Preliteracy assessment in children living with HIV in Tanzania: comparison to results from children living without HIV in Tanzania and the United States

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Objective: Children with HIV (CWH) are at increased risk for cognitive and developmental delays. Whether HIV affects literacy development, however, remains unknown. Rapid automatized naming (RAN) tasks offer the simplest preliteracy assessment a child can perform that predicts future reading skills across languages.

Design and Methods: RAN performance was analyzed cross-sectionally on 473 children (249 children without HIV and 217 CWH; ages 3–9) drawn from a longitudinal study in Tanzania. These data were compared to results from 341 normally developing children without HIV (ages 3–8) from the United States. Participants performed two RAN subtests: colors and objects.

Results: RAN object completion was greater than for the RAN color in Tanzanian children. CWH were less likely to complete either subtest and performed worse on the object subtest compared to Tanzanian children without HIV. Compared to the US cohort, the Tanzanian cohort was less likely to complete both subtests - in particular the colors subtest - and showed more variability in responses at younger ages. After approximately age 6, however, the trajectory of improvement between the United States and Tanzania was similar.

Conclusions: CWH performed worse on this per-literacy test, indicating literacy skill development in CWH needs further study. The differences between US and Tanzanian results likely reflect variability in when children learn to name colors and objects. The trajectory of improvement between countries became more similar as the children aged. This study motivates further longitudinal analyses aimed at assessing the developmental trajectory of the RAN, its predictive ability for reading skills, and its link with other preliteracy and cognitive skills.

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Introduction

In the last decade, significant progress has been made in understanding the pathogenesis, burden, and impact of HIV infection on the central nervous system. Yet, significant gaps in knowledge remain, especially in young children with HIV [1,2]. Children exposed to or with HIV show cognitive deficits and developmental delays

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[2]. A recent study documented how children with HIV (CWH) in Tanzania performed worse than children without HIV on nonverbal cognitive tasks [3]. Whether HIV impairs literacy development, even with effective treatment, is still unknown. Determining if literacy skills are developing and maturing appropriately in CWH is important. Reading is a foundational skill and a precondition for active and responsible participation in society. Therefore, early identification and intervention for literacy deficits are both crucial to promote better functional outcomes [4].

The prekindergarten version of the rapid automatized naming test (Pre-K RAN, Pro-Ed, Inc.) is a simple and quick preliteracy assessment for children. It offers insight into the complex set of processes involved in learning to read. The RAN provides a robust early predictor of reading ability across languages [5,6]. Performance of this task, however, has not been examined in children in a developing country where HIV is prevalent.

The current study assessed RAN performance of children with and without HIV in Dar es Salaam, Tanzania. The current study is among the first to explore RAN performance in a developing country. Consequently, we examined the reliability of the data by comparing the developmental trajectory in RAN results from the Tanzanian sample to the trajectory from a sample of US children living in wealthy households that has been previously used in other studies [7,8].

Materials and methods

Participants

Tanzania cohort: Participants were part of a longitudinal study in Dar es Salaam, Tanzania. Based on data availability, 466 children between the age of 3 and 9 (mean 6.04 ± 1.64 years) were included for this crosssectional study. Among these children, 217 were HIVpositive (45.9%). Only a minority of the Tanzanian children (N = 141) had CD4⁺ cell percentage values. The results were $\geq 15\%$ in all cases reported [mean = 35.19%; standard deviation (SD) = 7.94; minimum = 16.22; maximum = 56.72]. 100% of the CWH are reported to be currently on antiretroviral therapy. Swahili was the prevalent language spoken across the children: therefore, all assessment was conducted in Swahili. The Dartmouth College Committee for the Protection of Human Subjects and the Research Ethics Committee of the Muhimbili University of Health and Allied Sciences (MUHAS) approved the research. A parent or guardian provided consent for the children to participate.

US cohort: Participants between the age of 3 and 8 (mean 4.8 ± 1.08 years) were part of a longitudinal study in the Chicago area, Illinois, USA. All children were without HIV. 171 participants were tested 1, 2, or 3 times annually

on the Pre-K rapid automatized naming (Pre-K RAN) task. 341 data points were included in the analysis, meaning that some participants have multiple datapoints collected over time included in the analyses (average number of visits is 2; 68 kids came for 1 visit only, 37 for 2 visits, 66 for 3 visits). Northwestern University approved all research procedures. Written informed assent and consent were obtained from the children and their legal guardians, and the children were monetarily compensated. Table 1 provides all demographic information for both Tanzania and US cohorts.

Self-report questionnaire

To assess socio-economic status (SES), a medical history and demographic questionnaire were completed for each participant. The questionnaires administered to the Tanzania and the US cohorts were different, but they both covered topics related to SES, like education, health problems, early life experiences, developmental milestones, information on household members, caregiver/ parent status, parental education and employment, quality of life, income.

Rapid automatized naming task – prekindergarten version

Rapid automatized naming was assessed using the colors and objects subtests taken from the Prekindergarten Rapid Automatized Naming developed by Maryanne Wolf and Martha Bridge Denckla (RAN/RAS test, 2005). The children were asked to name three rows of five colors and objects out loud as fast as he/she could. The time (in seconds) on each subtest was used to calculate RAN performance and represents the primary dependent variable for the statistical analyses.

Statistical analysis

Statistical analysis was performed with the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, Illinois, USA). Descriptive statistics were used to summarize demographic variables for both Tanzanian and US children (see Table 1.) and to describe Prekindergarten RAN performance for both Tanzanian and US children (see Table 2.).

For the Tanzania data, an overall socio-economic score was also computed using principal component analysis (PCA) among the most relevant variables (for more details, see [3]). The PCA output score was used in the statistical analysis performed within the Tanzania group to assess SES differences between CWH and children without HIV. It was also used as a demographic predictor within the binary logistic regression performed to capture which variables predict the ability to complete a RAN subtest.

Qualitative comparisons were made between the Tanzania and the US cohorts to characterize the two different population profiles. Three main measures

Tanzania cohort		Children without HIV	CWH	Total		
Sex	Total <i>n</i> Female Male	249 130 119	217 104 113	466 234 232	$\chi^2 = 0.851$	0.356
Age Years of education SES (overall PCA score) Range of annual household income in shilling [and in PPP \$]	Mean (SD) Mean (SD) Mean (SD) n = 77 n = 247 n = 112 n = 14	5.94 (1.64) 2.06 (1.63) .087 (1.036)	6.16 (1.64) 1.78 (1.48) -0.075 (.961) < 1 200 00-3 600 3 600 000-6 000 >\$	$\begin{array}{llllllllllllllllllllllllllllllllllll$		
US cohort		Female	Male	Total		
Sex Age Maternal Years education Estimate of \$ annual household income based on zip code	Mean (SD) Mean (SD) 25' percentile 50' percentile 75'percentile Min Max	154 4.8 (1.08) 17.75 (2.33)	187 4.8 (1.08) 171 \$57 \$78 \$79 \$23 \$24	341 4.8 (1.08) 572 5250 414 429 8 243	F = 0.000	P=0.995

Table 1. C	haracteristics	of the	participants from	Tanzania	(top)	and	US	(bottom).
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considered: (a) annual household income, (b) household assets and access to resources, (c) maternal education. As for the first measure (a), to index socio-economic status for US participants, a zip-code analysis was performed whereby median household income for each zip code was pulled from 2015 census data. As for the second measure (b), the comparison was based on an estimate due to lack of same data for the US cohort.

To test whether children in the three different groups (Tanzania HIV+, Tanzania HIV-, US HIV-) displayed comparable developmental trajectories, we ran regressions of the kind:

$$\mathrm{RAN} = \alpha + \beta_1 \mathrm{agc} + \sum_{i = \mathrm{HIV} + \imath + \mathrm{HIV} - \imath + \mathrm{US}} \beta_2^i gr_i + \sum_{i = \mathrm{HIV} + \imath + \mathrm{HIV} - \imath + \mathrm{US}} \beta_3^i gr_i * \mathrm{agc} + \varepsilon_i$$

where RAN was the result (in seconds) of either the colors or objects subtest and gr_i are dummy variables for each of the three groups. α is a constant which equals the value of Ywhen the value of X=0 and ε is the error term. We then tested the joint significance of the β_3^i coefficients. This analysis includes only children able to complete the RAN subtests.

Binary logistic regressions within the Tanzania dataset were estimated to capture the demographic variables that predict who was able to complete a RAN subtask. One regression was conducted for RAN colors and another for RAN objects. The covariates were age of the children when the assessment was performed, sex, HIV status, years of education, and SES (overall score).

Two separate univariate ANOVAs, one for the RAN colors and one for the RAN objects, with age as covariate, were performed to compare RAN performance between CWH and children without HIV within the Tanzania cohort.

Finally, two repeated measure ANOVAs were performed to compare RAN performance across the two subtests within the Tanzania and US samples separately.

Results

Participants' characteristics and demographics

Within the Tanzanian cohort, age, gender, years of education, and SES (overall PCA score) did not differ between CWH and children without HIV (Table 1). Within the US cohort, age did not differ between Female and Male (Table 1).

Table 2. Descriptive statistics of prekindergarten rapid automatized naming time (seconds to complete the task) for participants able to complete the tasks.

	Со	lors	Objects		
	Tanzania	US	Tanzania	US	
Mean (SD)	25.82 (16.81)	20.33 (10.34)	20.39 (10.68)	19.82 (8.18)	
Min	8.00	4.97	6.00	7.00	
Max	100.00	80.00	70.00	59.00	
N	182	332	406	341	

Tanzania and US cohorts are characterized by distinct socio-economic status

To illustrate the Tanzania and US populations' profiles and better visualize the different sets of results, qualitative comparisons between the Tanzania and the US cohorts were made for three different measures: (a) annual household income; (b) household assets and access to resources; and (c) maternal education.

Annual household income

Table 1 reports annual household income for Tanzania and US cohorts' families. To compare between currencies that account for differences in buying power between geographies, the purchasing power parity (PPP) was computed (PPP = 929.2 LCU/\$). Considering the PPP, within the Tanzania cohort most of the families in the study live on the equivalent of \$1296-\$3876 a year, whereas the median household income for the US cohort was \$78 250.

Household assets and access to resources

Among the various questions from the Tanzania selfreport questionnaire, three questions were selected to compare household assets and access to resources between Tanzania and US cohorts. The US data are the result of an estimate due the lack of data on these topics for the US cohort.

The first question refers to the *Source of Power for Boiling Water and Cooking* and its answers were coded with *Yes* if there was in-home availability and *No* if there was not (Tanzania: Yes = 92%; US: Yes = 100%). The second question refers to the presence of a *Refrigerator* in the house and the answers were coded with *Yes* or *No* depending on its presence (Tanzania: Yes = 43.6%; US: Yes = 100%). The third question is about the main *Source of Water* and its answers were coded with *House* or *Plot* depending on the provenance (Tanzania: house = 53.8%; US; house = 100%).

Maternal education

Data on years of maternal education have been collected within both cohorts. The Tanzania educational system operates on the 7-4-2-3 system: 7 years of primary school, 4 years of secondary school, 2 years of advance level, 3 years of college. In the Tanzania cohort most of the mothers completed their education with Primary school (7 years) or Secondary school (12 years), whereas in the US cohort most of the mothers went to college to pursue either a Bachelor (18 years), a Master (20 years), or a Doctoral degree (22 years).

Prekindergarten rapid automatized naming performance across groups

Among the Tanzania cohort, 284 children (60.9%) could not complete the Colors task and 60 children (12.8%) could not complete the Objects task. Among the US cohort, only nine children (2.7%) could not complete the Colors task; all US children were able to complete the Objects task. Descriptive statistics (mean and standard deviations) for the Rapid Automatized Naming task are reported in Table 2 for both Tanzania and US cohorts.

Age is the most important determinant of rapid automatized naming completion for Tanzanian children

The age of the child is the most significant predictor of the probability of completing either RAN subtest, followed by HIV status. Years of education and SES appeared to be important determinants of successful completion of RAN colors, but not RAN objects (Table 3).

Children in the different cohorts displayed comparable rapid automatized naming developmental trajectories, after age 6

The relationship between age and RAN performance is comparable across the three groups, considering data for children able to complete the RAN subtests. For the objects subtest, the N of datapoints included was 738 (N HIV-=229, N HIV+=168; N US=341). For the colors subtest, the N of datapoints included was 508 (N HIV-=106, N HIV+=70; N US=332). For both the objects and colors subtests, the interactions between age × group were not significant after age 6 (objects: F=0.056; P=0.946; $\eta p^2=0.000$; colors: F=0.589; P=0.556; $\eta p^2=0.006$). Before age 6, the interaction between age*group was significant for colors subtest (colors: F=14.796; P<0.001; $\eta p^2=0.061$) and not significant for objects subtest (objects: F=2.125; P=0.121; $\eta p^2=0.009$) (Fig. 1).

Children with HIV perform worse than children without HIV on the rapid automatized naming objects subtest

The covariate age is significantly related to participants' RAN colors performance, F(1, 179) = 14.479, P < 0.001 ($\eta p^2 = 0.075$). But, there was no significant effect of HIV group on participants' RAN colors performance after controlling for age, F(1, 179) = 0.123, P = 0.727 ($\eta p^2 = 0.001$).

The covariate age is also significantly related to participants' RAN objects performance, F(1, 403) = 238.560, P < 0.001 ($\eta p^2 = 0.372$). There was a significant effect of HIV group on participants' RAN objects performance after controlling for age, F(1, 403) = 13.613, P < 0.001 ($\eta p^2 = 0.033$) (Fig. 2).

Children perform worse on the rapid automatized naming colors subtest than the rapid automatized naming objects subtest in both Tanzania and United States

There was a significant main effect of the type of RAN subtest (colors vs. objects) on the participants' performance. In both Tanzania and US cohorts, among the participants who were able to complete both subtests,

Colors	, , , ,	В	SE	Wald χ^2	<i>P</i> -value
Step 1	Age	0.914	0.138	43.919	< 0.001
-	Sex	-0.037	0.259	0.021	0.886
	HIV	-0.663	0.274	5.833	0.016
	Years education	0.298	0.125	5.656	0.017
	SES	0.292	0.133	4.856	0.028
Objects		В	SE	Wald χ^2	P-value
Step 1	Age	1.510	0.276	30.025	< 0.001
	Sex	0.169	0.372	0.207	0.649
	HIV	-0.897	0.384	5.453	0.020
	Years education	0.642	0.359	3.189	0.074
	SES	0.244	0.203	1.442	0.230

Table 3. Results	of binary logistic	regression for	completion o	n the RAN	within the	Tanzanian cohort.
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RAN, rapid automatized naming; SE, standard error.



Fig. 1. Scatterplots displaying the relationship between age and RAN performance on each subtest (objects and colors) for Tanzanian CWH (red), Tanzanian children without HIV (black) and US children (purple). CWH, children with HIV; RAN, rapid automatized naming.



Fig. 2. Bar graph of mean RAN performance ± 1 SE shows that Tanzanian CWH performed worse than children without HIV for the Objects RAN subtest. No differences emerged for colors RAN subtest. CWH, children with HIV; RAN, rapid automatized naming; SE, standard error.

contrasts revealed that participants' performance at the RAN colors task was significantly poorer than the participants' performance on the RAN objects task [Tanzania: F(1,181) = 105.498; P-value < 0.001; $\eta p^2 = 0.368$; US: F(1,331) = 5.145; P-value = 0.024; $\eta p^2 = 0.015$).

Conclusion and discussion

This study offers a description of performance on the simplest version of the RAN test for CWH and children without HIV. It is also among the first explorations of pre literacy skills conducted in a developing country, Tanzania.

Despite significant differences in the socioeconomic background between Tanzanian and US cohorts, within the Tanzanian sample, and across the HIV status of participants, all cohorts displayed a comparable improvement of RAN performance with age, after approximately age 6. Moreover, children in both countries performed better on the RAN objects than the RAN colors subtest. These parallels support the reliability of the Tanzanian data.

There were differences between the Tanzanian and US cohorts on RAN performance. Notably, only 39% of the Tanzanian children involved in the study were able to complete the RAN colors subtest, compared to 97.3% of the US children. One likely explanation is that a successful RAN colors assessment requires the child to be familiar with colors. While such knowledge is commonplace in Western countries as young as 3 years old, that is not the case for Tanzanian children, who tend to master colors later in development. Relatedly, not only age but also other demographic variables (years of

education and HIV status) appeared to be significant predictors of RAN colors performance among the Tanzanian children who completed the test. This evidence is consistent with the conclusion that color mastery at a young age is not a primary focus in Tanzania as it is in Western cultures, and therefore color acquisition is influenced by other factors in a child's experience, including education and SES. Differences in word length, frequency, and semantic categories between Swahili and English complicate a direct cross-country comparison.

It is also possible that repeat data collected from the US cohort affected trajectory of RAN performance across age. The Tanzanian cohort was sampled from child's first visit, while the US cohort included multiple visits. That is, a learning effect, particularly for those seen three times could have skewed trajectories at later ages.

Within the Tanzanian children it was possible to analyze whether HIV status affects RAN performance because almost 46% of the Tanzanian children were living with HIV. CWH performed worse than children without HIV controls on the objects subtest, revealing a potential impact of HIV on literacy skills. This was not seen for the colors subtest. This may be due to the smaller sample size resulting from a large share of children not being able to complete the colors subtest in Tanzania, as already discussed.

This study opens interesting avenues for further research. First, it will be informative to assess and compare RAN performance of CWH to determine whether the gap between children without HIV and CWH is reduced over time. Second, RAN offers a predictive measure of future reading outcomes. Future studies could aim at exploring actual reading outcomes in CWH and in children without HIV. The current study design in Tanzania follows children longitudinally to monitor their development of literacy skills over time. Moreover, it will give us the opportunity to directly assess the RAN developmental trajectories across groups by following the same children over time rather than deriving the trajectory from the performance of cohorts of children of different age as we did in the present study.

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Conflicts of interest

There are no conflicts of interest.

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