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Research Article

Performance on the African neuropsychology battery using the learning ratio in a sample of healthy Congolese

Jean Ikanga[1,2], Zinat Taiwo[3], Ketrin Lengu[4], Emmanuel Epenge[2], Herve Esambo[2], Guy Gikelekele[2], Christian Esselakoy[2], Immaculée Kavugho[2], Samuel M. Mampunza[2], Dustin Hammers[5], Anthony Stringer[1] and Robert J. Spencer[4]

[1]Emory University, School of Medicine, Department of Rehabilitation Medicine, Atlanta, GA, USA, [2]University of Kinshasa, Department of Psychiatry, Kinshasa, the Democratic Republic of the Congo, [3]Georgia State University, Department of Psychology, Atlanta, GA, USA, [4]Mental Health Service, VA Ann Arbor Healthcare System, Ann Arbor, MI, USA and [5]Indiana University, Department of Neurology, Indianapolis, USA

Abstract

Objective: Using the African Neuropsychology Battery (ANB), we seek to develop normative data by examining the demographic effects for two learning process scores: initial learning (Trial One) and learning ratio (LR, the percentage of items learned relative of to-be-learned material following Trial 1). **Methods:** Healthy participants from the Democratic Republic of Congo completed the four memory tests of the ANB: the African Story Memory Test (ASMT), African List Memory Test (ALMT), African Visuospatial Memory Test (AVMT), and African Contextual Visuospatial Memory Test (ACVMT). We developed indices of learning for each subtest, as well as aggregate learning indices for Trial 1 and LR, and composite indices examining verbal, visual, contextual, and noncontextual learning, and grand indices comprising all four subtests. **Results:** Trial 1 and LR scores each demonstrated acceptable intercorrelations across memory tests. We present normative data for Trial 1 and LR by age and education. **Conclusion:** These data provide normative standards for evaluating learning in Sub-Saharan Africa.

Keywords: assessment; learning; memory; neurocognitive tests; sub-Saharan Africa; ANB; cultural neuropsychology

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Introduction

The African Neuropsychology Battery (ANB, Ikanga et al., 2019) consists of cognitive tests developed for sub-Saharan African (SSA) populations and has been validated in the Democratic Republic of Congo (DRC). The ANB assesses visuospatial perception, naming, memory, and executive functioning using content drawn from SSA cultures. These are cultures of African countries below the Sahara Desert, mostly characterized by oral tradition and respect for elders. These collectivist cultures use metaphors, symbolisms, proverbs, and stories to communicate. Therefore, African cultures may provide an advantage of auditory verbal memory tests but disadvantage with written language, organizational skills, categorization, drawing, or graphomotor skills (Ikanga et al., 2019).

In the context of using appropriate tests for these SSA cultures, the authors developed the ANB. In test development, we first identified neuropsychological domains of interest and generated culturally appropriate tasks. After we selected items for each of the target domains, which were common and familiar in the Congo (as well in other SSA countries) and translatable to other Congolese languages. Items needed to be part of cultural practices in SSA and the tasks were to be inexpensive. All instructions of ANB were created in English, translated into French, and back translated into English. Finally, the ANB was translated into the 4 Congolese national languages (Lingala, Swahili, Kikongo, and Tshiluba).

The ANB measures memory through four subtests including the African List Memory Test (ALMT), African Story Memory Test (ASMT), African Visuospatial Memory Test (AVMT), and African Contextual Visuospatial Memory Test (ACVMT). These subtests assess verbal and visual learning and consist of stimuli that capture rote and context-dependent memory. The ANB yields primary outcomes of total scores for learning, immediate and delayed recall, and recognition. Although such scores are standard and largely quantify memory in broad strokes, analyzing the *process* of learning/memory performance on these measures can help contextualize an individual's performance (Kaplan, 1988) and potentially differentiate among pathological processes. Therefore, we sought to expand the validation of the memory indices of the ANB by drawing from the literature on process scores for quantifying single-trial learning and learning slope.

Within tests of memory, there are several ways to examine scores beyond tabulating the total number of items amassed across learning trials. Process scores include metrics pertaining to learning on initial trials and improving performance with repeated exposure to stimuli, which have demonstrated efficacy in

Corresponding author: Jean Ikanga, email: jikanga@emory.edu

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differential diagnosis. Individuals with neurocognitive disorders, such as Alzheimer's disease, tend to have suppressed encoding across learning trials and do not benefit appreciably from re-exposure to information (Aretouli & Brandt, 2010; Bondi et al., 1994; Weintraub et al., 2012). Such learning process scores potentially discriminate cognitively healthy and impaired individuals, perhaps aiding differential diagnosis among neuropsychological conditions (Mast & Allaire, 2006).

Common practice when using measures involving learning over multiple trials is to present total scores encompassing performances over trials. In this process, many potentially meaningful aspects of learning go unmeasured, as dissociable cognitive processes are subsumed under a single score. Users of such measures, however, often appreciate that total scores are the end result of component processes. For example, a process score capturing the amount of information learned on an initial learning trial (single-trial-learning) can be calculated to quantify initial learning efficiency. Various tests provide normative data for single-trial-learning scores (e.g., California Verbal Learning Test-3 [CVLT-3]; Delis et al., 2017). These individual scores usually consist of singular datapoints and are therefore modestly reliable, constraining their clinical utility. To increase stability of single-trial-learning scores, developers of the Wechsler Memory Scales – Third Edition (WMS-III; Wechsler, 1998) created an aggregate single-trial-learning score combining initial learning for two verbal learning tests. Despite the promise of a more stable aggregated score, this approach has been abandoned by the test publishers. Aggregated Trial 1 may nevertheless have merit, especially if more than two observations are used in the composite.

Whereas single-trial learning scores depict initial learning, learning slope scores provide complementary data by quantifying the improvements in subsequent trials. Learning slope has been calculated in various ways. The most common method involves calculating the difference between the scores on the first and last learning trial (e.g., Hopkins Verbal Learning Test-Revised (HVLT-R); Benedict et al., 1998), henceforth referred to as Raw Learning Slope (RLS). Many other iterations of learning slope are mathematical derivations of RLS. Approaches include subtracting the score on the first learning trial from best learning trial (e.g., Brief Visuospatial Memory Test-Revised [BVMT-R], Benedict, 1997) and the method of the CVLT – II and 3 (Delis et al., 2000; Delis et al., 2017), which computes a weighted average of the new words per trial an individual acquires. These alternative learning slope scores, which are psychometrically equivalent to traditional RLS methods, share one significant shortcoming – they are heavily influenced by the score on the initial learning trial (Spencer et al., 2020). Most problematically, obtaining high scores on the initial learning trial contributes to a ceiling effect resulting in minimal opportunities for improvement in the learning slope, thereby penalizing efficient learners. These ceiling effects are most apparent with a limited pool of to-be-learned items. In such scenarios, few items remain unlearned after the first learning trial, limiting opportunities for demonstrating improvement.

Mathematically, the computational constraints inherent in using RLS to quantify learning slope risk producing misleading results. That is, many results appearing to pertain to the concept of "learning slope" are contaminated by using RLS. Indeed, RLS-based methods, which only account for improvement past the first learning trial, negatively correlate with first trial scores (Spencer et al., 2020; Hammers et al., 2021c) and are minimally, inconsistently, and often inversely related to advanced age (e.g., see manuals for BVMT-R, CVLT 3, WMS-III). The lack of a clear correlation with age is surprising given that age is an established correlate of brain processes contributing to inefficient learning and memory (e.g., Small et al., 2002). Moreover, multiple studies have not supported learning slope to differentiate normal and abnormal cognition (e.g., Gifford et al., 2015; Lu et al., 2020; Thomas et al., 2018), possibly because these studies used RLS-based methods. Altogether, these findings are at odds with what is known about learning, aging, and pathology. This body of literature casts doubt on the conventional, RLS-based, methods for quantifying learning slope, suggesting that an alternative scoring system accounting for initial learning rates on learning slope is needed.

In response to the limitations of RLS, Spencer et al. (2020) proposed a new computation method, called the learning ratio (LR) that accounts for constraints introduced by first trial learning performance by dividing RLS by what remains to be learned following the first trial, mathematically depicted below.

$$\mathrm{LR} = \frac{(\text{Final Trial} - \text{Initial Trial})}{(\text{Maximum Score per Trial} - \text{Initial Trial})}$$

Using the RBANS List Learning and Story Memory subtests, Spencer et al. (2020) demonstrated psychometric superiority of LR relative to the conventional RLS method. Follow-up investigations comparing LR with RLS suggest LR is more robustly correlated with traditional memory and learning measures, provides superior diagnostic differentiation of clinical groups, and is correlated more strongly with relevant neuroanatomic (i.e., hippocampal volume) and other biomarker data such as ApoE4 status (Hammers et al., 2021a, 2021b, 2021c). Recent studies have developed LR aggregates by combining learning slope measures (i.e., List Learning and Story Memory on the RBANS), stabilizing resultant metrics. In fact, among studies using LR, aggregate scores show more robust psychometric properties relative to subtest specific metrics (Hammers et al., 2021a, 2021b, 2021c; Spencer et al., 2020). Such an aggregated measure was introduced by developers of the WMS-III, but the enterprise was limited by employing RLS. Perhaps because of poor reliability, small effect sizes, and a negative correlation with age, this aggregated learning index has subsequently been jettisoned by the test publishers of the fourth edition of the test. The current project revisits the spirit of WMS-III's use of an aggregated measure, while circumventing its primary limitation: failing to account for ceiling effects when computing learning slope.

We aimed to derive learning slope metrics, both individually and in aggregate form, for the ANB memory measures in a sample of healthy Congolese participants. We also present scores reflecting initial learning for each memory subtest and for aggregated indices of initial learning. Our aggregate scores were developed on theoretical constructs of verbal/visual, and contextual/noncontextual subtests. We present our results as normative data and predict significant positive correlations among all LR indices and composites. We also predict that age and education will be significantly predictive of both LR and Trial 1 learning and will thus need to be statistically accounted for when presenting normative data.

Methods

Participants

Participants included 254 healthy individuals (mean age = 48.42 [*SD* = 16.74], 52.8% male, Mean education = 11.8 years

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[*SD* = 5.7], 54.6% rural residence) assessed with the ANB as part of its validation. Participants were recruited through announcements at churches, schools, universities, and other public locations in the DRC. After obtaining the informed consent from participants, they were administered demographic and health questionnaires followed by neuropsychological evaluation. Subjects were evenly divided by adult age cohort and were multilingual (speaking Lingala, Kikongo, French, Swahili, and/or Tshiluba) (see Table 1). Participants needed to report no current or past developmental, neurological, or psychiatric diagnoses.

Participants completed a self-report medical history form in which they denied neurological, psychiatric, cardiovascular, or pulmonary diseases. There were no confirmatory medical evaluations; therefore, their medical status was determined by their medical history questionnaire. Therefore, there was no guarantee this sample did not have some individuals with psychiatric or neurological issues. Participants resided in Kinshasa and neighboring areas in the DRC and were 18 years or older. Participants had at least 1 year of formal education and were fluent in either French or one of the national languages of the DRC (Kikongo, Lingala, Swahili, and/or Tshiluba). Participants were evaluated one-on-one by members from a team of 6 medical residents who were trained by the first author. The study was approved by the respective Institutional Review Board. The study was approved by the Emory University and Protestant University of Congo respective Medical School Institutional Review Board in accordance with Helsinki Declaration.

Table 1. Demographic characteristics of the sample

Characteristic	*N*	Frequency
Gender		
Male	134	52.8%
Female	120	47.2%
Age decade		
18–29 years	44	17.3%
30–39 years	43	16.9%
40–49 years	41	16.1%
50–59 years	44	17.3%
60–69 years	42	16.5%
70 years and over	40	15.7%
Level of education		
1–6 years (primary school)	70	27.6%
7–12 years (secondary school)	77	30.3%
13–17 years (licentiate)	59	23.2%
18 years and more (masters and doctorate)	48	18.9%
Residence		
Urban	115	45.6%
Rural	137	54.4%
Occupation		
Professional specialty occupation	58	27.6%
Sales occupation	39	18.6%
Student	15	7.1%
Not employed	15	7.1%
Executive administrative	14	6.7%
Private household	14	6.7%
Technicians	13	6.2%
Farming	10	3.9%
Other	10	3.9%
Language spoken at home*		
French	65	25.6%
Lingala	163	64.4%
Kikongo	100	39.4%
Tshiluba	27	10.6%
Other language	130	51.2%
Overall health		
Poor	9	3.5%
Average	189	74.4%
Excellent	56	22.0%

*The percentages for languages spoken at home do not equal 100 because much of the sample was multilingual.

Measures

The ANB is a culturally appropriate battery of cognitive tests developed by Ikanga and Stringer and validated in the DRC (Ikanga et al., 2019). For the current study, all four memory measures on the ANB (two verbal and two visuospatial) were included: ASMT, ALMT, ACVMT, and AVMT. Memory measures consist of 3 learning trials, an interference trial, a short delay recall, a 20-min long-delay recall trial, and a recognition trial. The ALMT additionally includes a cued long delay recall trial.

African story memory test

Examiners read a cultural-themed story based on life in a traditional African village, and the examinee was asked to recall the story immediately after presentation of the story, across 3 learning trials. A second story was presented one time after the third learning trial of the initial story, followed by short- and long-delay recall trials. Scores for each learning and recall trial refer to the number of items correctly recalled which ranged from 0 to 49. The ASMT is one of two tests comprising of the contextual memory subtests of the ANB.

African contextual visuospatial memory test

The ACVMT, which assesses associative visuospatial learning and memory, involves colored pictures of natural and artificial environments at the top of the page are paired with 8 objects at the bottom of the page. For each of 3 learning trials and interference, the examinee was shown the 8 object–environment association stimuli for 10 s each. There were 8 object–environment pairings in each trial remained the same throughout the three learning trials, short and delayed recalls. These object–environment dyads were presented in a fixed semi-random order in every learning trial. During the interference trial, the previous 8 environments used in the three previous trials were presented for 10 s; however, they were now associated each with a different object than the one previously presented. In all the trials, the examinee was instructed not to give a verbal response, but to point to the answer. Scores in each trial ranged from 0 to 8. Higher scores indicated better performance. The ACVMT is considered contextual in the ANB.

African list memory test

The ALMT consists of 12 words from 4 semantic categories (body parts, means of transportation, animals, and food). The list was read at the rate of one word every 3 s. Across 3 trials, examinees are asked to recall words from the target list immediately after presentation of the list, earning scores ranging from 0 to 12. A second 12-word interference list was presented after the third learning trial, followed by the short-delayed recall, and then a long-delay free recall trial approximately 20 min later. The ALMT is considered as noncontextual memory.

African visuospatial memory test

The AVMT involves encoding and retaining traditional cultural symbols found in the arts, including woodcarving, textiles, and prints, of many SSA countries. The examinee was presented with a page of 4 symbols organized in a 2x2 matrix. The page is displayed for 10 s, after which examinees were asked to reproduce (on a blank sheet of paper) as many of the symbols, in their correct location on the page. For each of the 4 individual symbols,

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examinees could earn scores ranging from 0 to 5 yielding a total score (accuracy of the drawing and location) from 0 to 20 for each trial. The AVMT is considered noncontextual.

Design and data analysis

Scores for the ANB memory tests' initial learning indices and LR learning slope (RLS and LR) were derived. Composite scores combining verbal (ASMT and ALMT), visual (ACVMT and AVMT), contextual (ASMT and ACVMT), and noncontextual (ALMT and AVMT) measures were also calculated. Furthermore, weighted composite scores were calculated to account for the varying number of items across memory measures.

Initial learning

Initial learning was assessed using Trial 1 score for each measure. A weighted initial learning score was calculated by adjusting the point values for each test by the number of items, with the test awarding the most points per trial – ASMT (49 points) – serving as the standard. Since the highest score of items in ANB memory tests is 49, we made 49 the total for each trial to match the maximum total of 49 in ASMT. The weighted average is adjusted for the number of items for each test (e.g., 4.083 * 12 = 49; 6.125 * 8 = 49; 2.45 * 20 = 49). Therefore, the scores from each subtest trial had an equal total possible score when aggregating the tests into composites. For example, ALMT contains 12 possible points that are multiplied by 4.083 so the total approximated the 49 points of ASMT. The same principle applied to the ACVMT (x6.125) and AVMT (x2.45). Possible scores range from 0 to 196. We used the following formula:

$$\begin{aligned}\text{Initial learning} = {} & (4.083^{*}ALMT\ Trial\ 1) + (ASMT\ Trial\ 1) \\ & + (2.45^{*}AVMT\ Trial\ 1) \\ & + (6.125^{*}ACVMT\ Trial\ 1)\end{aligned}$$

Learning slopes

Raw learning slope (RLS) and LR of each ANB memory test were computed (see Spencer et al., 2020). For each test, RLS was calculated as Trial 1 subtracted from the score of Trial 3. We used the score on the last trial for the convenience of subsequent examiners and because the most points are typically obtained on the final trial. LR for each test was computed by dividing the RLS by the maximum total score that could be obtained on any single trial subtracted from the obtained score on Trial 1 (i.e., *RLS/(maximum score possible on Trial 1-Trial 1)*. The RLS and LR of each subtest were calculated as follows:

Composite LR scores were calculated as follows:

Verbal LR

Verbal LR = ((ASMT RLS) + (4.083 * ALMT RLS))/(98-(4.083 * ALMT Trial 1) – (ASMT Trial 1)).

Visual LR

Visual LR = ((2.45 * AVMT RLS) + (6.125 * ACVMT RLS))/(98-(6.125 * ACVMT Trial 1) – (2.45 * AVMT Trial 1))

Contextual LR

Contextual LR = ((6.125 * ACVMT RLS) + ASMT RLS))/(98 – (6.125 * ACVMT Trial 1) – ASMT Trial 1)).

Noncontextual LR

Noncontextual LR = ((2.45 * AVMT RLS) + (4.083 * ALMT RLS))/(98 – (2.45 * AVMT Trial 1) – (4.083 * ALMT Trial 1)).

Grand LR

Grand slope = ((2.45 * AVMT RLS) + (4.083 * List RLS) + (6.125 * ACVMT RLS) + (Story RLS))/(196-(2.45 * AVMT Trial 1) – (4.083 * List Trial 1) – (6.125 * ACVMT Trial 1) – (Story Trial 1)).

When Trial 1 and Trial 3 scores were perfect, scores of 1.00 were imputed. The latter imputation was only needed for the ACVMT subtest, for which several young and/or well-educated individuals obtained perfect scores for Trial 1.

Data analyses

Data were analyzed using IBM SPSS Statistics for Windows (Version 27; IBM Corporation, 2017) with the alpha level set *a priori* at .05. Zero-order correlations established linear relationships between initial learning indices and learning slopes. We examined the effects of demographic factors such as age, years of formal education, sex, and location of residence by conducting hierarchical regression. Linear regression using forced entry was conducted to developed demographic normative corrections. We conducted analyses of variances (ANOVA) comparing means between groups according to age and education. We calculated Cronbach's alpha for internal consistency. Finally, we compared indices of initial learning of all the subtests with those of learning slopes.

Results

Correlations of LR slope scores across the four ANB subtests

Across memory measures, the intercorrelations among the six LR indices were all positive and statistically significant, ranging from .15 to .43.

Correlations between Trial 1 and LR across the four ANB subtests

We examined the internal consistency of Trial 1 scores across the four memory subtests of the ANB, treating each subtest as a data point for a composite scale. Performances on initial learning trials (Trial 1) across ANB subtests were significantly correlated with each other, with values ranging from .26 to .42, with a median of .38. Corrected item-total correlations, correlations of subtests with the remaining subtests, ranged from .43 (AVMT) to .53 (ACVMT). When these scales were treated as 4 discrete items, the Cronbach's alpha was .64, with a coefficient of .69 for standardized items.

As displayed in Table 2, within and across ANB subtests, LR scores were significantly and positively correlated with Trial 1 scores (*r*s ranging from .17 to .45), with a median correlation of .31.

Learning slope composites

Learning composite scores were generated on conceptual grounds; intercomposite score correlations showed a significant positive correlation between LR verbal composite with LR visual composite ($r = .39, p < 0.001$). In addition, LR noncontextual composite had a significant association with LR contextual composite ($r = .40$, $p < 0.001$). As with Trial 1 composites, we examined the internal consistency of LR scores across memory subtests, treating each subtest as an item for a Grand Composite scale. LR scores across

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Table 2. Bivariate correlations of LR across the ANB subtests

ANB test slope metric	LR ASMT	LR ALMT	LR AVMT	LR ACVMT
LR ASMT	1	.16**	.40***	.36***
LR ALMT		1	.17**	.15*
LR AVMT			.1	.43***
LR ACVMT				1

Note. *$p < 0.05$, **$p < .01$, ***$p < .001$.
ACVMT: African contextual visuospatial memory test; ALMT: African list memory test; ASMT: African story memory test; AVMT: African visuospatial memory test; and LR: learning ratio.

subtests correlated between .15 to .43, with a median of .27. Internal consistency analyses with LR indicated a Cronbach's alpha of .56 (.60 for standardized items). Corrected item-total correlations for LR were .44 (ACVT), .44 (ASMT), and .48 (AVMT). Relative to the other 3 subtests, ALMT shared a smaller corrected item-total correlation of .20. Within the Verbal Composite, LR from each measure correlated at $r = .16$ ($p < .01$). Within the Visual Composite, LR from each measure correlated at $r = .43$. For the Contextual Composite, LR from each measure correlated at $r = .36$. For the Noncontextual Composite, LR from each measure correlated at $r = .17$ ($p < .01$). Visual and Verbal Composites for LR correlated at $r = .39$ ($p < .01$). Contextual and Noncontextual Composites correlated at $r = .40$ ($p < .01$) for LR. The Grand Composite for LR significantly correlated with the other composite LR scores as follows: Visual ($r = .92$), Verbal ($r = .69$), Contextual ($r = .84$), and Noncontextual ($r = .83$); the Grand Composite for LR correlated with the other LR subtests as follows: ASMT ($r = .62$, $p < .001$), ALMT ($r = .42$, $p < .001$), AVMT ($r = .76$, $p < .001$), and ACVT ($r = .71$, $p < .001$).

Table 3. Initial learning and LR hierarchical regressions of ANB ($n = 254$)

	Total model $F(df)$, p, R^2	Incremental R^2 change, p
Initial learning	$F(4,247) = 75.59$, $p < .001$, $R^2 = .55$	
Step 1: Age		$R^2 = .25$, $p < .001$
Step 2: Education		Change $R^2 = .30$, $p < .001$
Step 3: Sex		Change $R^2 = .00$, $p = .801$
Step 4: Residence		Change $R^2 = .00$, $p = .152$
LR ASMT	$F(4,247) = 29.46$, $p < .001$, $R^2 = .32$	
Step 1: Age		$R^2 = .12$, $p < .001$
Step 2: Education		Change $R^2 = .20$, $p < .001$
Step 3: Sex		Change $R^2 = .00$, $p = .532$
Step 4: Residence		Change $R^2 = .00$, $p = .655$
LR ALMT	$F(4,247) = 3.70$, $p = .006$, $R^2 = .04$	
Step 1: Age		$R^2 = .03$, $p = .002$
Step 2: Education		Change $R^2 = .01$, $p = .054$
Step 3: Sex		Change $R^2 = .00$, $p = .295$
Step 4: Residence		Change $R^2 = .00$, $p = .966$
LR AVMT	$F(4,247) = 31.07$, $p < .001$, $R^2 = .34$	
Step 1: Age		$R^2 = .17$, $p < .001$
Step 2: Education		Change $R^2 = .15$, $p < .001$
Step 3: Sex		Change $R^2 = .01$, $p = .076$
Step 4: Residence		Change $R^2 = .00$, $p = .461$
LR ACVMT	$F(4,247) = 22.20$, $p < .001$, $R^2 = .26$	
Step 1: Age		$R^2 = .17$, $p < .001$
Step 2: Education		Change $R^2 = .09$, $p < .001$
Step 3: Sex		Change $R^2 = .00$, $p = .239$
Step 4: Residence		Change $R^2 = .00$, $p = .859$
LR verbal composite	$F(4,247) = 21.05$, $p < .001$, $R^2 = .25$	
Step 1: Age		$R^2 = .10$, $p < .001$
Step 2: Education		Change $R^2 = .15$, $p < .001$
Step 3: Sex		Change $R^2 = .01$, $p = .154$
Step 4: Residence		Change $R^2 = .00$, $p = .737$
LR visual composite	$F(4,247) = 29.83$, $p < .001$, $R^2 = .33$	
Step 1: Age		$R^2 = .21$, $p < .001$
Step 2: Education		Change $R^2 = .11$, $p < .001$
Step 3: Sex		Change $R^2 = .01$, $p = .116$
Step 4: Residence		Change $R^2 = .00$, $p = .474$
LR contextual composite	$F(4,247) = 17.45$, $p < .001$, $R^2 = .22$	
Step 1: Age		$R^2 = .14$, $p < .001$
Step 2: Education		Change $R^2 = .08$, $p < .001$
Step 3: Sex		Change $R^2 = .00$, $p = .847$
Step 4: Residence		Change $R^2 = .00$, $p = .673$
LR noncontextual composite	$F(4,247) = 22.02$, $p < .001$, $R^2 = .32$	
Step 1: Age		$R^2 = .18$, $p < .001$
Step 2: Education		Change $R^2 = .14$, $p < .001$
Step 3: Sex		Change $R^2 = .00$, $p = .566$
Step 4: Residence		Change $R^2 = .00$, $p = .429$
LR grand composite	$F(4,247) = 24.31$, $p < .001$, $R^2 = .28$	
Step 1: Age		$R^2 = .17$, $p < .001$
Step 2: Education		Change $R^2 = .11$, $p < .001$
Step 3: Sex		Change $R^2 = .00$, $p = .611$
Step 4: Residence		Change $R^2 = .00$, $p = .754$

Note. LR = learning ratio, demographics reflects participant age, education, sex, and residence.

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Table 4. ANB initial learning and LR grand composite age x education

	Age	Education 1–6	Education 7–12	Education 13–17	Education 18+	Total stratified by age
Initial learning	18–29	81.41 (19.25) $N = 5$	89.32 (14.30) $N = 8$	92.96 (16.58) $N = 18$	112.1 (18.62) $N = 13$	96.63 (19.43)
	30–39	62.58 (22.73) $N = 3$	75.83 (25.11) $N = 8$	90.63 (16.78) $N = 19$	110.45 (19.90) $N = 13$	91.74 (24.20)
	40–49	59.53 (20.30) $N = 6$	82.21 (21.68) $N = 16$	89.46 (23.59) $N = 7$	103.17 (15.40) $N = 12$	86.26 (24.04)
	50–59	56.32 (18.95) $N = 18$	63.42 (14.30) $N = 15$	80.85 (21.56) $N = 5$	114.62 (16.15) $N = 6$	69.48 (25.82)
	60–69	52.11 (19.64) $N = 19$	74.78 (27.78) $N = 14$	85.18 (17.10) $N = 6$	98.07 (47.85) $N = 3$	67.68 (28.41)
	70+	51.23 (20.16) $N = 19$	57.49 (14.11) $N = 16$	68.75 (26.22) $N = 4$	92.48 $N = 1$	56.52 (19.48)
				Total stratified by education		
		56.13 (20.51) $N = 70$	71.62 (22.04) $N = 76$	88.34 (19.00) $N = 59$	108.36 (19.58) $N = 49$	Stratified by age
Grand LR	18–29	.45(.15) $N = 5$	.48 (.12) $N = 8$	.35 (.11) $N = 18$	.59 (.14) $N = 13$	.55 (.14)
	30–39	.37 (.21) $N = 3$	.45 (.13) $N = 8$	.57 (.14) $N = 19$	.61 (.10) $N = 13$	.52 (.15)
	40–49	.40 (.17) $N = 6$	.43 (.21) $N = 16$	.43 (.18) $N = 7$	.58 (.09) $N = 12$	.47 (.18)
	50–59	.35 (.16) $N = 18$	.30 (.12) $N = 15$	.54 (.13) $N = 5$	.51 (.19) $N = 6$	.38 (.17)
	60–69	.29 (.14) $N = 19$	.40 (.16) $N = 14$	.45 (.19) $N = 6$	.49 (.22) $N = 3$	.37 (.17)
	70+	.25 (.12) $N = 19$	.35 (.11) $N = 16$	.48 (.13) $N = 4$	.34 $N = 1$	.32 (.13)
				Total stratified by education		
		.32 (.15) $N = 70$	.39 (.16) $N = 77$	.51 (.15) $N = 59$	.57 (.13) $N = 48$	

Note. All scores Mean (*SD*) unless otherwise indicated.

Effects of demographic factors

Comparing the relative effect of education and age on learning slope using the ANB

We conducted hierarchical regressions to explore whether demographic variables (age, education, sex, and residence) predict LR scores above the other by entering age in Step 1, education age in Step 2, sex in step 3, and residence in step 4. The incremental R^2 change showed that age and education significantly contributed to the models ($p < .001$). The overall models accounted for 28% of the variance in the LR Grand Composite for the ANB. Age added 17% variance while education contributed an additional 11% variance. However, sex and residence consistently accounted for minimal variance to the models as shown in Table 3. Given the lack of effect for sex and residence, the remainder of analyses were conducted on the demographic variables of age and education.

Effect of age and education on initial learning

After weighting across measures, initial learning scores varied from 96.63 ($SD = 19.43$) for the youngest cohort to 56.52 ($SD = 19.48$) for the oldest cohort (see Table 4). Table 4 provides scores of ANB initial learning and LR Grand Composite of age by education. There was a significant effect of age on initial learning [$F(5,253) = 18.46$, $p < .001$] such that performances were poorer for older age cohorts. Initial learning scores varied between 51.23 ($SD = 20.10$) and 121.10 ($SD = 18.62$) (see Table 4). There was a significant effect of education on initial learning [$F(5,253) = 69.99$, $p < .001$], such that more years of education was associated with significantly better initial learning. Table 5 presents regression equations for initial (Trial 1) learning scores for each subtest and for a weighted initial learning composite score.

Effect of age on learning slope

Table 6 provides means and standard deviations for LR subtest and composite scores across age groups, and Table 7 depicts regression equations for calculating expected LR scores based on age and education. These equations can serve as norms for ANB in the DRC. There were significant effects of age on LR for all ANB subtests and composites ($ps < 0.05$). For the grand composite, LR was significantly lower for older age cohorts than younger age cohorts [$F(5,253) = 14.73$, $p < .001$], a finding associated with a large effect size ($\eta^2 = .23$).

Table 5. Regression equations for demographically corrected scores on raw trial 1 scores for each ANB subtest

	$F(df)$, p, R^2	Equation	SE_{est}
ASMT	$F(2,251) = 26.92$, $p < .001$, $R^2 = 0.18$	7.31 – (age * 0.10) + (education * 0.44)	5.28
ALMT	$F(2,251) = 44.27$, $p < .001$, $R^2 = 0.26$	6.51 – (age * 0.03) + (education * 0.10)	1.47
AVMT	$F(2,251) = 56.55$, $p < .001$, $R^2 = 0.31$	5.91 – (age * 0.06) + (education * 0.25)	3.19
ACVMT	$F(2,251) = 81.97$, $p < .001$, $R^2 = 0.40$	1.79 – (age * 0.02) + (education * 0.25)	1.93
Initial learning composite	$F(2,251) = 150.06$, $p < .001$, $R^2 = 0.54$	59.37 – (age * 0.337) + (education * 2.99)	18.70

Note. ACVMT: African contextual visuospatial memory test; ALMT: African list memory test; ANB: African neuropsychology battery; ASMT: African story memory test; AVMT: African visuospatial memory test; LR: learning ratio; and SE_{est}: standard error of the estimate.

Effect of level of education on learning slope

Means and standard deviations for LR subtest and composite scores were stratified by level of education as presented in Table 8. There was a statistically significant advantage of education on LR across subtests and composites ($ps < 0.05$), with effect sizes ranging from small (AVMT $\eta^2 = .04$) to large (ASMT $\eta^2 = .30$, AVMT $\eta^2 = .28$, ACVMT $\eta^2 = .18$). There was a significant effect of education on the LR Grand Composite [$F(3,253) = 39.75$, $p < .001$], which was associated with a large effect size ($\eta^2 = .32$).

Discussion

The ANB is a set of culturally appropriate cognitive tests for the Sub-Saharan African countries (Ikanga et al., 2019). The current study derived and validated learning process scores for the ANB focusing on Trial 1 learning and learning slope. We described learning slope according to LR, a calculation that weighs the degree that learning improves across trials relative to the amount of information not learned in the initial attempt. Our findings are presented and discussed below.

Our data reveal a consistent pattern of positive intercorrelations among LR scores and between LR scores and Trial 1 learning scores. The first trial learning and learning slope both involve processes of learning and memory; therefore, we would reasonably expect these two metrics to positively correlate. Indeed, we observed a significant and positive correlation between LR and Trial 1 scores (*r*s ranged from .17 to .45), with a median correlation

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Table 6. ANB LR subtest and composite scores by age cohort

LR subtest/composite	Age cohort	*N*	Mean	*SD*
ASMT	18–29 years	44	.35	.19
	30–39 years	43	.34	.15
	40–49 years	41	.28	.17
	50–59 years	44	.22	.16
	60–69 years	42	.22	.12
	70 years and over	40	.20	.12
	Total	254	.27	.16
ALMT	18–29 years	44	.64	.27
	30–39 years	43	.57	.28
	40–49 years	41	.55	.23
	50–59 years	44	.51	.22
	60–69 years	42	.51	.26
	70 years and over	40	.48	.20
	Total	254	.54	.25
AVMT	18–29 years	44	.53	.26
	30–39 years	43	.54	.24
	40–49 years	41	.47	.29
	50–59 years	44	.39	.24
	60–69 years	42	.28	.26
	70 years and over	40	.22	.24
	Total	254	.41	.28
ACVMT	18–29 years	44	.91	.19
	30–39 years	43	.87	.23
	40–49 years	41	.73	.39
	50–59 years	44	.43	.68
	60–69 years	42	.53	.40
	70 years and over	40	.44	.42
	Total	254	.66	.46
Verbal composite	18–29 years	44	.46	.16
	30–39 years	43	.42	.13
	40–49 years	41	.38	.15
	50–59 years	44	.33	.14
	60–69 years	42	.34	.12
	70 years and over	40	.32	.10
	Total	254	.38	.14
Visual composite	18–29 years	44	.65	.22
	30–39 years	43	.63	.25
	40–49 years	41	.55	.28
	50–59 years	44	.42	.28
	60–69 years	42	.39	.25
	70 years and over	40	.31	.22
	Total	254	.49	.28
Contextual composite	18–29 years	44	.52	.20
	30–39 years	43	.48	.19
	40–49 years	41	.42	.21
	50–59 years	44	.30	.22
	60–69 years	42	.34	.20
	70 years and over	40	.31	.19
	Total	254	.39	.22
Noncontextual composite	18–29 years	44	.57	.19
	30–39 years	43	.55	.19
	40–49 years	41	.51	.20
	50–59 years	44	.43	.19
	60–69 years	42	.38	.20
	70 years and over	40	.32	.16
	Total	254	.46	.21

ACVMT: African contextual visuospatial memory test; ALMT: African list memory test; ANB: African neuropsychology battery; ASMT: African story memory test; AVMT: African visuospatial memory test; and LR: learning ratio.

Table 7. Regression equations for demographically corrected scores on subtest and aggregated LR scores

	F(df), p, R²	Equation	SE_{est}
ASMT	$F(2,251) = 59.19$, $p < .001$, $R^2 = 0.32$	0.147 – (age * 0.001) + (education * 0.015)	0.135
ALMT	$F(2,251) = 6.85$, $p = .001$, $R^2 = 0.05$	0.566 – (age * 0.002) + (education * 0.006)	0.242
AVMT	$F(2,251) = 60.30$, $p < .001$, $R^2 = 0.33$	0.324 – (age * 0.004) + (education * 0.021)	0.231
ACVMT	$F(2,251) = 43.92$, $p < .001$, $R^2 = 0.26$	0.687 – (age * 0.007) + (education * 0.027)	0.397
Verbal composite	$F(2,251) = 41.15$, $p < .001$, $R^2 = 0.25$	0.291 – (age * 0.001) + (education * 0.011)	0.124
Visual composite	$F(2,251) = 58.41$, $p < .001$, $R^2 = 0.32$	0.497 – (age * 0.005) + (education * 0.018)	0.230
Contextual composite	$F(2,251) = 34.97$, $p < .001$, $R^2 = 0.22$	0.399 – (age * 0.003) + (education * 0.012)	0.192
Noncontextual composite	$F(2,251) = 58.41$, $p < .001$, $R^2 = 0.32$	0.412 – (age * 0.003) + (education * 0.015)	0.172
Grand composite	$F(2,251) = 80.34$, $p < .001$, $R^2 = 0.39$	0.400 – (age * 0.003) + (education * 0.014)	0.139

Note. ACVMT: African contextual visuospatial memory test; ALMT: African list memory test; ANB: African neuropsychology battery; ASMT: African story memory test; AVMT: African visuospatial memory test; LR: learning ratio; and SE_{est}: standard error of the estimate.

of .31. By using LR, which accounts for the number of to-be-learned stimuli after trial one, we illustrated how slope and initial learning are distinct aspects of learning sharing similar underlying constructs. Such consistently positive correlations between Trial 1 learning and LR scores are often not observed when simple difference scores (RLS) are used to represent learning efficiency (e.g., Spencer et al., 2020; Wechsler, 1998).

LR robustly correlates with age and education. Learning is affected by (and therefore theoretically should correlate with) aging and general fund of knowledge (Shing & Brod, 2016). When using LR, we found age and education to predict 28% of variance in the learning slope grand composite score. Education was more strongly and consistently predictive of learning scores relative to age and accounted for an additional 20% variance in LR above and beyond age. In contrast, sex and location of residence did not significantly contribute to learning scores. As such, we suggest that ANB LR norms be based on age and education and sex and location of residence be excluded from normative calculations.

The variability in the literature about the utility of the learning slope as a sensitive marker for distinguishing normal cognition from MCI or mild dementia (Gifford et al., 2015; Thomas et. al., 2018) may be due to using RLS calculations for learning slope. Our findings support the use of LR to measure learning slope for the ANB. Although clinical applications of LR within the ANB require further investigation, it is encouraging that prior research in clinical samples using LR methodology in other learning tests has shown that LR differentiates between those with and without neurocognitive impairments (Spencer et al., 2020; Hammers et al., 2021a, 2021b) – with receiver operating characteristics area under the curve (AUC) in the acceptable to excellent range. Further, LR scores correlate significantly with other neuropsychological tests of memory, Alzheimer's-related biomarkers, hippocampal volume, and genetic risk for Alzheimer's (Hammers et al., 2021b, 2021c; Spencer et al., 2020). Similarly, we would expect LR scores from the ANB to show similar clinical utility, but additional research is needed.

From a clinical perspective, performances on trial 1 learning and LR can describe each test-taker's learning process, potentially leading to personalized recommendations for treatment and aftercare. Theoretically, performances on initial learning trials reflect how much information an individual learns following a single exposure, an experience that resembles many real-world encounters. Determining the degree of information patients learn through repetition, measured with LR, allows clinicians to determine when reiteration is fruitful versus futile, which informs the nature of compensatory strategies provided to the patient. When reiteration helps, clinicians can be sure that learning is likely with additional effort. When LR reflects a flat learning curve, however, continued repetition may cause frustration and yield minimal results, and

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Table 8. ANB LR subtest and composite scores by level of education

LR subtest/composite	Level of education	*N*	Mean	*SD*
ASMT	1–6 years	70	.18	.10
	7–12 years	77	.22	.14
	13–17 years	59	.34	.15
	18 years and more	48	.41	.15
	Total	254	.27	.16
ALMT	1–6 years	70	.52	.21
	7–12 years	77	.49	.21
	13–17 years	59	.58	.27
	18 years and more	48	.62	.30
	Total	254	.54	.25
AVMT	1–6 years	70	.24	.21
	7–12 years	77	.33	.24
	13–17 years	59	.53	.28
	18 years and more	48	.62	.22
	Total	254	.41	.28
ACVMT	1–6 years	70	.42	.40
	7–12 years	77	.58	.58
	13–17 years	59	.80	.29
	18 years and more	48	.94	.24
	Total	254	.66	.46
Verbal composite	1–6 years	70	.31	.11
	7–12 years	77	.33	.12
	13–17 years	59	.43	.13
	18 years and more	48	.48	.14
	Total	254	.38	.14
Visual composite	1–6 years	70	.33	.24
	7–12 years	77	.44	.26
	13–17 years	59	.60	.26
	18 years and more	48	.68	.22
	Total	254	.49	.28
Contextual composite	1–6 years	70	.29	.19
	7–12 years	77	.37	.22
	13–17 years	59	.46	.22
	18 years and more	48	.51	.16
	Total	254	.39	.22
Noncontextual composite	1–6 years	70	.35	.17
	7–12 years	77	.40	.17
	13–17 years	59	.54	.20
	18 years and more	48	.62	.17
	Total	254	.46	.21
	7–12 years	77	.39	.16
	13–17 years	59	.51	.15
	18 years and more	48	.57	.14
	Total	254	.43	.18

ACVMT: African contextual visuospatial memory test; ALMT: African list memory test; ANB: African neuropsychology battery; ASMT: African story memory test; AVMT: African visuospatial memory test; and LR: learning ratio.

patients are likely better served with instruction on external resources to aid with learning and memory. When both initial learning and learning curve are poor, treatment and daily living plans that compensate for poor learning are more likely to be beneficial.

This study has the strength of introducing ANB normative data acquired from sample representative of Congolese participants from various age decades, levels of education, gender, and location of residence. The study used four memory tests from both verbal and visuospatial modalities with similar task demands. We present trial 1 and LR data across age groups and levels of education and advise users of the tests to interpret results according to these factors. Users looking to account for both age and education jointly may wish to employ regression-based equations when interpreting ANB learning scores.

Despite these strengths, our study has limitations. First, exclusionary criteria were self-reported rather than from a review of medical records. Some participants could have had medical and/or neurocognitive disorders. In addition, some participants obtained perfect scores on Trial 1 of ACVMT and ALMT (8 and 12 items, respectively). Consequently, in some instances, this led to a negative learning slope score due to ceiling effects. Future studies should examine LR from the ANB across clinical disorders and factors impacting learning such as fatigue, sleep, substance abuse, and mood disorders.

Another limitation is that the participants in this study were administered the ANB either in French, Lingala, or both. Some participants who had difficulty understanding task instructions in French or Lingala were evaluated in other national languages of Congo (i.e., Kikongo, Tshiluba, or Swahili). Although the participants were multilingual, language proficiency across languages was not formally assessed, and it is unlikely that participants were equally fluent across languages. Since participants were not administered multiple language versions of the measure, we were unable to conduct any analyses that examined cross-language comparisons (Ikanga et al., 2022).

Although the ANB has the potential to be used in the SSA countries, its applicability requires some caution across all SSA countries. As Ikanga et al. (2022) have suggested, the SSA is not a "cultural monolith" and some memory items on ANB tests may not be culturally appropriate in each country in SSA. Therefore, national and regional adaptation to the ANB memory tests may be necessary to some degree. Finally, the educational system in SSA countries, and in the DRC especially, presents many challenges that result in a low overall quality of education for residents, which may impact performance on standardized neuropsychological tests. However, quality of education and its impact on memory tests performance were not assessed in this study and are an important direction for future research.

In summary, Trial 1 learning and LR have the potential to add clinically meaningful information when evaluating learning in Sub-Saharan Africa countries, especially in the DRC. Users of the ANB can examine initial learning and learning slope (measured by LR) within subtests or aggregated across subtests to discover how examinees acquire new information. Although total learning scores may appear equivalent using traditional metrics, there may be value in examining distinct paths to common endpoints. Process scores potentially illuminate junctures wherein the learning process breaks down for individual patients; such information has direct bearing on treatment interventions.

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