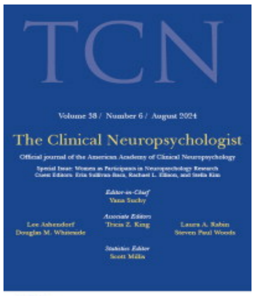

The Clinical Neuropsychologist

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ntcn20

Age-stratified norms for Raven's standard progressive matrices for Sri Lankan adults

Tharaka L. Dassanayake, Dewasmika I. Ariyasinghe, Anuradha Baminiwatta & Chandana Hewawasam

THE CLINICAL NEUROPSYCHOLOGIST
https://doi.org/10.1080/13854046.2024.2370908

Age-stratified norms for Raven's standard progressive matrices for Sri Lankan adults

Tharaka L. Dassanayake[a], Dewasmika I. Ariyasinghe[b], Anuradha Baminiwatta[c] and Chandana Hewawasam[d]

[a]Department of Physiology, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka; [b]Department of Physiology, Faculty of Medicine and Allied Health Sciences, Rajarata University of Sri Lanka, Saliyapura, Sri Lanka; [c]Department of Psychiatry, Faculty of Medicine, University of Kelaniya, Ragama, Sri Lanka; [d]Department of Psychiatry, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka

ABSTRACT

Objective: The aim of this study was to create age-stratified norms for the Raven's Standard Progressive Matrices (SPM) for Sri Lankan adults.

Methods: A sample of 610 adults (age: 18–72 years; education: 1–19 years), underwent the 60-item version of the SPM under individual supervision of a test administrator. The sample was stratified into 5-year age bands, and the norms are presented as percentile tables and percentile curves.

Results: The age-related changes were more accurately predicted by a curvilinear model (overall R^2 = 0.961) than a linear regression model (R^2 = 0.639). The SPM norms are presented as age-stratified percentile tables, as well as sex-, age- and education-adjusted multiple regression equations. The highest percentiles in the younger end of the age spectrum showed a ceiling effect. In the context of age-stratified US (1993) and British (1992) norms, older individuals in the Sri Lankan sample scored much lower than their Western counterparts. However, the difference narrowed in the younger age bands, showing no difference among the 18-to-22-year age bands in the three countries.

Conclusions: This age-by-country interaction can be partly explained by poorer education in the older individuals in the present sample compared to those in the US and UK standardization samples. SPM norms presented in this paper fill a hiatus in assessment of general intellectual ability in Sri Lankan adults. Given that Sri Lanka improves its educational, socioeconomic and health standards faster than the nations who have already reached higher standards, these norms would require re-standardization in the coming decades.

Abbreviations: RPM: Raven's Progressive Matrices; SPM: Standard Progressive Matrices; WAIS: Wechsler Adult Intelligence Scale

ARTICLE HISTORY
Received 21 February 2024
Accepted 18 June 2024
Published online 27 June 2024

KEYWORDS
Raven's progressive matrices; standard progressive matrices; intelligence; norms; Sri Lanka adults

CONTACT Tharaka Lagath Dassanayake tharaka.dassanayake@med.pdn.ac.lk Department of Physiology, Faculty of Medicine, University of Peradeniya, Peradeniya 20400, Sri Lanka.

Introduction

Raven's Progressive Matrices (RPM) is a test of fluid intelligence (Raven, 1941). It specifically taps into the educative component of general intelligence, i.e. ability to form novel, largely non-verbal schemata that enable the individual to handle complexity of a problem and thus think clearly (Raven, 2000). The standard adult version, Standard Progressive Matrices (SPM), consists of a pattern or a matrix of figures with the last component missing. The subjects have to use the eductive ability and choose the missing part/design from 6 or 8 options printed beneath each set to complete the matrix. The SPM consist of 60 such matrices in five sections (A–E), with increasing difficulty. The raw score (out of 60) is used as a measure of general cognitive ability. The language-independent, intuitive, abstract, visuospatial nature of SPM makes it less susceptible to cultural biases (Raven, 2000), although the test is not culture-free (Gonthier, 2022). SPM scores correlate well with Wechsler Adult Intelligence Scale (WAIS) IQ scores (Bingham et al., 1966; O'Leary et al., 1991; Sinha, 1951).

Two widely cited adult SPM standardization samples originate from the UK (1992; from Dumfries, Scotland) and the US (1993, from Des Moines, Iowa) (Raven, 2000; Raven et al., 2004). Both studies used the same methods of data collection and presentation of norms: as percentiles for 5-year age bands. The samples were recruited from one locality in each country; however, the demographic structure of each sample was representative of the national statistics. It is customary to tabulate the percentile scores of newer standardization samples of other countries against the corresponding percentiles of these British and US norms (Raven et al., 2004). The RPM norms for healthy community-living adults in different countries have been extensively published, and meticulously reviewed (see Brouwers et al., 2009; Wongupparaj et al., 2015, 2023 for reviews). In the most recent systematic review, Wongupparaj et al. (2023) cite 431 independent studies in 1038 independent samples from 71 different countries that included a total of around 270,000 participants. The majority of those studies were conducted in children and adolescents. Three-hundred-and-two samples (consisting a total of around 45,000 participants) consisted of adults 20 years or older. Differences of normative scores across countries and increasing average SPM scores with time (the Flynn effect) have been now widely documented (Brouwers et al., 2009; Daley et al., 2003; Flynn, 2009; Raven, 2000; Wongupparaj et al., 2015). Two recent meta-analyses indicate that this Flynn effect is most prominent in middle-income countries (Brouwers et al., 2009; Wongupparaj et al., 2023). The Flynn effect was minimal in high-income countries. Interestingly, a reverse Flynn effect in measures of intelligence has been reported in the last decade or two in some high-income countries (Dutton et al., 2016; Dworak et al., 2023). Overall, global trends highlight the need for new standardized norms especially for developing countries, including Sri Lanka (a lower-middle-income country), where the secular trends are most prominent.

Although Sri Lankan norms are available for some cognitive screening tests (De Silva et al., 2009; Srinivasan, 2010; Suraweera et al., 2016; Suriyakumara et al., 2019) and neuropsychological tests of specific cognitive domains (Dassanayake & Ariyasinghe, 2019; Dassanayake, Baminiwatta, et al., 2021; Dassanayake, Hewawasam, et al., 2021; Dassanayake et al., 2020; Srinivasan & Jaleel, 2015), there are no validated general intelligence tests for Sri Lankan adults. Some items in the IQ tests like WAIS need to be significantly modified to make the test culturally valid for Sri Lanka, whereas simpler tests like National Adults Reading Test cannot be adapted to the native languages spoken in Sri Lanka (Sinhala and Tamil) because the vocabularies of both languages are phonetically regular. In contrast, the intuitive, educative nature of the SPM minimized the dependence of the test performance on language. In this context, the aim of the present study was to create age-stratified norms for the SPM for Sri Lankan adults.

Methods

Participants

SPM data were collected as a part of a larger study that generated norms for a number of other neuropsychological tests for Sri Lankan adults (Dassanayake, Hewawasam, et al., 2021; Dassanayake et al., 2020). The study was conducted at the Faculty of Medicine, University of Peradeniya, located in the Central Province; and the Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Anuradhapura, located in the North Central Province of the country. The study was conducted according to the Declaration of Helsinki (World Medical Association, 2013), with the approval of the respective institutional ethics review committees. Potential participants (18 years or older) were recruited from February 2017 to September 2021, through word-of-mouth and flyers and posters displayed within the respective universities, the university-affiliated tertiary-care Teaching Hospitals (Peradeniya and Anuradhapura), and the surrounding localities. The participants thus also included the employees of the universities and the hospitals (who were originally from various parts of the country), their acquaintances, and the visitors and the persons accompanying the patients referred to the tertiary-care centers from different parts of the country. Informed written consent was obtained from all participants. Each participant was compensated with 500 Sri Lankan Rupees (equivalent to about 3 US dollars at the time of the data collection) for the time they spent on the study.

We excluded the respondents who had a history of neurological or psychiatric illnesses, dependence on alcohol or other substances, gross uncorrected visual impairment or severe/terminal medical illnesses. All included participants were able to carry out activities of daily living independently. However, we did not exclude the individuals who had medical conditions that do not affect their general functionality or cognitive performance: We envisaged that such exclusions would make the sample overly healthy, thus limiting the generalizability of the norms to the adult population in general (Strauss et al., 2006).

The years of schooling, post-schooling diplomas, and graduate and postgraduate education were summed to count the total years of formal education. Part-time courses were converted to full-time equivalents before aggregating. Except two participants who did not have any schooling, the duration of education of the sample ranged between 1 and 19 years. We have described the formal education setting in Sri Lanka in more detail in a recent paper (Dassanayake & Ariyasinghe, 2019). As of 2019, out of a total around 4.4 million students, around 4.06 million (92%) were in government schools, 138,000 (3%) in private schools (that follow the local academic curriculum) and 140,000 (3%) in international schools that follow international curricula (National Human Resource Development Council of Sri Lanka, 2022). All participants in the present sample were educated in public (government) schools or private schools (that follow the local curriculum and exams set by the Ministry of Education), or both at different times of their school career. No participants were educated in international schools.

Socio-demographic characteristics of the sample (age, years of education, province of residence, occupational group) are summarized in Table 1. The initial sample consisted of 643 participants aged between 18 and 83 years [mean (SD) age = 46.3 (16.9), mean (SD) years of education = 12.0 (3.7)]. Two hundred and ninety (45.2%) were males [mean (SD) age = 44.0 (17.3) years, mean (SD) years of education = 12.2 (3.5)],

Table 1. Sample characteristics ($n = 643$).

	Count	Percentage (%)
Age (years)		
18–22	51	7.9
23–27	64	10.0
28–32	64	10.0
33–37	50	7.8
38–42	51	7.9
43–47	55	8.6
48–52	58	9.0
53–57	56	8.7
58–62	52	8.1
63–67	57	8.9
68–72	52	8.1
≥73	33	5.1
Years of education		
0 (No schooling)	2	0.3
1–6 (Primary education)	65	10.1
7–11 (Lower secondary ± Ordinary Level qualifications)	243	37.8
12–13 (Upper secondary ± Ordinary Level qualifications)	165	25.7
14–17 (Post-schooling diploma, graduate education)	112	17.4
≥18 (Postgraduate education)	56	8.7
Province		
Central	163	25.3
Eastern	34	5.3
North Central	94	14.6
Northern	30	4.7
North Western	62	9.6
Sabaragamuwa	59	9.2
Southern	35	5.4
Uva	62	9.6
Western	104	16.2
Occupational group (according to ISCO-08)		
Managers	4	0.6
Professionals	79	12.3
Technicians and associate professionals	104	16.2
Clerical support workers	41	6.4
Service and sales workers	76	11.8
Skilled agricultural, forestry and fishery workers	2	0.3
Craft and related trades workers	11	1.7
Plant and machine operators and assemblers	5	0.8
Elementary occupations	193	30.0
Fulltime students	31	4.8
Not employed/retired	97	15.1

Note. ISCO-08: International Standard Classification of Occupations – version 08.

and 352 were females [mean (SD) age = 48.2 (16.4) years, mean (SD) years of education = 11.7 (3.9)]. Compared to the percentage of population living in each province in the country (Central Bank of Sri Lanka, 2020), the sample significantly overrepresented the Central and North Central Provinces (where the participant recruitment was done) and underrepresented the Southern Province. As per the ethnic distribution, the sample consisted of 490 Sinhalese (76.2%), 65 Sri Lankan Tamils (10.1%), 25 Indian Tamils (3.9%) and 63 Moors (9.8%). This distribution was similar to the national demographic statistics (Central Bank of Sri Lanka, 2020).

The first language of ethnic Sinhalese in Sri Lanka (74.9% of the population) is Sinhala, and Tamils (15.3% of the population) is Tamil. Most moors (9.3% of the population) also identify Tamil as their first language. Most Tamils and Moors in Sri Lanka speak both Sinhala and Tamil. In the present sample, 419 (76.4%) reported that their primary language as Sinhala and 152 (23.6%) as Tamil.

SPM test administration

The 60-item version of the SPM (Standard Progressive Matrices®; 2000 Edition: Updated 2004) was administered individually to each participant by a test administrator in the primary language of the participants. Verbal instructions and explanations were provided with the first question (for which all participants of the sample made the correct answer); and then the participants were allowed to complete the test at their own pace. Any further clarifications about what is being required of the participants during the test were provided by the test administrator. The number of correct responses were counted by the test administrator upon completion of the test to obtain the SPM raw score.

Data analysis

Initially, multiple linear regression models were used to explore the potential effect of age, sex and years of education on SPM raw scores of the sample. Further exploration of the data showed that the SPM scores did not change linearly, but in a curvilinear fashion with age (Figure 1)—an observation consistent with Raven's original observations and subsequent normative studies (Raven, 2000). For norming, the sample was stratified in to 5-year age bands (18–22, 23–27, 28–32, 33–37, 38–42, 43–47, 48–52, 53–57, 58–62, 63–67, 68–72) as commonly stratified in previous SPM norms; and the percentile scores were derived for each age band. The internal consistency of SPM was also calculated (as indexed by Cronbach's alpha) for the full sample and each age band.

To create smoothed percentile curves and norm tables, the cNORM package in R was used in accordance with methods described by Lenhard et al. (2018). cNORM generates continuous test norms by modelling the higher order three-dimensional relationship between the expected test raw score, age-specific norm score, and the explanatory variable (i.e. age) using Taylor polynomials. By drawing on the complete dataset, this approach smooths out imbalances of distinct subsamples, thus reducing local violations of representativeness and raising statistical power. In comparison to conventional norming, this approach achieves higher norming quality even with

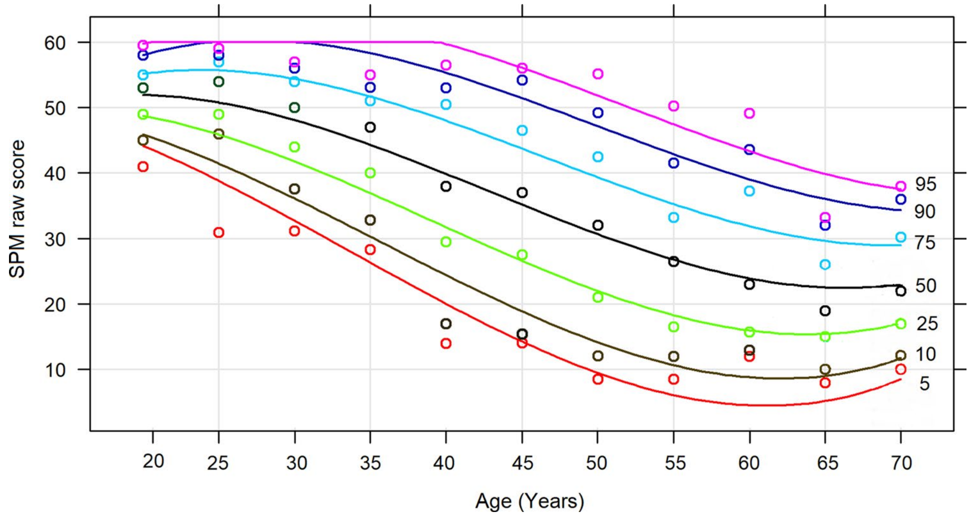

Figure 1. Observed percentiles (circles) and smoothed percentile curves for 5, 10, 25, 50, 75, 90 and 95th percentiles for SPM in the sample (overall model R^2 = 0.961). Age axis values denote the middle value of each age band.

considerably smaller normative samples (Lenhard & Lenhard, 2021). cNORM selects the best fitting model which explains as much variance as possible in the original data (higher R^2) with as few predictors as possible.

Results

As expected, SPM raw scores had a strong negative correlation with age (Pearson's $r = -0.683$, $p < .0001$), and a strong positive correlation with years of education ($r = 0.722$, $p < .0001$). However, age was also negatively correlated with years of education ($r = -0.534$, $p < .0001$); and the duration of education in older age bands were significantly less compared to the younger age bands (one-way ANOVA, F_{11} = 29.908, $p < .0001$). Table 2 summarizes the duration of education in each age band. The mean (SD) years of education in the youngest age band (18–22 years)—although some were yet to complete their tertiary education—was 13.1 (1.1) years, whereas that of the 68-to-72-year age band was 9.0 (3.1) years.

Regression models

Multiple linear regression analysis (including sex, age and years of education as explanatory variables) accounted for 63.9% of the SPM variance of the SPM scores (adjusted R^2 = 0.639, $p < .0001$). In this model, SPM raw scores were lower in the older individuals (unstandardized $B = -0.362$, $p < .0001$, shared variance = 11.3%) and better in those who had longer education ($B = 2.076$, $p < .0001$, shared variance = 18.2%). After adjusting for age and education males had a small ($B = 1.704$), significant (p =.021) advantage over females: However, sex accounted for only 0.3% of the variance of SPM scores.

The regression equations are as follows:

Table 2. Years of education in different age bands ($n = 643$)

Age band (years)	Count	Mean (SD) years of education	95% confidence intervals
18–22	51	13.08 (0.43)	12.24, 13.92
23–27	64	15.63 (0.38)	14.88, 16.37
28–32	64	14.47 (0.38)	13.72, 15.22
33–37	50	13.58 (0.43)	12.74, 14.42
38–42	51	13.08 (0.43)	12.24, 13.92
43–47	55	12.49 (0.41)	11.69, 13.30
48–52	58	11.10 (0.40)	10.32, 11.89
53–57	56	10.32 (0.41)	9.52, 11.12
58–62	52	9.81 (0.42)	8.98, 10.64
63–67	57	9.67 (0.40)	8.88, 10.46
68–72	52	9.02 (0.42)	8.19, 9.85
≥73	33	8.82 (0.53)	7.78, 9.86

For males:

$$\text{Predicted SPM raw score} = 27.096 - 0.362 \times \text{age in years} + 2.076 \times \text{years of education}$$

For females:

$$\text{Predicted SPM raw score} = 25.392 - 0.362 \times \text{age in years} + 2.076 \times \text{years of education}$$

The Supplementary File presents a Microsoft Excel-based calculator which—upon entry of age, sex, years of education of the SPM raw score of an individual—gives the predicted SPM raw score, and the standard score of the individual (i.e. how many standard deviations above or below the predicted score).

Percentile scores

There were only 33 participants older than 72 years. Given the cognitive functions change significantly in this age range, percentile scores were not derived for this age group. Therefore, the percentile scores are based on 610 participants aged between 18 and 72 [mean (SD) age = 44.6 (15.8), mean (SD) years of education = 12.1 (3.7), 272 (44.6%) men]. Importantly, the curvilinear model had a much better predictive power (overall model R^2 = 0.961) than the linear regression model (overall model R^2 = 0.639) even if the former has only age as a predictor. Figure 1 shows the percentile curves, and Table 3 shows the smoothed percentile scores of different age bands. A ceiling effect was observed for the 95th percentile of the SPM scores up to 47 years. Interestingly, we also observed flattening of the SPM scores of the lower half of the samples from the age band 63–67 to 68–72 (Figure 1). Apart from these exceptions, the general trend was for the percentile scores to markedly decline with age. Table 4 and Figure 2 compare the percentile scores of the present sample those of the standardization samples from US (1993, from Des Moines, Iowa: $n = 625$) and UK (1992; from Dumfries, Scotland: $n = 645$) (Raven, 2000; Raven et al., 2004). The comparison shows that the older individuals in the Sri Lankan sample score much lower than their counterparts in US and UK. However, the difference narrowed in the younger

Table 3. Raven's Standard Progressive Matrices percentile scores (smoothed) by age band.

	Percentiles by age band (years)										
Raw score	18 to 22	23 to 27	28 to 32	33 to 37	38 to 42	43 to 47	48 to 52	53 to 57	58 to 62	63 to 67	68 to 72
60	96	90	90	92	95	98	99	>99	>99	>99	>99
59	93	87	88	91	94	97	99	>99	>99	>99	>99
58	90	84	86	90	93	96	98	>99	>99	>99	>99
57	86	80	83	88	92	96	98	>99	>99	>99	>99
56	81	76	80	86	91	95	98	99	>99	>99	>99
55	74	72	77	84	90	94	97	99	>99	>99	>99
54	67	67	74	81	88	93	97	99	>99	>99	>99
53	59	62	70	79	86	92	96	98	>99	>99	>99
52	51	57	66	76	84	91	95	98	>99	>99	>99
51	42	51	62	73	82	89	94	97	99	>99	>99
50	34	46	58	70	80	88	93	97	99	>99	>99
49	27	40	54	67	78	86	92	96	98	>99	>99
48	20	35	47	63	75	84	91	95	98	>99	>99
47	15	30	45	60	72	82	90	95	98	99	>99
46	10	26	41	56	70	80	88	94	97	99	>99
45	7	21	37	53	67	78	87	93	96	98	>99
44	5	18	33	49	63	76	85	92	96	98	>99
43	3	14	29	45	60	73	83	90	95	97	99
42	2	11	26	42	57	70	81	89	94	97	98
41	1	9	22	38	54	68	79	87	93	96	98
40	<1	7	19	35	51	65	77	85	91	95	97
39	<1	5	17	31	47	62	74	83	90	94	97
38	<1	4	14	28	44	59	72	81	88	93	96
37	<1	3	12	25	41	56	69	79	87	92	94
36	<1	2	10	22	37	53	66	77	85	90	93
35	<1	2	8	20	34	50	63	74	83	88	91
34	<1	1	7	17	31	46	60	72	80	86	89
33	<1	<1	5	15	29	43	57	69	78	84	87
32	<1	<1	4	13	26	40	54	66	75	82	85
31	<1	<1	3	11	23	37	51	63	73	79	82
30	<1	<1	3	10	21	34	48	60	70	76	79
29	<1	<1	2	8	18	31	45	57	67	73	75
28	<1	<1	2	7	16	29	42	54	64	70	71
27	<1	<1	1	6	14	26	39	51	60	66	67
26	<1	<1	<1	5	13	24	36	48	57	63	63
25	<1	<1	<1	4	11	21	33	44	54	59	59
24	<1	<1	<1	3	9	19	30	41	50	56	54
23	<1	<1	<1	3	8	17	28	38	47	52	50
22	<1	<1	<1	2	7	15	25	35	44	48	45
21	<1	<1	<1	2	6	13	23	32	40	44	41
20	<1	<1	<1	1	5	12	20	30	37	41	37
19	<1	<1	<1	1	4	10	18	27	34	37	32
18	<1	<1	<1	<1	4	9	16	24	31	33	28
17	<1	<1	<1	<1	3	8	14	22	28	30	25
16	<1	<1	<1	<1	2	7	13	20	25	27	21
15	<1	<1	<1	<1	2	6	11	17	23	24	18
14	<1	<1	<1	<1	2	5	10	16	20	21	15
13	<1	<1	<1	<1	1	4	9	14	18	18	13
12	<1	<1	<1	<1	1	3	7	12	16	16	11
11	<1	<1	<1	<1	<1	3	6	11	14	14	9
10	<1	<1	<1	<1	<1	2	5	9	12	12	7
9	<1	<1	<1	<1	<1	2	5	8	10	10	6
8	<1	<1	<1	<1	<1	2	4	7	9	8	4
7	<1	<1	<1	<1	<1	1	3	6	8	7	4
6	<1	<1	<1	<1	<1	1	3	5	6	6	3
5	<1	<1	<1	<1	<1	<1	2	4	5	5	2
4	<1	<1	<1	<1	<1	<1	2	4	5	4	2
3	<1	<1	<1	<1	<1	<1	2	3	4	3	1
2	<1	<1	<1	<1	<1	<1	1	2	3	3	<1
1	<1	<1	<1	<1	<1	<1	<1	2	3	2	<1

(Continued)

Table 3. Continued.

Raw score	Percentiles by age band (years) 18 to 22	23 to 27	28 to 32	33 to 37	38 to 42	43 to 47	48 to 52	53 to 57	58 to 62	63 to 67	68 to 72
0	<1	<1	<1	<1	<1	<1	<1	<2	<3	<2	<1
n	51	64	64	50	51	55	58	56	52	57	52

age bands, showing no difference among the 18-to-22-year age bands in the three countries.

Internal consistency

The SPM showed excellent internal consistency in the overall sample (Cronbach's alpha = 0.97), and in each age band (Cronbach's alpha: 18–22 = 0.87, 23–27 = 0.92, 28–32 = 0.90, 33–37 = 0.94, 38–42 = 0.96, 43–47 = 0.96, 48–52 = 0.96, 53–57 = 0.94, 58–62 = 0.95, 63–67 = 0.90, 68–72 = 0.88).

Discussion

This article provides percentile-based norms for SPM in 5-year age bands for Sri Lankan adults between 18 and 72 years. The general trend was a marked decline of percentile scores with age: The 50th percentile score of the youngest age band (18–22 years) was 52 whereas that of the oldest group (68–72 years) was 23. Comparing these Sri Lankan data with US (1993) and UK (1992) norms indicates an age-by-country interaction of the SPM scores, where the older Sri Lankans scoring much lower than those in US and UK, and the younger generations approaching their counterparts in the developed countries. This is consistent with recent reviews and meta-analyses that show a more pronounced Flynn effect in the developing countries (Brouwers et al., 2009; Daley et al., 2003; Flynn, 2009; Raven, 2000; Wongupparaj et al., 2015, 2023). In the light of the evidence that years of education is a main predictor of the SPM scores on adults (Brouwers et al., 2009; Pontón et al., 1996; Raven, 2000), we believe that poorer education in the older age groups in the present sample has significantly contributed to the age-related fallback of SPM scores in the present sample compared to US and British samples: The average years of education of an adult over 54 years in the present sample is about 9.5 years. This is still less than that of a US adult of similar age in 1993 (about 12.5 years) or a British adult of similar age in 1992 (about 10.6 years) (Institute for Health Metrics and Evaluation, 2022). The assertion of lower SPM scores for poor education can only be statistically tested by comparing age-and-education adjusted SPM scores of the three samples, but we do not have individual-participant-level data for either 1993 US sample or 1992 British sample. Brouwers et al. (2009) in a comprehensive meta-analysis based on the data from 45 countries show that increasing levels of education over the years is a main determinant of the Flynn effect of SPM scores. Apart from education, we cannot rule out potential contribution of other factors that are known to affect intellectual capacity (health and nutritional status, socioeconomic standards, complexity of environmental stimulation etc.), and that could account for the differences in SPM norms among

Table 4. Raven's Standard Progressive Matrices percentile scores (5, 10, 25, 50, 75, 90 and 95th percentiles) of the Sri Lankan (SL) sample against the UK (1992) and US (1993) norms.

	Age band (years)																																
	18 to 22			23 to 27			28 to 32			33 to 37			38 to 42			43 to 47			48 to 52			53 to 57			58 to 62			63 to 67			68 to 72		
Percentile	SL	UK	US	SL	UK	US	SL	UK	US	SL	UK	US	SL	UK	US	SL	UK	US	SL	UK	US	SL	UK	US	SL	UK	US	SL	UK	US	SL	UK	US
95	60	59	59	60	59	59	60	59	59	60	59	59	60	59	59	56	59	59	52	58	59	48	58	58	43	58	57	40	58	54	38	54	55
90	58	58	58	60	58	58	60	58	58	58	58	58	55	58	58	52	58	58	47	57	58	43	57	57	39	57	56	36	57	53	35	51	53
75	55	57	54	56	57	54	54	57	54	52	56	54	48	56	54	44	56	54	39	55	54	35	55	55	32	55	54	30	55	52	29	45	51
50	52	54	52	51	54	52	48	54	52	44	54	52	40	53	52	35	52	52	31	51	51	27	50	50	24	49	49	23	48	47	23	39	45
25	49	49	47	46	49	47	42	49	47	37	49	47	32	48	47	27	47	47	22	46	47	18	45	45	16	44	41	15	43	39	17	29	35
10	46	44	41	42	44	41	36	44	41	30	44	41	25	43	41	19	41	41	14	39	41	11	37	39	9	35	35	9	33	31	12	29	27
5	44	39	35	39	39	35	33	39	35	26	39	35	20	37	35	14	34	35	10	30	35	6	27	31	5	24	27	5	20	23	9	14	18
n	51	58	28	64	71	54	64	84	72	50	69	77	51	54	121	55	67	69	58	54	35	56	39	36	52	44	28	57	43	33	52	44	55

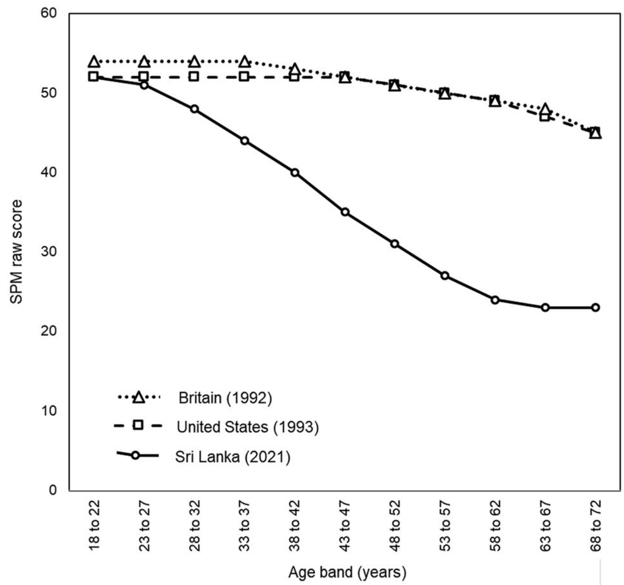

Figure 2. 50th percentile scores of standard progressive matrices (SPM) by age band in adult Sri Lankans (2021, present study, $n = 610$), compared with those of the standardization samples of United States (1993, $n = 625$) and Britain (1992, $n = 645$).

countries (Anum, 2022; Raven, 2000), and education-independent increase in SPM scores with time observed across the globe (Brouwers et al., 2009). Moreover, cross-cultural evidence suggests that visuospatial intelligence tests like RPM are not entirely culture independent (see Gonthier, 2022 for a review). While abstract visuospatial reasoning in the SPM minimizes obvious sources of linguistic biases, SPM is culture-reduced and not entirely culture-free. How this has factored into the differences of our SPM norms (and those of other developing countries) from the Western norms is yet to be explored.

After adjusting for age and education, males had a significant but small advantage over females. However, sex explained only 0.3% of the variance of the SPM scores. This is consistent with some published data (Lynn & Irwing, 2004). In contrast, our concurrent data from a largely overlapping sample also shows small, significant female advantage in verbal tasks: namely letter fluency (Dassanayake, Hewawasam, et al., 2021) and verbal learning (Dassanayake et al., 2020). This dissociation of visuospatial and verbal skills between genders is not limited to our sample, but also an observation made elsewhere among the adults (Barel & Tzischinsky, 2018; Voyer et al., 2021). It would be interesting to see whether these—albeit small—differences would continue with blurring of traditional gender roles and norms in newer generations.

The strengths and limitations of our SPM norms are worth discussing. The SPM showed an excellent internal consistency in the present sample across different age bands, indicating a high reliability of the test. The size of our normative sample is comparable to the sizes of the UK (1992) and US (1993) SPM standardization samples. We also stratified our sample into narrow, 5-year age bands mirroring those US (1993) and UK (1992) standardization samples. The steeper age-related decline we observed in the present sample (compared to the decline of the US and UK samples)—in retrospect—justifies such narrow stratification because the SPM raw scores were different by few points between even two adjacent bands (e.g. 50th percentile scores declined 1–5 points for each 5-year increase in age). Consequently, we believe that our age-stratified norms increase the accuracy of interpretation of clinical data of individual clients. However, our norms do not extend beyond 72 years of age, so that they cannot be used to interpret the test results of older individuals. Flooring effect of the lower half of the percentile scores in the oldest age groups is an exception, which has not been observed in developed countries and counterintuitive to age-related impairment pattern of fluid intelligence. We speculate that this is because the lower percentiles from the seventh decade have very low raw scores in our sample. The poorest performing participants thus seem have solved the easiest of the matrices that only require completion of the missing part of a simple pattern. These items—which tap largely into posterior cortical visuospatial processing—do not test complex reasoning or analytical skills which engage prefrontal executive control mechanisms (Prabhakaran et al., 1997) that are most vulnerable to age related decline (Raz et al., 2005; Salthouse et al., 2003). In contrast, at the younger end of the age spectrum, we observed a celling effect of the 95th percentile scores. This observation suggests that Ravens Advanced Progressive Matrices might be a more appropriate tool to use in this group for characterizing general intellectual functioning. Our linear regression model disregards the flooring effect of the norms in older age groups and those with poor education, thus over estimating test performance in old, poorly educated individuals. The linear regression model also disregards the ceiling effect in the younger age groups, thus underestimating the test performance in young adults. As such, we caution against using the regression-based norms in the young adults and old individuals.

We acknowledge that this study is not a nationwide norming study: We did not stratify sampling according to geographical or other socioeconomic factors. We believe that the final sample however has a reasonable geographic distribution within the island, especially compared to the sample from Dumfries-Scotland that set UK norms (1992) and the sample from Des Moines-Iowa that set the US norms (1993) at the time. Moreover, it should also be noted that Sri Lanka is much smaller than the US and even UK, and many people in the island commute between provinces, or reside in one province and work/study in another. As such, the residential area does not necessarily correlate with the education or occupational status of a citizen. Although we did not stratify recruitment based on education, the years of education in the sample was representative of the national statistics: The mean years of schooling in a Sri Lankan aged 25 years or above in 2021 was 11.25 years (UNESCO Institute for Statistics, 2023) whereas our subsample of the same age range ($n = 571$) had mean years of education of 11.76 (SD = 3.88) years. However, the average duration and the quality of formal education, and access to informal learning and bilingual education (first language and English) have improved in Sri Lanka over the last couple of decades. These trends might introduce potential biases in application of the current SPM norms to more affluent socioeconomic strata of the country and the emigrants of Sri Lankan origin.

In conclusion, we believe that the SPM norms presented in this article fill a hiatus in assessment of general intellectual ability in Sri Lankan adults. The age-stratified percentile charts will enable clinicians to interpret the test performance of their patients easily and accurately. We also believe that these norms will serve as a comparison SPM database for other countries in Asia and other developing countries beyond the region. Given that Sri Lanka and the neighboring countries improve their educational, socioeconomic and health standards faster than the nations who have already reached higher standards, it would be interesting to explore how these norms would evolve with re-standardization studies in the future.

Acknowledgements

We thank Mrs. Subhagya Kulatunga and Mrs. Gamage Shiroma for their assistance in recruiting the participants and collecting data; and Dr. Tharika Neelawathura and Dr. Poornima Nimashi for their assistance in data entry.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This study was supported by the University of Peradeniya research grant URG/2016/5/M.

ORCID

Tharaka L. Dassanayake http://orcid.org/0000-0002-7963-9012
Dewasmika I. Ariyasinghe http://orcid.org/0000-0002-9032-912X
Anuradha Baminiwatta http://orcid.org/0000-0002-5495-2029
Chandana Hewawasam http://orcid.org/0000-0001-9573-7272

References

Anum, A. (2022). Does socio-economic status have different impact on fluid and crystallized abilities? Comparing scores on Raven's progressive matrices, Kaufman Assessment battery for Children II story completion and Kilifi Naming test among children in Ghana. *Frontiers in Psychology*, *13*, 880005. https://doi.org/10.3389/fpsyg.2022.880005

Barel, E., & Tzischinsky, O. (2018). Age and sex differences in verbal and visuospatial abilities. *Advances in Cognitive Psychology*, *2*(14), 51–61. https://doi.org/10.5709/acp-0238-x

Bingham, W. C., Burke, H. R., & Murray, S. (1966). Raven's progressive matrices: Construct validity. *The Journal of Psychology*, *62*(2), 205–209. https://doi.org/10.1080/00223980.1966.10543785

Brouwers, S. A., Van de Vijver, F. J. R., & Van Hemert, D. A. (2009). Variation in Raven's Progressive Matrices scores across time and place. *Learning and Individual Differences*, *19*(3), 330–338. https://doi.org/10.1016/j.lindif.2008.10.006

Central Bank of Sri Lanka. (2020). *Sri Lanka Socioeconomic Data 2020*. https://www.cbsl.gov.lk/sites/default/files/cbslweb_documents/publications/otherpub/publication_sri_lanka_socio_economic_data_folder_2020_e.pdf.

Daley, T. C., Whaley, S. E., Sigman, M. D., Espinosa, M. P., & Neumann, C. (2003). IQ on the rise: The Flynn effect in rural Kenyan children. *Psychological Science*, *14*(3), 215–219. https://doi.org/10.1111/1467-9280.02434

Dassanayake, T. L., & Ariyasinghe, D. I. (2019). Sex-, age-, and education-adjusted norms for Cambridge Neuropsychological Test Automated Battery in literate Sri Lankan adults. *The Clinical Neuropsychologist*, *33*(sup1), 106–124. https://doi.org/10.1080/13854046.2019.1662090

Dassanayake, T. L., Baminiwatta, A., & Ariyasinghe, D. I. (2021). Demographically-adjusted normative data for Symbol Digit Modalities Test (SDMT) among Sri Lankan adults. *Sri Lanka Journal of Psychiatry*, *12*(1), 18–24. https://doi.org/10.4038/sljpsyc.v12i1.8284

Dassanayake, T. L., Hewawasam, C., Baminiwatta, A., & Ariyasinghe, D. I. (2021). Regression-based, demographically adjusted norms for Victoria Stroop Test, digit span, and verbal fluency for Sri Lankan adults. *The Clinical Neuropsychologist*, *35*(Sup1), S32–S49. https://doi.org/10.1080/13854046.2021.1973109

Dassanayake, T. L., Hewawasam, C., Baminiwatta, A., Samarasekara, N., & Ariyasinghe, D. I. (2020). Sex-, age- and education-adjusted norms for the WHO/UCLA version of the Rey Auditory Verbal Learning Test for Sinhala-speaking Sri Lankan adults. *The Clinical Neuropsychologist*, *34*(sup1), 127–142. https://doi.org/10.1080/13854046.2020.1829069

De Silva, R., Disanayaka, S., De Zoysa, N., Sanjeewanie, N., Somaratne, S., Foster, J., Srikanth, S., Kathriarachchi, S. T., & Martins, R. M. (2009). Norms for the Mini-Mental State Examination from a sample of Sri Lankan older people. *International Journal of Geriatric Psychiatry*, *24*(7), 666–670. https://doi.org/10.1002/gps.2168

Dutton, E., van der Linden, D., & Lynn, R. (2016). The negative Flynn Effect: A systematic literature review. *Intelligence*, *59*, 163–169. https://doi.org/10.1016/j.intell.2016.10.002

Dworak, E. M., Revelle, W., & Condon, D. M. (2023). Looking for Flynn effects in a recent online U.S. adult sample: Examining shifts within the SAPA Project. *Intelligence*, *98*, 101734. https://doi.org/10.1016/j.intell.2023.101734

Flynn, J. R. (2009). Requiem for nutrition as the cause of IQ gains: Raven's gains in Britain 1938-2008. *Economics and Human Biology*, *7*(1), 18–27. https://doi.org/10.1016/j.ehb.2009.01.009

Gonthier, C. (2022). Cross-cultural differences in visuo-spatial processing and the culture-fairness of visuo-spatial intelligence tests: An integrative review and a model for matrices tasks. *Cognitive Research: Principles and Implications*, *7*(1), 11. https://doi.org/10.1186/s41235-021-00350-w

Institute for Health Metrics and Evaluation. (2022). *Global Educational Attainment 1970-2015*. https://ghdx.healthdata.org/record/ihme-data/global-educational-attainment-1970-2015

Lenhard, W., & Lenhard, A. (2021). Improvement of norm score quality via regression-based continuous norming. *Educational and Psychological Measurement*, *81*(2), 229–261. https://doi.org/10.1177/0013164420928457

Lenhard, A., Lenhard, W., Suggate, S., & Segerer, R. (2018). A continuous solution to the norming problem. *Assessment*, *25*(1), 112–125. https://doi.org/10.1177/1073191116656437

Lynn, R., & Irwing, P. (2004). Sex differences on the progressive matrices: A meta-analysis. *Intelligence*, *32*(5), 481–498. https://doi.org/10.1016/j.intell.2004.06.008

National Human Resource Development Council of Sri Lanka. (2022). *Statistical Bulletin on Education - 2022*. https://nhrdc.gov.lk/nhrdc/media/attachments/2023/05/09/stat-bulletine-on-edu-2022-for-web_compressed.pdf.

O'Leary, U. M., Rusch, K. M., & Guastello, S. J. (1991). Estimating age-stratified WAIS-R IQS from scores on the Raven's standard progressive matrices. *Journal of Clinical Psychology*, *47*(2), 277–284. https://doi.org/10.1002/1097-4679(199103)47:2<277::AID-JCLP2270470215>3.0.CO;2-I

Pontón, M. O., Satz, P., Herrera, L., Ortiz, F., Urrutia, C. P., Young, R., D'Elia, L. F., Furst, C. J., & Namerow, N. (1996). Normative data stratified by age and education for the Neuropsychological Screening Battery for Hispanics (NeSBHIS): Initial report. *Journal of the International Neuropsychological Society: JINS*, *2*(2), 96–104. https://doi.org/10.1017/s1355617700000941

Prabhakaran, V., Smith, J. A., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. (1997). Neural substrates of fluid reasoning: An fMRI study of neocortical activation during performance of the Raven's Progressive Matrices Test. *Cognitive Psychology*, *33*(1), 43–63. https://doi.org/10.1006/cogp.1997.0659

Raven, J. (2000). The Raven's progressive matrices: Change and stability over culture and time. *Cognitive Psychology*, *41*(1), 1–48. https://doi.org/10.1006/cogp.1999.0735

Raven, J. C. (1941). Standardization of progressive martices, 1938. *British Journal of Medical Psychology*, *19*(1), 137–150. https://doi.org/10.1111/j.2044-8341.1941.tb00316.x

Raven, J., Raven, J. C., & Court, J. H. (2004). *Manual for Raven's progressive matrices and vocabulary scales, Section 3: The standard progressive matrices, including the parallel and plus versions. 2000 Edition, updated 2004.*

Raz, N., Lindenberger, U., Rodrigue, K. M., Kennedy, K. M., Head, D., Williamson, A., Dahle, C., Gerstorf, D., & Acker, J. D. (2005). Regional brain changes in aging healthy adults: General trends, individual differences and modifiers. *Cerebral Cortex (New York, N.Y.: 1991)*, *15*(11), 1676–1689. https://doi.org/10.1093/cercor/bhi044

Salthouse, T. A., Atkinson, T. M., & Berish, D. E. (2003). Executive functioning as a potential mediator of age-related cognitive decline in normal adults. *Journal of Experimental Psychology. General*, *132*(4), 566–594. https://doi.org/10.1037/0096-3445.132.4.566

Sinha, U. (1951). A study of the reliability and validity of the progressive matrices test. *British Journal of Educational Psychology*, *21*(3), 238–239. https://doi.org/10.1111/j.2044-8279.1951.tb02794.x

Srinivasan, S. (2010). The concise cognitive test for dementia screening: Reliability and effects of demographic variables as compared to the mini mental state examination. *Neurology India*, *58*(5), 702–707. https://doi.org/10.4103/0028-3886.72167

Srinivasan, S., & Jaleel, Q. (2015). Norms for a neuropsychological test battery to diagnose dementia in the elderly: A study from Sri Lanka. *Journal of Neurosciences in Rural Practice*, *6*(2), 177–181. https://doi.org/10.4103/0976-3147.153223

Strauss, E., Sherman, E. M. S., & Spreen, O. *A compendium of neuropsychological tests: administration, norms, and commentary*. Oxford University Press, New York (2006).

Suraweera, C., Anandakumar, D., Dahanayake, D., Subendran, M., Perera, U. T., Hanwella, R., & de Silva, V. A. (2016). Validation of the Sinhala version of the Repeatable Battery for Assessment of Neuropsychological Status (RBANS). *The Ceylon Medical Journal*, *61*(4), 167–170. https://doi.org/10.4038/cmj.v61i4.8383

Suriyakumara, V., Srikanth, S., Wijeyekoon, R., Gunasekara, H., Muthukuda, C., Rajapaksha, D., Weerasekara, R., Gonawala, L., Wijekoon, N., & de Silva, K. R. D. (2019). Validation of the Sinhala Version of the Addenbrooke's Cognitive Examination-Revised for the Detection of Dementia in Sri Lanka: Comparison with the Mini-Mental Status Examination and the Montreal Cognitive Assessment. *Dementia and Geriatric Cognitive Disorders*, *47*(4-6), 198–208. https://doi.org/10.1159/000497743

UNESCO Institute for Statistics. (2023). *Educational Attainment*. http://data.uis.unesco.org/

Voyer, D., Saint Aubin, J., Altman, K., & Gallant, G. (2021). Sex differences in verbal working memory: A systematic review and meta-analysis. *Psychological Bulletin*, *147*(4), 352–398. https://doi.org/10.1037/bul0000320

Wongupparaj, P., Kumari, V., & Morris, R. G. (2015). A cross-temporal meta-analysis of Raven's progressive matrices: Age groups and developing versus developed countries. *Intelligence*, *49*, 1–9. https://doi.org/10.1016/j.intell.2014.11.008

Wongupparaj, P., Wongupparaj, R., Morris, R. G., & Kumari, V. (2023). Seventy years, 1000 samples, and 300,000 SPM scores: A new meta-analysis of Flynn effect patterns. *Intelligence*, *98*, 101750. https://doi.org/10.1016/j.intell.2023.101750

World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA*, *310*(20), 2191–2194. https://doi.org/10.1001/jama.2013.281053