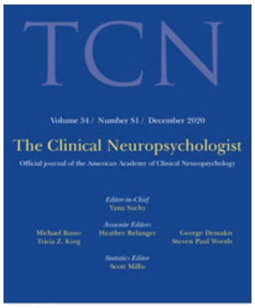

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Sex-, age- and education-adjusted norms for the WHO/UCLA version of the Rey Auditory Verbal Learning Test for Sinhala-speaking Sri Lankan adults

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ABSTRACT

Objective: The aim of this study was to create sex-, age- and education-adjusted norms for the WHO/UCLA version of the Rey Auditory Verbal Learning Test (RAVLT) for Sinhala-speaking Sri Lankan adults.

Methods: Five-hundred and sixty-one healthy, community-living adults (252 men), aged 19–83 years, and had 0–23 years of education completed the WHO/UCLA RAVLT in Sinhala language. We conducted multiple linear regression analyses with sex, age and years of education to predict RAVLT list A1–A5 individual trial scores; trials A1–A5 total learning; list B score; immediate and delayed recall and recognition trial scores; and retroactive interference.

Results: We report regression equations to predict RAVLT norms based on sex, age and years of education; and the test variances accounted by those variables. Accordingly, all measures, except retroactive interference had a significant age-related decline. All measures, except the recognition trial hits, significantly improved with more years of education. Women had significantly higher scores in all measures except in trial B and retroactive interference. Proactive interference, learning rate, learning over trials were not associated with sex, age or education. A confirmatory factor analysis loaded the RAVLT outcome measures into two factors: acquisition and retention.

Conclusions: We report sex-, age- and education-adjusted WHO/UCLA RAVLT norms for Sinhala-speaking Sri Lankans aged 19–83 years; and supplement the regression formulae with a calculator that produces predicted and standard scores for given test participant. These norms would help clinicians accurately interpret individual test results, accounting for the variability introduced by sex, age and education.

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Introduction

Rey Auditory Verbal Learning Test (RAVLT) is a supraspan episodic verbal memory test (Rey, 1958). It measures multiple indices of learning and memory including learning over trials, retention, delayed recall and recognition memory (Lezak et al., 2012; Schmidt, 1996; Strauss et al., 2006). In addition, derived measures tap into more complex processes including *proactive interference* (i.e. the interference caused by the information acquired first in subsequent acquisition of new information) and *retroactive interference* (i.e. interference caused by new information in retrieval of previously acquired information).

The RAVLT is sensitive to multiple neurological and psychiatric conditions including dementia, mild cognitive impairment, Parkinson disease, left temporal lobe dysfunction, Korsakoff syndrome, depression and schizophrenia (Lezak et al., 2012; Schmidt, 1996; Strauss et al., 2006). It's psychometric properties, sensitivity to clinical conditions, simplicity and low cost of administration have made RAVLT a most widely used test by clinical neuropsychologists. The original French version of RAVLT (Rey, 1958) has been translated and used in many languages including English (a large body of studies), Spanish (Correia & Osorio, 2014; Marques et al., 2013; O'Bryant et al., 2018), Portuguese (Magalhaes & Hamdan, 2010), German (Speer et al., 2014), Dutch (Van der Elst et al., 2005), Greek (Messinis et al., 2016), Czech (Bezdicek et al., 2014), Arabic (Poreh et al., 2012) and Hebrew (Vakil et al., 2010; Vakil & Blachstein, 1997); however, most translated versions have not been revalidated to assess different clinical conditions. In the present study we aimed to create norms for the WHO/UCLA version (Maj et al., 1993) of the Auditory Verbal Learning Test (AVLT).

This study is part of a larger project that aims to create demographically adjusted norms for a number of neuropsychological tests for Sinhala-speaking Sri Lankan adults. In 1997, Sri Lanka moved from a low-income to a middle-income country, and over the period life expectancy of its population has increased almost to the levels of high-income countries, increasing the proportion of elderly in the community (United Nations Development Programme, 2019). This trend in turn makes the neuropsychiatric diseases, neurodegenerative conditions and other neurological disorders of the old age more prevalent in the country, increasing the need of standard neuropsychological tests. However, very few validated neuropsychological tests are available to the clinicians in Sri Lanka (Dassanayake & Ariyasinghe, 2019; De Silva & Gunatilake, 2002; Srinivasan, 2010; Srinivasan & Jaleel, 2015; Suraweera et al., 2016; Suriyakumara et al., 2019), and even less have demographically adjusted norms (Dassanayake & Ariyasinghe, 2019; De Silva et al., 2009) that are essential for interpretation of individual results. There are two main limitations in using the standard neuropsychological tests and norms in the local context. The first is the language barrier: The most widely spoken native language in Sri Lanka is Sinhala, and it is spoken as the first language only in Sri Lanka. The second is the cultural differences from the countries where the tests were originally developed–cultural differences have been found to affect even norms of nonverbal tests (Bakos et al., 2010; Fasfous et al., 2013; Ostrosky-Solis et al., 2004). The WHO/UCLA version of the AVLT aims to mitigate the sociocultural effects on the original RAVLT performance (Maj et al., 1993). In the present study we aimed to generate sex-, age- and education-adjusted norms for the WHO/UCLA version of the AVLT in Sinhala-Speaking Sri Lankan adults, envisaging its generalizability to an adult population with a wide age range, educational backgrounds and verbal abilities. Based on the data collected, we also examined the factor structure of the Sinhala version of test to assess its construct validity.

Materials and methods

Participants

The WHO/UCLA AVLT data were collected as a part of a larger study that generated norms for a number of neuropsychological tests for Sri Lankan adults. The study was conducted at the Faculty of Medicine, University of Peradeniya, located in the Central Province of Sri Lanka with the approval of the institutional Ethics Review Committee. In addition, AVLT data were obtained from a group of healthy older control participants (>50 years) recruited for a different study conducted at the Faculty of Medicine and Allied Sciences, Rajarata University of Sri Lanka, Anuradhapura, located in the North Central Province with the approval of the respective institutional Ethics Review Committee. The potential participants were recruited from February 2017 to August 2019, 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 included the employees of the universities and the hospitals (who are originally from various parts of the island), their acquaintances, and the visitors and the persons accompanying the patients referred to the hospitals from various parts of the country. Consequently, the sample had a broader geographical representation, although the data were collected at two centres.

We excluded the responders who had a history of neurological or psychiatric illnesses, dependence on alcohol or other substances, gross hearing impairment or severe/terminal medical illnesses. All included participants were able to carry out activities of daily living independently. However, we did not actively exclude the individuals who had other 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 general adult population (Strauss et al., 2006). We ensured the sample who completed AVLT ($n = 561$) consisted of similar proportions of men ($n = 252$, 44.92%) and women ($n = 309$, 55.08%). All recruited participants were adults, 19 years or older. The years of schooling, graduate and postgraduate education, post-schooling diplomas, were summed to count the total years of formal education. Part-time courses were converted to full-time equivalents before summing. We have described the formal education setting in Sri Lanka in more detail in a recent paper (Dassanayake & Ariyasinghe, 2019). The years of education of the sample varied between no formal education (one participant) to 23 years. The sampling was not strictly stratified in terms of education or age, however we ensured that different educational strata (≤11 years – Ordinary Level or less; 12-13 years – between Ordinary Level and Advanced Level, 14-17 years – post-schooling diploma, graduate education; ≥18 years – postgraduate education) included individuals of all ages within the range (Table 1). Since we used the Sinhala

Table 1. Characteristics of the normative sample.

	Count	% of total
Sex		
Male	252	44.92
Female	309	55.08
Age (years)		
19 – 29	62	11.05
30 – 39	75	13.37
40 – 49	91	16.22
50 – 59	161	28.70
60 – 69	129	22.99
70 – 83	43	7.66
Years of education		
$\leq$ 11	226	40.29
12 – 13	127	22.64
14 – 17	153	27.27
$\geq$ 18	55	9.80

translation of the AVLT, only the individuals who reported their first language as Sinhala were recruited as participants. Each participant was compensated with 500 Sri Lankan Rupees (equivalent to about three US Dollars at the time of the data collection) for the time they spent on the study.

WHO-UCLA AVLT description and outcome measures

WHO/UCLA AVLT (Maj et al., 1993) comprises of two lists of words (A and B) common to most cultures, each consisting of 15 nouns; three each from parts of the body, animals, tools, household objects and transportation methods (see Supplemental File 1). On testing, the interviewer reads the list A, one word per second; and immediately after its completion, the test participant repeats as many words as possible, not necessarily in the same order in the list. The number of words repeated in the first trial (A1) is an index of the participant's short-term verbal memory span. The list A is tested over five trials (i.e. *trials A1* to *A5*). Typically, the number of words recalled increases over trials and the total number of words over all five trials is an index of *total learning*. A number of composite measures have been derived from these trials, including *learning rate* i.e. the number of words recalled in A5 minus number recalled in A1 (Lezak et al., 2012); and *learning over trials* i.e. (A1 to A5 total/(A1 $\times$ 5)) (Ivnik et al., 1992). After the five trials of list A, the interviewer reads list B–an interference list–and the participant repeats as many words as possible from this new list (*trial B*). Immediately after this interference trial, the participant is asked to recall as many words as possible from list A (i.e. *trial A6*). Repeated presentation of list A interferes with remembering words in list B (i.e. *proactive interference*, mathematically A1 – B), and presentation of list B also interferes with subsequent recall of words from list A (i.e. *retroactive interference*, mathematically A5 – A6) (Strauss et al., 2006). Twenty or 30-minutes after the trial A6, the participant is again asked to recall as many words as possible from memory (i.e. *trial A7*), and this taps into memory encoding and *delayed recall*. After the delayed recall, the participant is again presented with a list of 30 words that contain words intermixed from list A and 15 new nouns which the participant now needs to distinguish in a *recognition memory* task of which the *hit* count equals the total number words recognised correctly as those from list A or new words.

Development of the Sinhala version of the WHO-UCLA AVLT test

Commonly used Sinhala terms for the English words in the lists A and B were used in the translated version, with two replacements: In commonly used Sinhala, the word 'atha' is used to designate both arm (in the List A) and hand (in the List B). Therefore, we replaced the word arm with the Sinhala word for head (viz. 'hisa') in list A. The Sinhala term for bee is a two-word name (i.e. 'mī maessā') and its first word is the adjective form of the Sinhala term for mouse (i.e. 'mīyā') which is also in list B. Therefore, in the List B we replaced bee with the Sinhala word for wasp (i.e. 'bam̆barā'). The final lists of words are given in the Supplemental File 1. Further, the test instructions were translated from Strauss et al. (2006) to spoken Sinhala by one author (TLD), and back translated to English by another author (DIA). The two English versions were compared by a third author (CH) and when there were ambiguities, all three authors discussed and modified the Sinhala version of the instructions to the most appropriate format (see Supplemental File 2).

Testing protocol

The participants were instructed to sleep at least 6 hours the night before testing and not to consume alcohol from the night before testing. The standard test administration procedure described above was followed. The test instructions were provided in Sinhala. The delayed recall (trial A7) was tested 20 minutes after the trial A6. The 20-minute delay was shorter than the typical 30-minute delay of the original RAVLT task, but has been used in many previous normative studies (Pontón et al., 1996; Strauss et al., 2006; Vakil & Blachstein, 1993; Weitzner et al., 2020). The participants underwent visuospatial and digit-span tasks during the 20-minute gap, thus averting the possibility of rehearsal of the word lists or exposure to any new verbal information that might interfere with verbal memory processes. In addition to the raw scores of individual trials, total learning, learning rate, learning over trials, and proactive and retroactive interference scores were calculated.

Statistical analysis

Multiple linear regression (MLR) analyses with sex, age and years of education as predictors were fitted to model each AVLT outcome variable (except for learning rate, learning over trials and proactive interference that were not significantly associated with the demographic variables). Sex was treated as a dichotomous variable having assigned a value of 0 for females and 1 for males, whereas age and years of education were treated as continuous variables in the data analyses. In a series of preliminary univariate analyses, we correlated each outcome variable with age and years of education. In those, curvilinear fits did not significantly improve the R-squared values over linear fits in any of the correlations. Neither adding quadratic terms or interaction terms as predictors significantly improved the MLR models–as has been observed by some previous authors (Geffen, Moar, O'Hanlon A, Clark, & Geffen et al., 1990; Van der Elst et al., 2005). The final MLR models were thus created with sex, age and years of education as predictors. We also calculated the semipartial correlations and shared variances of each AVLT measure with sex, age and years of education. To maintain the uniformity of future application of the final models in interpreting individual data, we retained all three predictors for all MLR models even if a demographic variable was not a significant predictor in the final model.

The construct validity of the translated version was assessed by performing a confirmatory factor analysis, entering the following outcome variables: the raw scores of trials A1, B1, A6, A7 and the recognition trial; and total learning, learning rate and learning over trials. The principal component analysis was performed and the components (factors) were extracted if the Kaiser's eigenvalue was greater than 1.0. Scree plots were also created and were examined for additional breakpoints that suggest important minor factors. The resulting factors were orthogonally rotated using equamax procedure (Sawicki & Golden, 1984; Vakil & Blachstein, 1993). All statistical analyses were conducted using IBM® SPSS® version 20.0.0. Statistical significance was defined as a p value less than 0.05.

Results

Sample characteristics

Of the total sample of 561 (252 men, 44.92%), 422 (202 men) were recruited from Peradeniya and 139 (50 men) from Anuradhapura. The sample characteristics are summarized in Table 1. The mean (*SD*) age of the sample was 50.7 (14.1) years. The mean (*SD*) years of education was 12.7 (3.6) years. Because one test administrator could not administer the AVLT recognition task for his participants, data from only 451 (80.3%) participants were available for recognition task. However, the sex ratio (42.35% men), mean age (47.92, $SD = 13.82$) and mean years of education (12.4, SD = 3.7) of this subset was similar to that of the total sample. Of note, the average years of education is higher than the national average (11.1 years) for adults (United Nations Development Programme, 2019): This is primarily because we ensured the sample consisted of adequate number of participants from all different levels of education to make the variable better fit the regression models. However, of the 226 participants who had education for 11 years or less, only 42 (i.e. 18.5% of that subgroup) had 7 or fewer years education.

There was no significant difference between the mean age of men (49.97, $SD = 13.95$ years) and women (51.27, $SD = 14.14$ years), t (559) = 1.090, $p = 0.276$. The mean years of education was also similar between men (mean = 12.8, $SD = 3.4$ years) and women (mean = 12.5, $SD = 3.7$ years), t (559) = 0.919, $p = 0.358$. The years of education had a moderate negative correlation with age, $r = -0.410$, $p < 0.0001$, reflecting younger generations having more years of education.

Table 2 shows the descriptive statistics (mean, *SD*, minimum, maximum) for each AVLT outcome measure for the full sample. Supplemental File 3 presents the same statistics in lookup tables stratified by sex, age bands and bands years of education. However, stratification has led to 48 potential groups leaving very limited participant numbers in many groups, (and none in some) leading to poor precision of those norms. Therefore, the Supplemental File 3 includes only 44 groups – the ones that

Table 2. Sample means and standard deviations (*SD*) of WHO/UCLA Auditory Verbal Learning Test (AVLT) scores.

AVLT measure	Minimum	Maximum	Mean	*SD*
Trial A1	2	13	6.94	1.72
Trial A2	3	15	9.22	2.14
Trial A3	3	15	10.44	2.20
Trial A4	4	15	11.20	2.12
Trial A5	5	15	11.84	2.02
Sum of A1 to A5	20	73	49.64	8.52
Trial B1	0	11	5.27	1.66
Trial A6	1	15	10.08	2.61
Trial A7	0	15	10.28	2.63
Learning rate	−1	11	4.91	1.94
Learning over trials	1	3	1.48	0.29
Proactive interference	−4	8	1.66	1.77
Retroactive interference	−3	8	1.76	1.78
Recognition	13	30	24.02	3.47

[a] $n = 451$ for recognition task; for all other measures, $n = 561$.

comprised at least 2 participants. Intercorrelations among AVLT outcome variables are tabulated in the Supplemental File 4.

AVLT measures that were not associated with demographic variables

AVLT learning rate, learning over trials and proactive interference showed Gaussian distributions within the sample. None of these measures were significantly associated with any of the demographic predictors viz. sex, age or years of education in univariate analyses, $p > 0.05$ – except a greater proactive interference was observed in women than men, $t = 2.151$, $p = 0.032$. Neither did the combination of these demographic variables significantly predict any of those AVLT measures in MLR models, adjusted $R^2 < 0.002$, $p > 0.05$. Therefore, we report means and standard deviations of those derived measures for the whole sample.

Multiple linear regression models

The overall MLR models with sex, age and years of education were significant for all other AVLT measures (Table 3). Overall MLR models explained between 8.0% (recognition task) to 30.9% (Sum of trials A1 to A5, i.e. total learning) of the variance of main AVLT performance measures. However, only 1.8% of the variance of retroactive interference was explained by the regression, adjusted $R^2 = 0.018$, $p = 0.004$. The shared variances of the outcome measures with sex, age and years of education are summarised in Table 4.

Sex differences

Once adjusted for age and education, women had significantly higher scores in trials A1 – A5, A6, A7, recognition task and total learning (Table 3). Sex explained 2.0% (trial A6) to 6.4% (trial A3) of the variance of those measures (Table 4). No significant sex differences were observed in trial B scores and retroactive interference.

Table 3. Multiple linear regression models and regression formulae for generating demographically corrected WHO/UCLA Auditory Verbal Learning Test (AVLT) scores for Sinhala-speaking Sri Lankan adults between 19 and 83 years.

	Overall model				Sex		Age (Years)		Years of Education		
AVLT Measure[a]	Adjusted R^2	degrees of freedom	F statistic	p value	B (SE)	p value	B (SE)	p value	B (SE)	p value	Raw score regression formula[b]
Trial A1	0.179	3, 557	41.742	<0.0001	−0.517 (0.132)	0.0001	−0.033 (0.005)	<0.0001	0.104 (0.020)	<0.0001	7.508 − (0.517 × sex) − (0.033 × age) + (0.104 × education)
Trial A2	0.205	3, 557	49.257	<0.0001	−0.723 (0.162)	<0.0001	−0.052 (0.006)	<0.0001	0.096 (0.025)	<0.0001	10.981 − (0.723 × sex) − (0.052 × age) + (0.096 × education)
Trial A3	0.259	3, 557	66.132	<0.0001	−1.123 (0.167)	<0.0001	−0.054 (0.006)	<0.0001	0.117 (0.025)	<0.0001	12.221 − (1.123 × sex) − (0.054 × age) + (0.117 × education)
Trial A4	0.224	3, 557	54.833	<0.0001	−0.883 (0.159)	<0.0001	−0.048 (0.006)	<0.0001	0.122 (0.024)	<0.0001	12.467 − (0.883 × sex) − (0.048 × age) + (0.122 × education)
Trial A5	0.204	3, 557	48.723	<0.0001	−0.730 (0.154)	<0.0001	−0.041 (0.006)	<0.0001	0.127 (0.023)	<0.0001	12.645 − (0.730 × sex) − (0.041 × age) + (0.127 × education)
Sum A1 to A5 (TL)	0.309	3, 557	84.668	<0.0001	−3.975 (0.602)	<0.0001	−0.228 (0.023)	<0.0001	0.565 (0.091)	<0.0001	55.823 − (3.975 × sex) − (0.228 × age) + (0.565 × education)
Trial B	0.162	3, 557	37.074	<0.0001	−0.193 (0.129)	0.136	−0.032 (0.005)	<0.0001	0.098 (0.020)	<0.0001	5.740 − (0.193 × sex) − (0.032 × age) + (0.098 × education)
Trial A6	0.200	3, 557	47.780	<0.0001	−0.752 (0.199)	0.0002	−0.052 (0.008)	<0.0001	0.175 (0.030)	<0.0001	10.829 − (0.752 × sex) − (0.052 × age) + (0.175 × education)
Trial A7	0.202	3, 557	48.303	<0.0001	−1.109 (0.200)	<0.0001	−0.057 (0.008)	<0.0001	0.135 (0.030)	<0.0001	11.938 − (1.109 × sex) − (0.057 × age) + (0.135 × education)
Trial A5 − A6 (RI)	0.018	3, 557	4.506	0.004	0.022 (0.150)	0.884	0.011 (0.006)	0.086	−0.049 (0.023)	0.034	1.816 + (0.022 × sex) + (0.011 × age) − (0.049 × education)
Recognition: hits	0.080	3, 447	13.994	<0.0001	−1.320 (0.319)	<0.0001	−0.060 (0.014)	<0.0001	0.005 (0.052)	0.916	27.414 − (1.320 × sex) − (0.060 × age) + (0.005 × education)

TL: Total learning; RI: Retroactive interference.
[a] $n = 451$ for recognition task; for all other measures, $n = 561$.
[b] For sex, female = 0 and male = 1. For education, use completed years.

Table 4. Semipartial correlations and shared variances of the WHO/UCLA Auditory Verbal Learning Test (AVLT) with sex, age and years of education.

	Sex		Age		Years of education	
AVLT Measure[a]	r	r^2	r	r^2	r	r^2
Trial A1	−0.150	0.023	−0.244	0.060	0.199	0.040
Trial A2	−0.168	0.028	−0.313	0.098	0.146	0.021
Trial A3	−0.253	0.064	−0.316	0.100	0.173	0.030
Trial A4	−0.207	0.043	−0.287	0.082	0.188	0.035
Trial A5	−0.179	0.032	−0.259	0.067	0.204	0.042
Sum A1 to A5 (Total learning)	−0.232	0.054	−0.343	0.118	0.217	0.047
Trial B	−0.058	0.003	−0.247	0.061	0.193	0.037
Trial A6	−0.143	0.020	−0.254	0.065	0.219	0.048
Trial A7	−0.209	0.044	−0.276	0.076	0.168	0.028
Trial A5 − A6 (Retroactive interference)	0.006	0.001	0.078	0.006	−0.089	0.008
Recognition: hits	−0.187	0.035	−0.195	0.038	0.005	<0.001

r: Pearson's correlation coefficient.
[a]$n = 451$ for recognition task; for all other measures, $n = 561$.

Effect of age

Of the AVLT measures for which MLR models were created, all except retroactive interference had a significant age-related decline (Table 3). The variances of these different outcome measures explained by age ranged from 3.8% to 11.8%, total learning having the highest sensitivity to aging (Table 4).

Effect of education

Of the AVLT measures for which MLR models were created, scores of all trials, except the hit count in the recognition task significantly improved with more years of education (Table 3). The variances of those main AVLT trial scores explained by education ranged from 2.8% to 4.8% (Table 4). Retroactive interference also showed a small (semipartial correlation $r = -0.089$, shared variance = 0.8%) but significant ($p = 0.034$) reduction with more years of education.

Regression-based AVLT norms and scoring

Regression equations with coefficients for sex, age and years of education are listed in Table 3. 'WHO/UCLA AVLT predicted and standardized score calculator' (see Supplemental File 5) is a Microsoft Excel® worksheet with embedded regression equations, so that a clinician can interpret the WHO/UCLA AVLT results of a given individual as following: (1) Demographically predicted AVLT scores can be obtained by entering sex (coded 0 for females and 1 for males), age and years of education in the worksheet. (2) For each AVLT measure, the standardized score (i.e. number of standard deviations to the observed score from the predicted score) can then be obtained by entering the test participant's observed scores into the worksheet. For example, AVLT total learning predicted score for a 60-year-old man (value 1 for sex) with 12 years of education would be 44.95. If the observed total learning score of the participant is 25, his calculated standardized score would be −2.83.

Factor structure

Subjected to an eigenvalue cut-off of 1.0, two factors emerged significant with eigenvalues of 3.680 and 2.246; cumulatively accounting for 74.1% of the variance (Table 5). Scree plots also did not show additional breakpoints, indicating no significant influence of any minor factors. The first factor, tapped into memory retention (i.e. storage and retrieval), included raw scores of trials A1, B1, A6, A7 and the recognition trial; and total learning. The second factor represented learning or acquisition, and that included learning rate and learning over trials.

Discussion

In this study, we generated norms for the WHO/UCLA version of the RAVLT for Sinhala-speaking Sri Lankan adults aged 19–83 years. RAVLT norms have been presented mainly in previous work as demographically-stratified lookup tables (see Strauss et al., 2006 for examples). We rather created demographically-adjusted regression equations, similar to what has been reported by previous workers on RAVLT (Bezdicek et al., 2014; Ferman et al., 2005; Knight et al., 2006) and other neuropsychological tests (Crawford et al., 2001; Paolo et al., 1996; Rossetti et al., 2019; Van der Elst et al., 2005). The verbal learning over trials of the present sample was similar to what has been already observed in other cultures (Poreh et al., 2012).

The better AVLT performance we observed in women concurs with previous work (Bleecker et al., 1988; Gale et al., 2007; Geffen et al., 1990; Knight et al., 2006; Speer et al., 2014; Sundermann et al., 2019; Vakil & Blachstein, 1997; Van der Elst et al., 2005). We chose to keep sex in all AVLT regression models, even if it was not a significant predictor of some test measures. In support of this approach, recent evidence shows that sex-specific norms for verbal memory tests enable more accurate classification of individuals into amnesic mild cognitive impairment (Sundermann et al., 2016; 2019).

All AVLT outcome measures, except learning rate, learning over trials and proactive interference, showed age-related impairment, and this effect is well-documented in many samples from different parts of the world (Bezdicek et al., 2014; Correia & Osorio, 2014; Knight et al., 2006; Lavoie et al., 2018; Messinis et al., 2007; Query & Megran, 1983; Vakil et al., 2010). We found a linear function was the best fit for age-related decline in AVLT performance measures within the age range of our sample i.e. 19–83 years.

More years of education was associated with better performance in all AVLT measures except recognition, learning rate, learning over trials and proactive interference. This also is in general agreement with previous studies (Bezdicek et al., 2014; Correia & Osorio, 2014; Ferman et al., 2005; Lavoie et al., 2018; Messinis et al., 2007; Van der Elst et al., 2005). Since we sampled the participants from a wide range of education–0 to 23 years– (Table 1), the regression equations will be applicable for a broad population in terms of educational background.

Factor structure of the Sinhala version of the WHO/UCLA AVLT was consistent with the general construct of learning and memory. We identified two underlying components: learning/acquisition and retention (storage and retrieval) and they accounted

Table 5. Equamax rotated factor matrix of the outcome variables of the Sinhala version of the WHO/UCLA Auditory Verbal Learning Test (AVLT).

	Factor	
AVLT measure	1	2
Trial A1	**.695**	-.669
Trial B1	**.574**	-.225
Trial A6	**.883**	.198
Trial A7	**.897**	.160
Recognition	**.593**	.040
Total learning	**.919**	-.059
Learning rate	.272	**.889**
Learning over trials	-.059	**.947**

for nearly 75% of the variance. It is noteworthy that no distinction emerged between measures of immediate recall (trial A1 score) and delayed recall (trial A7 score) – both variables converged into a single component. Although there are some differences in the variables entered into analyses among studies, our factor structure is similar to the two-factor models described by Vakil and Blachstein (1993) for the Hebrew translation of the RAVLT among heathy adults. However, unlike in their three-factor extraction, our results do not favor further division of the 'retention' construct into storage and retrieval components. More recently, Weitzner et al. (2020) examined the factor structure of the English version of the RAVLT in healthy adults, also including process scores (i.e. serial position effects, word intrusions and repetitions) in to the analysis: The main addition to our and previous findings was that they identified a third component–inaccurate memory–that consisted of word intrusions and repetitions.

Some limitations of the present study should be taken into account in interpreting the AVLT norms and applying the test in the future. The translated AVLT can be reliably administered and its norms should be applied only for the Sri Lankans whose first language is Sinhala, who constitute about 75% of the population. The first language of almost all ethnic Tamils and most Moors in Sri Lanka (about 24.5% in total) is Tamil (Department of Census & Statistics Sri Lanka, 2012). Therefore, the Sinhala version of the test may not be valid for them although many of them do speak some Sinhala. We did not systematically cover the whole country through a geographically stratified sampling procedure. However, the recruitment procedure at the two centres located in two provinces covered participants from various parts of the island. We did not measure IQ, instead used the years of education as a predictor of RAVLT performance as has been done in a number of previous studies through education-based stratification (Fichman et al., 2010; Magalhaes & Hamdan, 2010; Messinis et al., 2016; Pontón et al., 1996; Poreh et al., 2012) or regression (Bezdicek et al., 2014; Ferman et al., 2005; Lavoie et al., 2018; Messinis et al., 2007; Van der Elst et al., 2005). Some workers highlight the advantages of adjusting individual neuropsychological test results for IQ over education (Steinberg et al., 2005), but there is no validated translated version of an IQ test in any of the native Sri Lankan languages. Given the limited numbers of participants in each stratum defined by sex-, age- and education, we recommend referring to the regression-based norms (see Table 3 and Supplemental File 5) rather than the lookup tables (in Supplemental File 3), in interpreting individual AVLT test results. It should also be noted that the regression-equations would be valid only for adults between 19 and 83 years of age – we caution against applying these equations for individuals beyond this age range. Finally, those with 7 or fewer years of education represented only 18.5% of the 0 – 11 years of education subgroup in our sample, so that the regression-based norms may not precisely represent them. We urge caution in the use of these regression equations for adults who had education 7 years or less (Table 5).

Only few neuropsychological tests are translated and validated for use in Sri Lanka. Most of them are screening tests: viz. Mini Mental State Examination (De Silva et al., 2009; De Silva & Gunatilake, 2002), Repeatable Battery for the Assessment of Neuropsychological Status (Suraweera et al., 2016), Addenbrooke's Cognitive Examination-Revised (Suriyakumara et al., 2019); and a Concise Cognitive Test that screen for language, episodic verbal memory, visuospatial skills and executive functions (Srinivasan, 2010; Srinivasan & Jaleel, 2015). Of these tests, valid norms are only available for the MMSE, only for adults older than 55 years. As for comprehensive neuropsychological assessment, demographically-adjusted, country-specific norms are available only for Cambridge Neuropsychological Test Automated Battery (Dassanayake & Ariyasinghe, 2019); however the test battery or its clinically reliable component memory tests (e.g. Paired Associated Learning) are not widely available, partly owing to the cost of test administration. It should be noted that almost all the above neuropsychological tests are available only in Sinhala, thus limiting the testing ability of the native speakers of Tamil–the second mostly spoken language in Sri Lanka. An exception is the Cambridge Neuropsychological Test Automated Battery–a language independent comprehensive neuropsychological test–of which the instructions are available both in Sinhala and Tamil (Dassanayake & Ariyasinghe, 2019).

In that context, WHO/UCLA version of the AVLT and its demographically adjusted norms offer clinicians a low-cost, psychometrically powerful neuropsychological tool to help diagnose and monitor patients with a variety of clinical conditions. The software application with embedded regression equations provided with this paper (Supplemental File 5) will further assist the clinicians to rapidly interpret individual test results, by converting the raw scores into sex-, age- and education-adjusted standard scores.

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