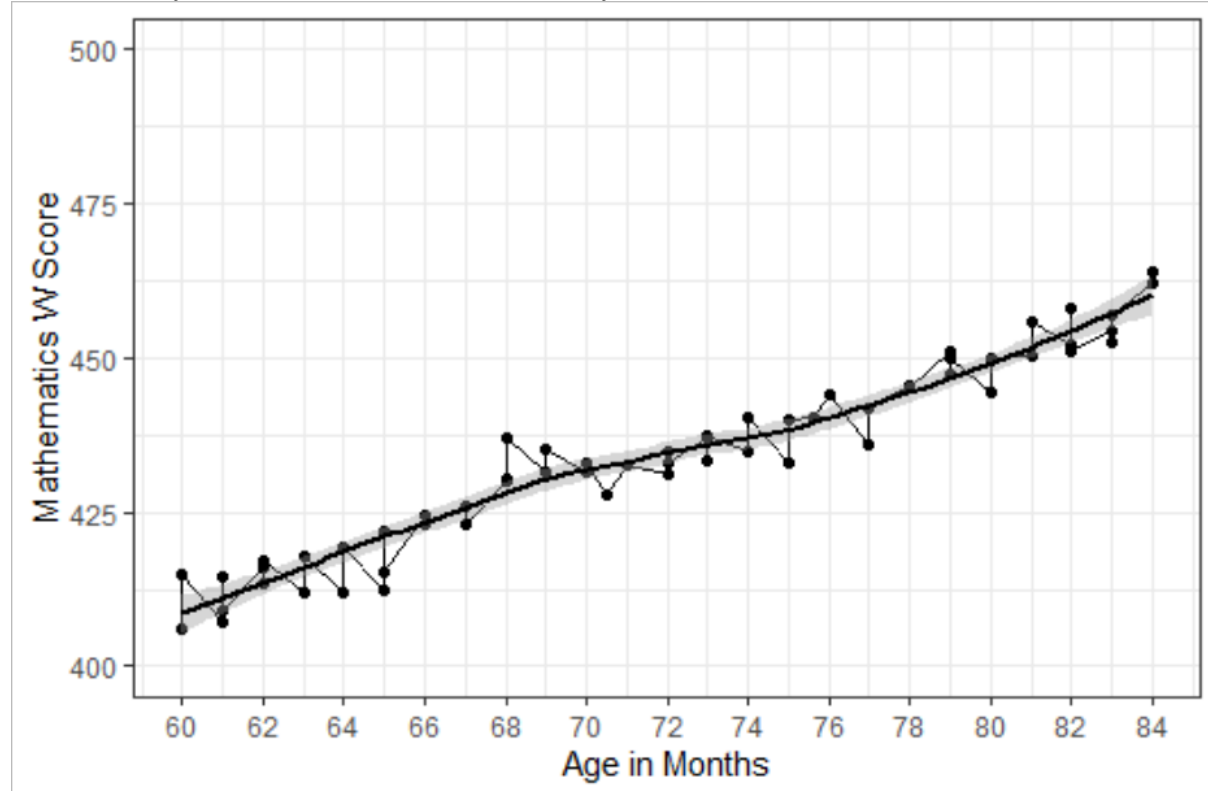
**Figure 7**

*Norm Curve for the WJ IV Achievement Test of Reading (54 – 84 Months)*



**Figure 8**

*Norm Curve for the WJ IV Achievement Test of Mathematics (60 – 84 Months)*



#### ***Step 4 Constructing Norm Tables***

At this step, norm tables with information of the age-equivalent reference scores and standard deviations were constructed (Table 2 to Table 7). Specifically, by drawing a vertical line from a specific age, the values on the y-axis of the intersection represented the age-equivalent reference scores (i.e., the average score for the Singaporean children of the same age). Standard deviations (SD) for each age group were generated through a bootstrap-based procedure which is the same procedure of constructing the normalized test scores, except that the SDs were calculated separately for the low-performers (i.e., performing below the median) and high-performers (i.e., performing above the median). In each of the 250 bootstrapped resamples, we used the scores below the median to calculate the SD low and the score above the median to calculate the SD high in each resample. Two distinct distributions of SD were generated, one for low performers and one for high performers. Then we fitted the curves for SD low and SD high separately with the 50% confidence interval of the SDs retrieved from the 250 resamples. After having the SD curves, we retrieved the age-equivalent SDs by finding the intersection between the curve and the vertical line representing a specific age. Calculating SDs separately for high and low performers is meant to capture the non-normal distribution of the test scores. As reflected in the norm tables (Table 2 – 7), high and low performers show different patterns of variances in scores.

#### **Application of the Norm Tables**

The norm tables can be used to calculate the percentile ranks to understand children's relative standing among his/her Singaporean peers. For example, let's assume Mike aged 40-month-old scored 351 in the WJ IV Achievement Test of Letter-Word Identification. Since Mike scored higher than the reference score for his age group (i.e., 329.10), the SD for high performers would be used to calculate Mike's percentile rank. First, the z-score (mean = 0, SD = 1) would be calculated by dividing the difference between Mike's test scores and the reference scores by the SD for high performers, which was  $(351-329.10) / 15.33 = 1.43$ . Then the calculated z-score was transformed into percentiles, which was 92% in Mike's case. This meant Mike performed higher than 91% of the children of his age in Singapore. The z-score can also be transformed into a conventional standardized score (mean = 100, SD = 15) using the function  $z * 15 + 100$ . The conventional standardized score for Mike will be 121.

The W-difference scores used to calculate the standardized scores such as the percentile ranks for the Reading and Mathematics Test were calculate by averaging the W-differences for their composite tests. For example, the W-difference score for the Reading Test is the average for the W-difference for the Letter-Word Identification Test and the W-difference for the Passage Comprehension Test. The W-difference score refers to the difference between the child's score and the norm-referenced score for the child's age group.



**Table 2***Norm Table for the WJ IV Achievement Test of Letter-Word Identification*

Age	Reference Score	SD for Low Performers	SD for High Performers
36	319.56	18.44	12.46
37	322.00	19.21	13.22
38	324.42	19.93	13.95
39	326.79	20.59	14.66
40	329.10	21.19	15.33
41	331.33	21.73	15.97
42	333.48	22.20	16.58
43	335.57	22.61	17.15
44	337.61	22.96	17.70
45	339.62	23.26	18.22
46	341.61	23.51	18.73
47	343.61	23.72	19.22
48	345.51	23.85	19.65
49	347.26	23.89	20.03
50	348.93	23.85	20.36
51	350.59	23.77	20.67
52	352.30	23.67	20.98
53	354.13	23.58	21.33
54	355.97	23.40	21.73
55	357.71	23.08	22.18
56	359.44	22.68	22.66
57	361.25	22.30	23.12
58	363.23	22.01	23.55
59	365.46	21.89	23.90
60	367.91	21.89	24.24
61	370.50	21.92	24.59
62	373.20	21.98	24.93
63	375.98	22.09	25.25
64	378.84	22.25	25.51
65	381.74	22.49	25.70
66	384.68	22.81	25.78
67	387.63	23.23	25.78
68	390.63	23.76	25.71
69	393.71	24.35	25.58
70	396.92	24.99	25.39
71	400.28	25.63	25.14
72	403.82	26.25	24.82
73	407.52	26.88	24.45
74	411.32	27.55	24.03
75	415.23	28.25	23.54

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**Table 2***Continued*

Age	Reference Score	SD for Low Performers	SD for High Performers
76	419.26	28.98	23.00
77	423.42	29.73	22.40
78	427.71	30.50	21.75
79	432.15	31.28	21.04
80	436.73	32.09	20.28
81	441.45	32.91	19.45
82	446.29	33.76	18.57
83	451.27	34.63	17.63
84	456.36	35.53	16.63

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**Table 3***Norm Table for the WJ IV Achievement Test of Applied Problems*

Age	Reference Score	SD for Low Performers	SD for High Performers
36	378.00	18.25	10.78
37	380.37	18.98	10.80
38	382.68	19.65	10.83
39	384.92	20.27	10.85
40	387.11	20.85	10.86
41	389.23	21.38	10.88
42	391.29	21.86	10.88
43	393.28	22.30	10.88
44	395.21	22.69	10.87
45	397.08	23.03	10.86
46	398.90	23.31	10.86
47	400.67	23.55	10.86
48	402.38	23.75	10.86
49	404.02	23.90	10.84
50	405.59	24.01	10.82
51	407.11	24.07	10.80
52	408.58	24.07	10.79
53	410.00	24.00	10.80
54	411.28	23.79	10.81
55	412.36	23.40	10.81
56	413.34	22.92	10.81
57	414.31	22.41	10.82
58	415.36	21.96	10.85
59	416.59	21.64	10.92
60	417.95	21.36	11.05
61	419.34	20.99	11.24
62	420.75	20.60	11.46
63	422.18	20.22	11.70
64	423.63	19.91	11.93
65	425.10	19.70	12.13
66	426.59	19.65	12.28
67	428.10	19.77	12.40
68	429.63	19.99	12.51
69	431.18	20.30	12.62
70	432.76	20.65	12.70
71	434.40	21.01	12.76
72	436.10	21.35	12.77
73	437.85	21.68	12.75
74	439.64	22.07	12.72
75	441.47	22.49	12.66

**Table 3***Continued*

Age	Reference Score	SD for Low Performers	SD for High Performers
76	443.34	22.95	12.58
77	445.25	23.43	12.48
78	447.20	23.94	12.35
79	449.20	24.47	12.20
80	451.23	25.03	12.03
81	453.31	25.60	11.83
82	455.43	26.21	11.61
83	457.59	26.85	11.37
84	459.79	27.52	11.10

**Table 4***Norm Table for the WJ IV Achievement Test of Passage Comprehension*

Age	Reference Score	SD for Low Performers	SD for High Performers
54	342.74	8.03	22.24
55	351.33	11.68	21.09
56	359.43	15.04	20.03
57	367.05	18.08	19.06
58	374.16	20.81	18.18
59	380.77	23.22	17.40
60	386.90	25.36	16.69
61	392.57	27.24	16.06
62	397.86	28.79	15.51
63	402.75	29.97	15.06
64	407.11	30.87	14.70
65	410.81	31.61	14.43
66	413.36	32.11	14.31
67	414.87	32.33	14.34
68	416.08	32.44	14.40
69	417.75	32.60	14.38
70	419.76	32.80	14.33
71	421.59	32.94	14.32
72	423.42	33.00	14.29
73	425.42	32.96	14.15
74	427.56	32.76	13.90
75	429.74	32.44	13.57
76	432.02	32.14	13.20
77	434.46	32.00	12.83
78	437.04	31.99	12.46
79	439.73	31.99	12.05
80	442.55	32.06	11.62
81	445.51	32.19	11.16
82	448.59	32.39	10.68
83	451.79	32.63	10.17
84	455.11	32.93	9.63

**Table 5***Norm Table for the WJ IV Achievement Test of Calculation*

Age	Reference Score	SD for Low Performers	SD for High Performers
60	393.46	5.26	17.54
61	398.55	7.71	16.03
62	403.33	10.05	14.74
63	407.78	12.24	13.61
64	411.86	14.28	12.69
65	415.59	16.16	11.94
66	419.03	17.88	11.31
67	422.19	19.52	10.94
68	425.07	21.09	10.83
69	427.69	22.42	10.69
70	429.81	23.37	10.44
71	431.51	24.02	10.19
72	433.28	24.55	10.02
73	435.10	24.89	9.88
74	436.78	24.98	9.75
75	438.59	25.04	9.72
76	440.56	25.14	9.94
77	442.54	25.15	10.27
78	444.45	24.92	10.43
79	446.30	24.44	10.42
80	448.12	23.78	10.37
81	449.91	22.92	10.22
82	451.68	21.85	9.94
83	453.43	20.57	9.57
84	455.16	19.09	9.10

**Table 6***Norm Table for the WJ IV Achievement Test of Reading*

Age	Reference Score	SD for Low Performers	SD for High Performers
54	357.49	19.87	20.65
55	361.19	19.85	20.55
56	364.81	19.90	20.44
57	368.36	20.00	20.33
58	371.85	20.18	20.19
59	375.27	20.44	20.04
60	378.61	20.78	19.90
61	381.87	21.18	19.76
62	385.10	21.65	19.59
63	388.32	22.18	19.36
64	391.42	22.76	19.14
65	394.31	23.36	18.99
66	396.79	24.10	19.01
67	398.90	25.00	19.18
68	400.92	25.88	19.36
69	403.14	26.60	19.42
70	405.28	27.17	19.51
71	407.14	27.71	19.72
72	409.09	28.18	19.87
73	411.54	28.54	19.78
74	414.57	28.79	19.40
75	417.94	28.96	18.86
76	421.50	29.13	18.21
77	425.10	29.38	17.50
78	428.78	29.68	16.74
79	432.64	29.98	15.86
80	436.67	30.31	14.90
81	440.83	30.67	13.85
82	445.13	31.05	12.72
83	449.57	31.45	11.50
84	454.17	31.86	10.19

**Table 7***Norm Table for the WJ IV Achievement Test of Mathematics*

Age	Reference Score	SD for Low Performers	SD for High Performers
60	408.47	13.85	10.80
61	411.02	13.99	10.94
62	413.58	14.28	11.06
63	416.09	14.66	11.15
64	418.56	15.14	11.22
65	420.99	15.71	11.25
66	423.31	16.29	11.25
67	425.70	17.06	11.24
68	428.15	18.03	11.22
69	430.34	18.88	11.14
70	431.96	19.47	10.85
71	433.23	19.90	10.46
72	434.63	20.28	10.21
73	435.93	20.37	10.10
74	436.97	20.17	10.00
75	438.35	20.14	9.98
76	440.23	20.58	10.10
77	442.29	21.11	10.31
78	444.44	21.28	10.39
79	446.70	21.09	10.35
80	449.11	20.77	10.29
81	451.67	20.26	10.14
82	454.38	19.52	9.88
83	457.22	18.57	9.55
84	460.21	17.44	9.15

**Use of WJ SG normed scores in analysis**

In data analysis, we recommend using Singapore-normed zscore and standardized score which represent children's relative standing compared with their Singaporean peers in the same age group. Below is an example of how to interpret the scores. Table 8 presents the weighted regression of children's gender on their Letter-word identification Singapore-normed scores. The variable boy is a dummy variable with 1=boy, and 0=girl. The coefficient of boy is 0.0733 (non-significant), which means boys are 0.07 of a SD higher than girls in Letter-word identification. For standardized scores, the coefficient of boy is 1.099 (non-significant), which means boys are 1.1 points higher than girls in their Letter-word identification standardized scores.

**Table 8. Weighted regression on Letter-word scores**

VARIABLES	Letter-word Identification SG-normed zscore	Letter-word Identification SG-normed standardized score
Boy (1=yes)	0.0733 (0.062)	1.099 (0.924)



Constant	-0.0172 (0.045)	99.74*** (0.667)
Observations	2,947	2,947
R-squared	0	0

### Caution when using the broad Reading and Mathematics scores

We have generated broad Reading and Mathematics scores. As suggested by Woodcock-Johnson Test of Achievement IV development team, data users should not report and interpret the broad score of children who have answered none of the questions correctly in all the subtests of that broad score. For example, we should not interpret the broad Reading score if the child has no correct answer in both Letter-word identification test (wscore=268) and Passage comprehension test (wscore=293) (33 children who are aged 54 months and above). We should not interpret the broad Mathematic score if the child has no correct answer in both Applied-problems test (wscore=324) and Calculation test (wscore=369) (20 children who are 60 months and above). Having no correct answers in the abovementioned subtests doesn't mean the child has very low achievement in other aspects of reading and mathematics skills that are not covered in the subtests. Reporting that the child has a zero Reading or Mathematics raw score may be misleading. Thus, we suggest not to report and use the broad Reading and Mathematics scores when the child have a raw score of zero in all subsets of a broad score.

### Comparison between the SG norms and the US norms

In order to understand how Singaporean children perform reading and mathematics achievement tests differently as compared to their US counterparts, Singaporean children's percentiles on the four tests on the US national representative norming sample against their percentiles on the Singapore national representative norming sample were plotted (Figure 9 to Figure 14). The US percentiles were exported from the WJ Offline Solution and the Singapore percentiles were generated using the norm tables constructed in the earlier steps. In each of the four comparison plots, a red-dashed line is plotted. Dots above the red line represent that children's percentiles on the US norming sample are higher than their percentiles on the Singapore norming sample, which suggests that children in the Singapore norming sample perform better than the children in the US norming sample; and vice versa.

#### Letter-Word Identification:

The plot suggests that low performers of Singaporean children performed better than low performers of the US children, while high performers of Singaporean children performed worse than high performers of the US children.

#### Applied Problems:

The plot suggests that Singaporean children performed worse than the US children and the gap is bigger for high performers.

#### Passage Comprehension:

Cautions need to be taken when interpreting the results for four-year-olds because larger discrepancy is observed between percentiles calculated based on SG norm and the percentiles generated from WJ offline solution. The reason could be that the small variance in the Passage Comprehension scores for children aged 54 to 58 months may affect the accuracy of the SG-norms for that age group. The plots suggests that lower performers of Singaporean

children performed better than lower performers of the US children, while high performers of Singaporean children performed worse than higher performers of the US children.

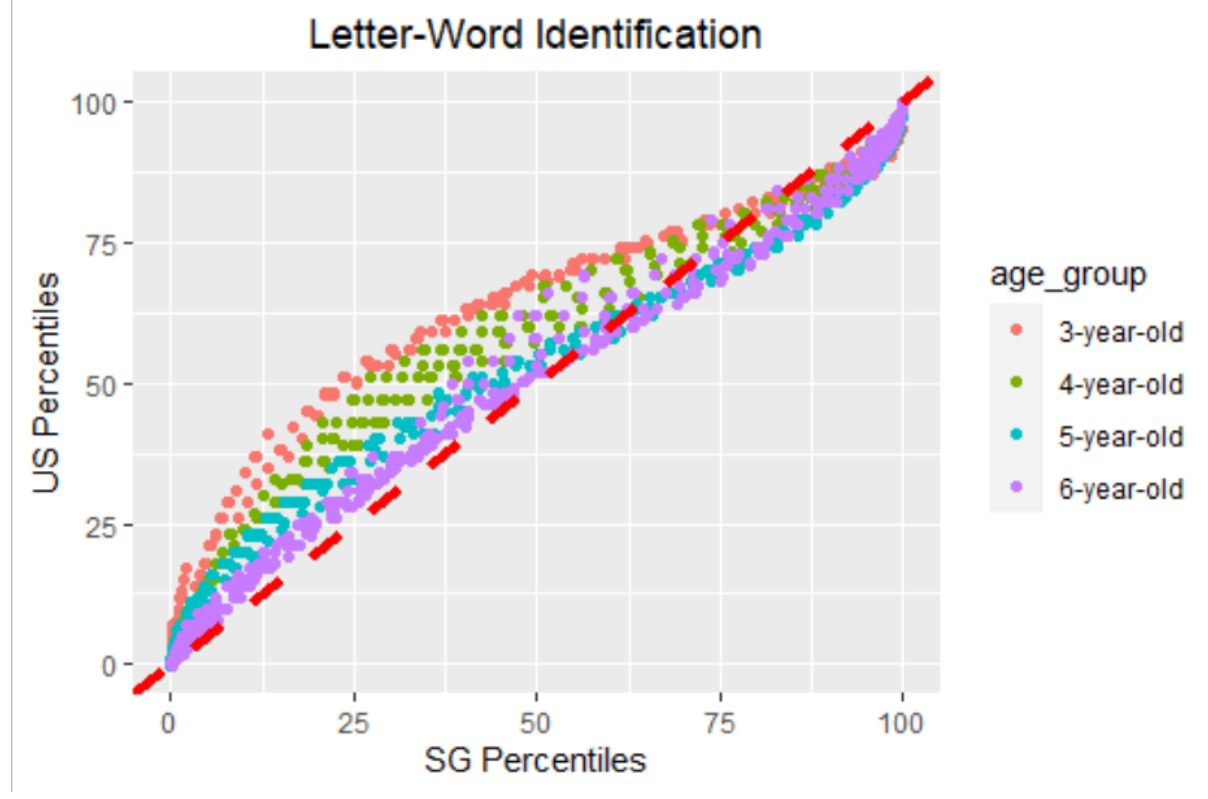
**Calculation:**

The plot suggests that Singaporean children performed better than the US children at the lower 80% of the sample. But for children ranked above 80% in the Singaporean sample, it seems that they performed poorer than their US counterparts.

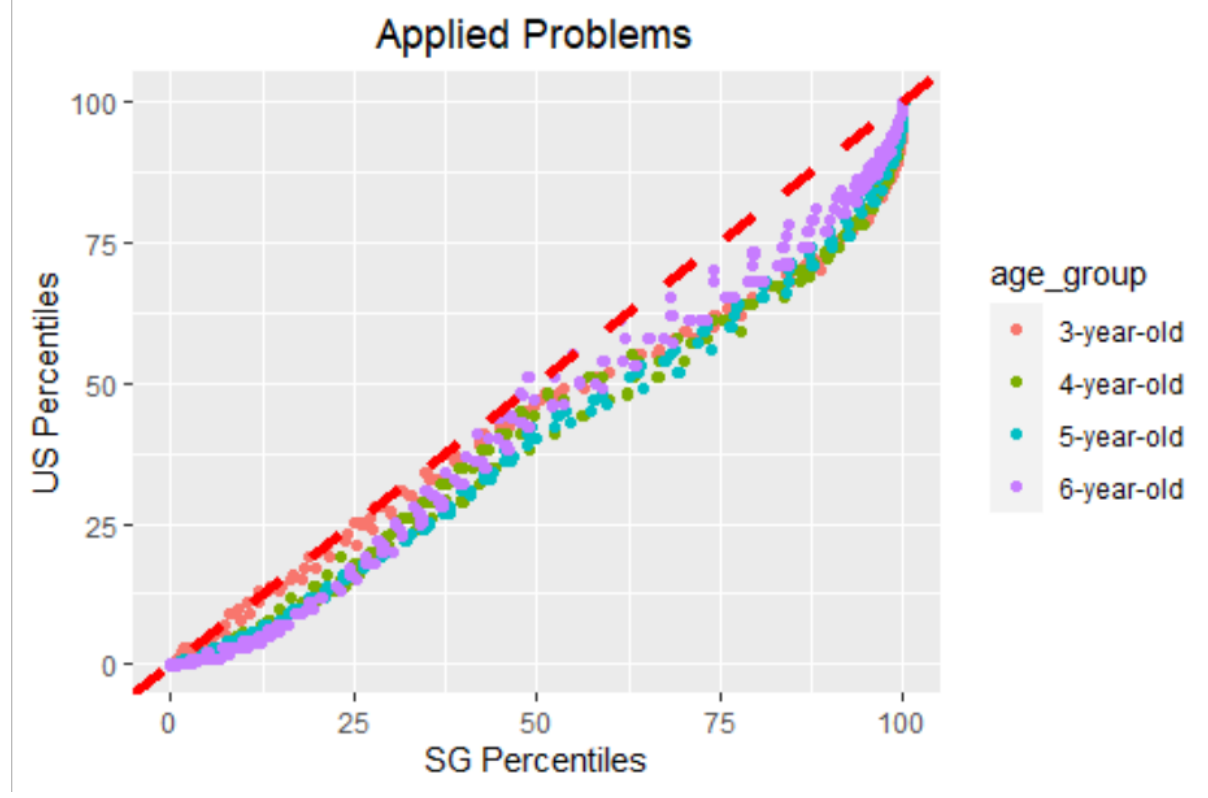
**Reading and Mathematics:**

The plots suggests that low performers of Singaporean children performed better than their US counterparts, while high performers of Singaporean children performed worse than higher performers of the US children.

**Figure 9**  
*Norm Comparison Between Singapore and the US – Letter-Word Identification*

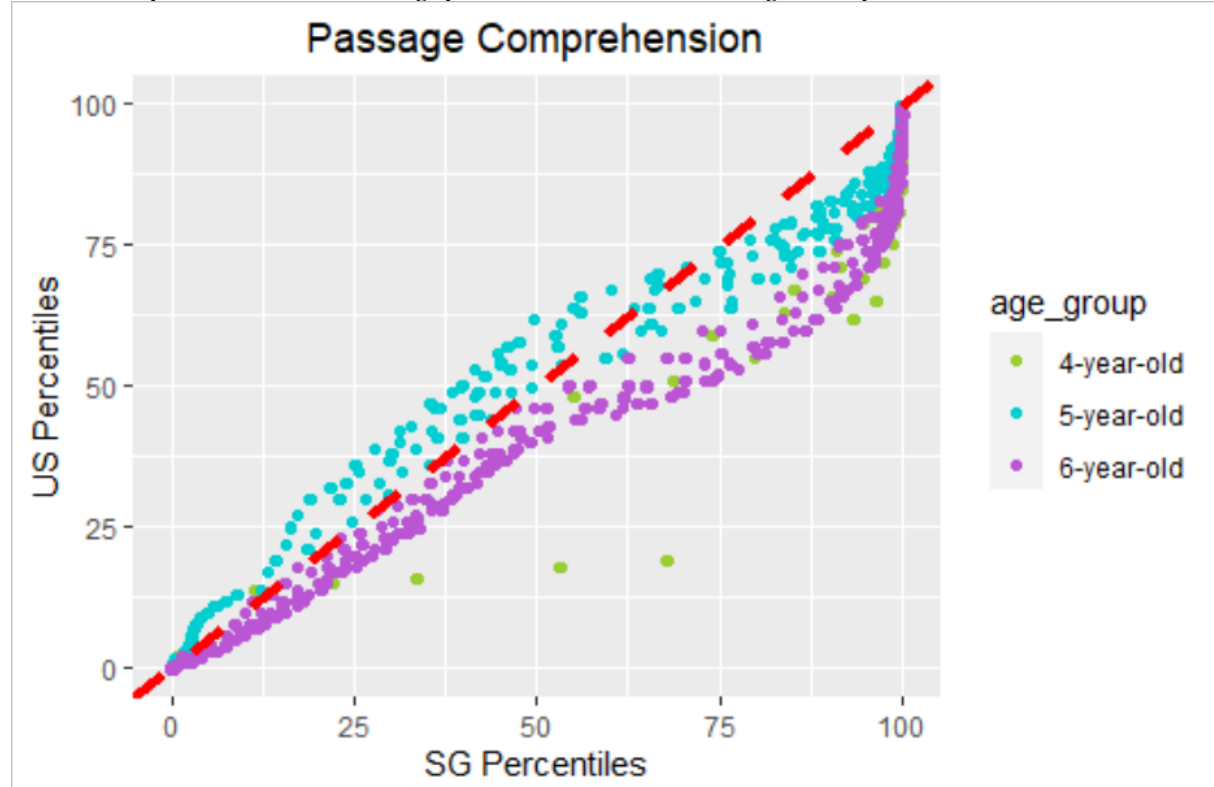


**Figure 10**  
*Norm Comparison Between Singapore and the US – Applied Problems*



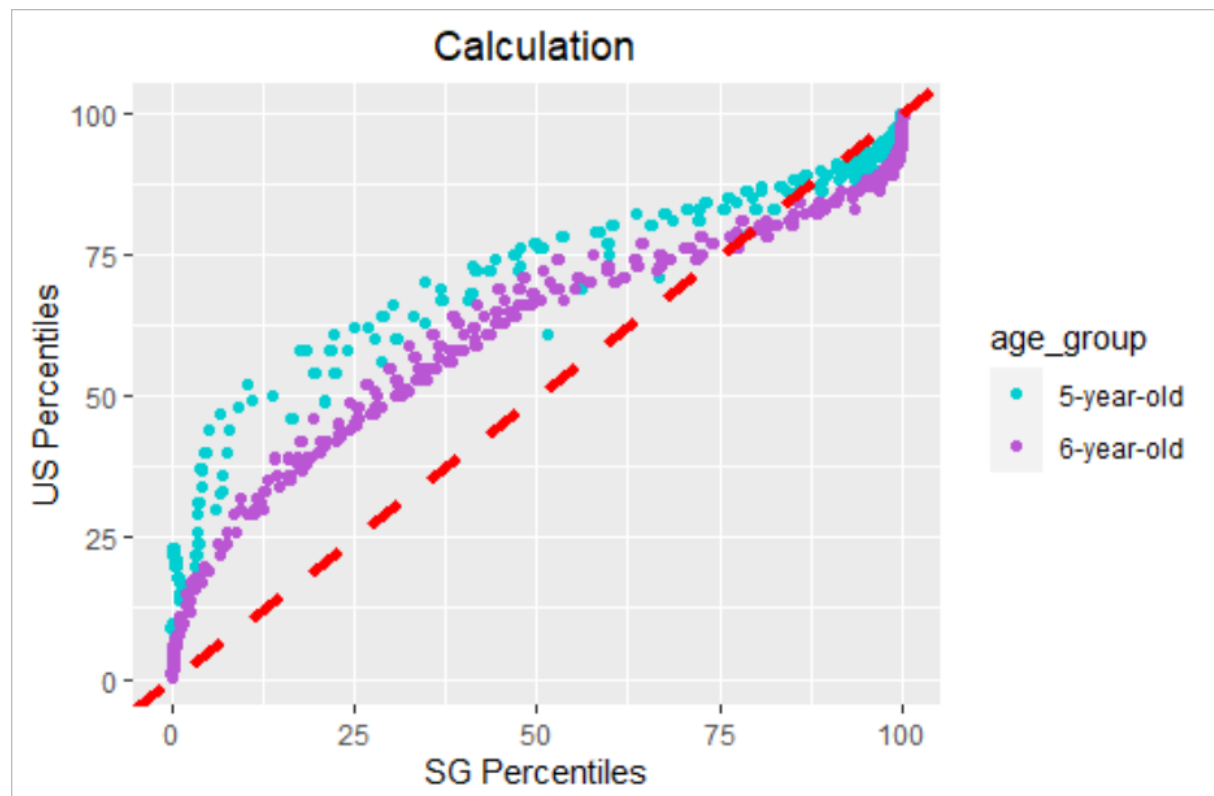
**Figure 11**

*Norm Comparison Between Singapore and the US – Passage Comprehension*

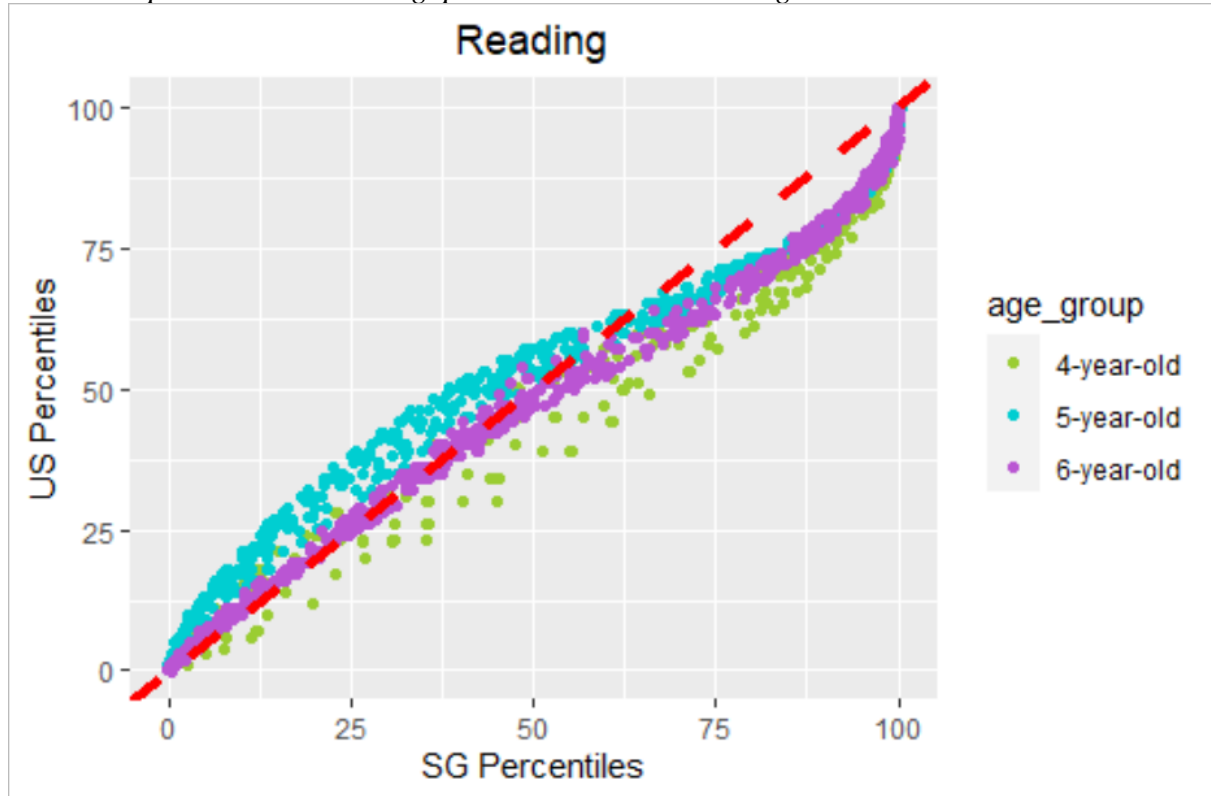


**Figure 12**

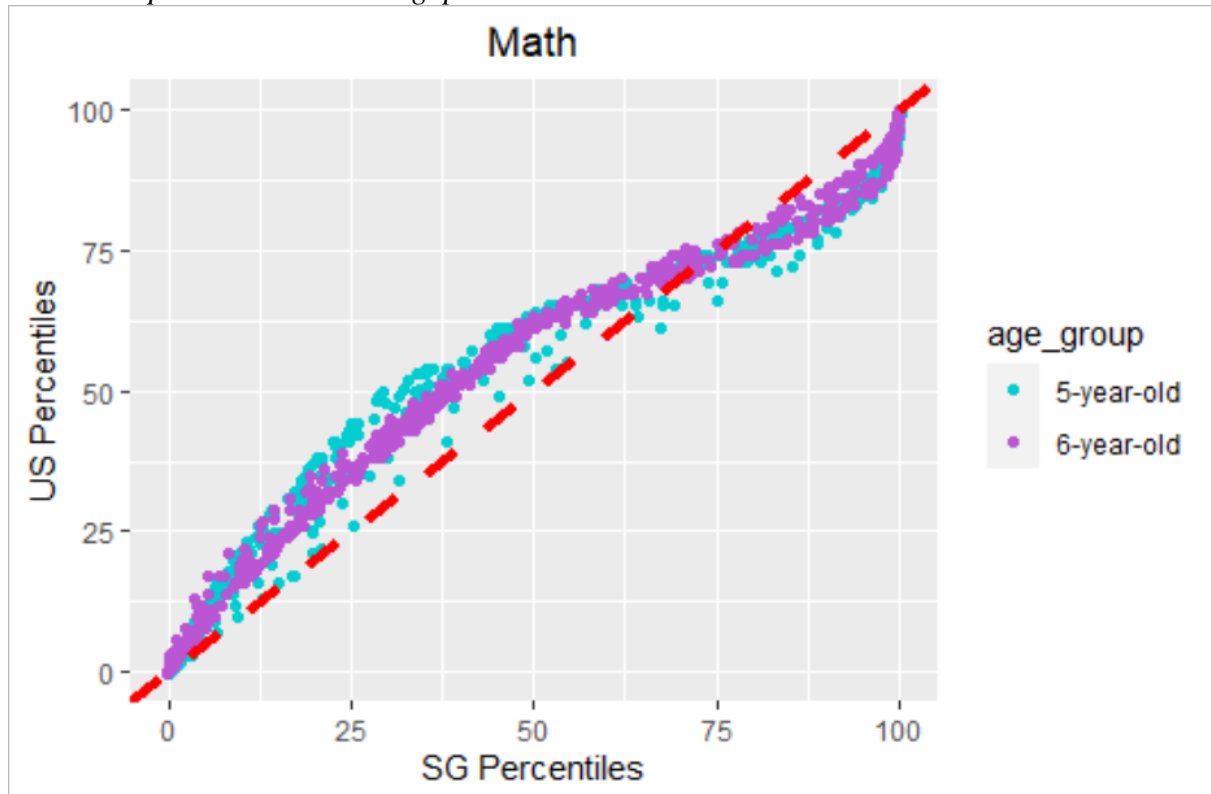
*Norm Comparison Between Singapore and the US – Calculation*



**Figure 13**  
*Norm Comparison Between Singapore and the US – Reading*



**Figure 14**  
*Norm Comparison Between Singapore and the US – Math*



## Reference

- McGrew, K. S., LaForte, E. M., & Schrank, F. A. (2014). Technical manual: Woodcock-Johnson IV. Rolling Meadows, IL: Riverside.
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