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Do Neuropsychological Test Norms From African Americans in the U.S. Generalize to a Zambian Population?

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Abstract

Healthy Zambian adults ($N = 324$) were evaluated to determine to what degree a Western neuropsychological (NP) test battery, with African American norms adjusted for age, gender, and education could be used in healthy Zambians, including 157 (48.46%) men and 167 (51.54%) women with an average age of 38.48 ($SD = 12.80$) years and an average education level of 11.02

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($SD = 2.58$) years. The NP battery included tests of attention/working memory, executive function, verbal fluency, processing speed, verbal and visual episodic memory, and fine motor skills. The Zambian Achievement Test (ZAT) and the U.S. Wide Range Achievement Test-4 (WRAT-4) reading subtest also were administered to assess literacy and quality of education. Similar to findings in Western countries, the Zambian results show substantial age and education effects on most tests and smaller, less consistent effects of gender. Beyond the basic demographic effects, urban/rural background had small effects on some cognitive variables, and the ZAT (but not WRAT-4) reading level was a robust predictor of performance on many NP tests, even when other background characteristics were controlled. Women in the United States tend to outperform men on tests of processing speed and episodic memory, Zambian women showed modest but statistically significant disadvantages versus their male counterparts. The results show that tests developed in the United States may be used in Zambia, but development and use of local cultural norms remains very important and is a must. New demographically corrected norms were developed for the cohort that was examined.

Keywords

neuropsychological tests; neuropsychological performance; U.S. norms; Zambia; African Americans; cross-cultural; Zambian norms

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To perform a scientifically rigorous neuropsychological (NP) examination, normative standards that are appropriate for the individual or population being assessed are essential (Heaton & Marcotte, 2000; Heaton, Ryan, & Grant, 2009; Woods et al., 2004). The purpose of such standardization is to make the best possible judgment with respect to whether the observed pattern of test results is within expectations for people with this type of background, or reflects an acquired brain disorder. Most NP tests were originally standardized in the United States or Europe and the generalizability of the resulting normative standards to other countries is not universal.

Background differences can have major effects on NP test results when the tests are used in countries where people have different linguistic, cultural and educational experiences than the U.S. standardization sample (Nell, 2012). On the one hand, several studies have compared U.S. NP performances and those in Western Europe, for instance Norway, that indicate only minor differences across Western, industrialized countries (e.g., Egeland, Landrø, Tjemsland, & Walbækken, 2006; Egeland et al., 2005; Hestad, Dybing, Haugen, & Kløve, 1998; Hestad, Dybing, & Kløve, 1997; Hestad, Kløve, & Bylsma, 2003; Kløve, 1974;).

However, generalizability of Western norms to non-Western cultures is more difficult (Cysique et al., 2007; Gupta et al., 2011; Heaton et al., 2008; Kanmogne et al., 2010; Nell, 2012; Robertson, Liner, & Heaton, 2009). Norms developed in the United States and other Western countries typically have been based primarily upon middle class, community dwelling people who are relatively homogeneous with regard to Caucasian ethnicity as well as education (average high school with some college). Establishing norms across different cultures and social classes is difficult and complex. Interpretation of behavioral data for diagnosis and treatment is clearly subject to the effects of culture and uncertain equivalence

of cognitive/behavioral constructs across populations. We are dealing here with what are sometimes clearly defined deficits, but also human variety (differences) within and across cultures that should be recognized and accepted in our interpretations (Cole, 2013). The insidious harm caused by using norms not derived from the group in question, in order to arrive at judgments about their state of development or health, and the social challenges that arise when it is discovered that presumably immutable deficits attributed to individuals can be ameliorated or obliterated by changes in social practice are well recognized (Cole, 2013).

In recent years reference groups from minority groups in the U.S. population and in international settings has been increasingly used (Heaton, Miller, Taylor, & Grant, 2004; Lucas et al., 2005; Robertson et al., 2009).

In developing normative standards for NP tests, the longstanding practice has been to control for age, and eventually also for education and other demographic factors that may account for significant variance in the cognitive performance of healthy people. On most tests older people achieve lower scores than younger people, and people who are more highly educated typically perform better than people who are less educated. These and other factors (e.g., ethnicity and gender, for some tests) are therefore taken into consideration in the development of norms (Heaton et al., 2004; Hestad et al., 2003). Not only have typical levels of NP test performances differed across cultures, but normative demographic corrections often do not generalize well because of population differences in effects of aging, as well as education, gender and ethnicity in various international (especially non-Western) settings. For example, an influential factor is qualitative educational differences, even within the United States (Manly, 2005). Of note, even though people with different backgrounds may perform differently on NP tests, the validity of the tests (e.g., for detecting effects of brain disorders on cognition) may remain adequate as long as population-appropriate norms are used (Robertson et al., 2009; Heaton et al., 2008). This was demonstrated in people living with HIV disease in China (Cysique et al., 2007; Cysique et al., 2009; Heaton et al., 2008; Schrier et al., 2012; Spector et al., 2010) and in two recent pilot studies in Africa (Zambia and Cameroon); Hestad et al., 2012; Kanmogne et al., 2010). The present study aimed to determine the accuracy of a Western NP battery in a large sample of healthy adults in Zambia and to explore how well norms developed for African Americans performed in this African population. Our initial question was whether the Zambian participants evidenced any unusual difficulty understanding the standard NP test instructions, test stimuli and procedures. Because no serious difficulties of this nature were observed, we expected that the Zambian sample would show significant effects of basic demographics (age, education and gender) on test performance, but recognized that such effects may be different than those seen in the U.S. normative samples. For example, the cultural and familial roles of Zambian women may disadvantage them relative to men in ways that could affect cognitive test performance in adults (Hestad et al., 2012), whereas in the American women tend to outperform men on NP tests of processing speed and episodic memory, in particular (Heaton, Taylor, & Manly, 2003). With regard to effects of education in Zambia, there are reasons to suspect variability compared to Western countries and over time in Zambia itself. English has been the official language because the British colonial days, and is used in the school system, but a total of 10 major languages are spoken in various segments of the population and most citizens speak at least two local languages in

addition to English (Serpell, 2014). Also, while the school system in Zambia consistently has been based on an English model, major changes in the school system have occurred since the country achieved independence in 1964. These changes, in turn, may have affected the degree to which academic skills and perhaps other cognitive processes (e.g., communication skills, memorization vs. problem solving emphases) were developed and practiced during different time frames. Briefly, the first decade following political independence in 1964 saw a rapid growth in the numbers of indigenous Zambians enrolling in primary schooling, concurrently with the desegregation of the racially stratified school system established in the cities by the colonial government. Although the government invested heavily in the construction of new secondary schools and the national university, primary school infrastructure was not sufficiently expanded to accommodate the large number of new entrants, resulting in overcrowded classrooms with low teacher-to-student ratios. Shortly after independence, the government introduced into the lower primary school curriculum an immersion program in English, and phased it in nationwide around 1970. This resulted in a bimodal distribution of educational achievement. On the one hand, a relatively small group (about 30%) truly mastered the English language (which is used as a medium of communication at home in few Zambian families), facilitating better performance in the upper primary curriculum which has all along been offered in English. By contrast, another approximately 30% failed to master the language and left school after several years, virtually illiterate. Further complicating the educational landscape in Zambia across time, an economic recession began in the late 1970s and reached its nadir in the 1990s. This led to a drastic decline in the purchasing power of civil service salaries that resulted in demoralisation of the teaching service. During this same period, the AIDS pandemic struck the general population and the teaching service hard (1990s), further reducing the numbers of serving teachers, and pushing down the teacher-to-student ratios. The economic recession also made un-affordable the printing, distribution and purchase by families of teaching/learning materials such as textbooks. So, by the late 1990s students enrolled in public primary schools faced a combination of poorly designed curricula, minimal teaching/learning materials, understaffed, overcrowded classrooms and teachers employed with inadequate wages and often absent due to low morale and illness. Enrolment levels fell dramatically, and learning outcomes were generally considered to be poor. Then in the late 1990s and early 2000s, a large World Bank funded program called Basic Education Subsector Investment Program was introduced, that built new schools, provided new teaching-learning materials, and trained new teachers, resulting in much higher rates of enrolment than in the mid 1990s (World Bank, 2007). For these reasons we added a test of oral reading to the NP battery to explore whether there were also unique effects of quality of education as indexed by current reading skill in English (Byrd, Sanchez, & Manly, 2005). We chose to use the Zambian Achievement Test (ZAT) for this purpose, which is standardized for the Zambian school system (Stemler et al., 2009), with the premise that it might serve as an index of historical fluctuations in quality of Zambian education.

In turn, the reading scores may enhance demographic predictions of normal NP test performance in Zambia, and serve as a useful component of demographically corrected normative standards. We included also a reading test from the United States (Wide Range Achievement Test [4th ed.]; Wilkinson and Robertson, 2006) for comparison purposes,

because it is more widely used in other (especially Western) English-speaking countries. Because Zambian residents of urban versus rural areas are likely to have somewhat different cultural and socioeconomic backgrounds, we also were interested in determining whether there were differences in NP test performance in the urban areas relative to the countryside. Perhaps the most important practical question about the use of U.S. norms in Zambia is whether they may overclassify “impairment” in that population. If they do, we planned to provide new, demographically corrected NP norms based upon the current data set, which may facilitate future NP studies there and in other non-Western countries.

Method

Participant Recruitment

The sample was recruited in 2010 from medical clinics actively involved in HIV screening in both rural and urban areas. In 2009, an estimated 14.3% of Zambia’s 12.9-million population was infected with HIV, and Zambia is ranked seventh among the countries most affected by this epidemic (National AIDS Council, 2010). As a consequence a national priority has been to strongly encourage testing regarding HIV status throughout the country. The District Health Management Team (DHMT) of each district was approached to obtain permission to have access to the different health centers in their catchment areas. The DHMT also provided guidance on which clinics were classified as urban versus rural. Urban clinics were all in the Lusaka District, whereas the rural participants were from clinics in the Chongwe, Chibombo and Kafue Districts. The specific clinics were chosen as the recruitment areas for HIV-uninfected, normal adults because they were well placed for capturing confirmed HIV seronegative individuals without causing undue apprehension, as the clinics were carrying out routine voluntary counseling and testing services. Adults who tested negative were contacted as prospective participants for the present study. The actual identification of HIV negative individuals was done by the clinic staff who forwarded the contact details of the prospective participants to the research team after they were tested HIV seronegative on ELISA testing.

Procedure

Nine trained neuropsychology graduate students recruited and tested the 324 participants in single sessions that took an average of 2 hr 30 min per participant to complete. The students who did the testing were all individually trained under supervision to do the testing, followed by a practical and theoretical exam to ensure that they had the necessary qualifications to administer and score the tests. Supervision was performed by senior staff members of the neuropsychological laboratories at the University of California at San Diego; The Norwegian University of Science and Technology, Trondheim, Norway; and a clinical psychologist from Zambia.

The testing was carried out at the clinic where the participants were recruited. During a structured interview, prior to the test administration, participants were administered questionnaires with sections on demographic characteristics, as well as more detailed educational, medical, and psychiatric information. They were also asked about their drug and alcohol use practices in terms of frequency and recency of consumption, as well as the

typical amounts consumed per occasion. As a rule to ensure reliable test results, each test protocol was first scored by the examiner who administered the tests; the scoring was then repeated independently by a second examiner. Scoring changes in all protocols were then reviewed together with experienced examiners in a round table conference.

Subjects

Inclusion and exclusion criteria—Subjects could be included if they were HIV seronegative, had completed at least 5 years of schooling, with an age range between 20 and 65 years and having the ability to speak and understand English. Exclusion criteria were a history of any significant neurological or psychiatric conditions such as epilepsy, closed head injury with loss of consciousness, history of encephalitis, schizophrenia or bipolar disorders. A total of 324 healthy Zambian adults were recruited. They were 157 (48.5%) men and 167 (51.5%) women, with an average age of 38.5 ($SD = 12.80$) years and an average education level of 11.0 ($SD = 2.58$) years. The sampling strategy involved stratified recruitment by age group (range 20–65 years), education group (range 5–19 years), gender, and rural versus urban background (see Table 1). A total of 152 (46.9%) were of a rural background and 172 (53.1%) had an urban background. All participants could understand English, and their schooling had been in English. The medium of instruction for all Zambian schools from Grade 5 upward has always been English. With a minimum level of completed schooling of Grade 5, participants should all be able to read and understand English at a practical level. In practice, however, recent large-scale surveys of reading ability in Zambia's public schools have reported that in 2007 the percentage of Grade 6 learners able to read (in English) above Levels 1, 2, and 3 (prereading, emergent reading, basic reading) was only 24%. The percentage of those who could read beyond that was higher among urban and higher socioeconomic background pupils, but even in this group it did not exceed 50%. Therefore an apt description of the English literacy level of the group with the lowest range of schooling (primary, Grades 5 through 7) is highly variable, ranging from adequate for understanding basic written instructions through virtually illiterate. This is one of the reasons that formal reading assessment was undertaken in the current study. See Table 1 regarding the sample distribution according to demographic characteristics.

Age

Table 1 summarizes the distribution of age in the study sample. Age ranged from 20 to 65 years. Participants were grouped into age-range categories, and specified frequencies were targeted in the age ranges of 20–25, 26–35, 36–45, 46–55, and 56+ years.

Education

We counted only full years of regular academic coursework that were successfully completed. Years in which the person primarily was in special education placements, or in regular classes but obtained overall failing grades, are not counted. For example, a person who dropped out of school during the 11th grade would be given credit for 10 years, provided that he or she (at least reportedly) received passing grades in regular classes until that time. We have not counted vocational training in the years of education. We took into

consideration the education level as represented in Zambia Demographic Health Survey regarding our recruitment of participants.

Test Battery

The neurobehavioral examination with the structured interview took 2 to 4 hr to complete ($M = 2.5$ hours). It consisted of 17 NP tests that cover seven ability domains: verbal fluency, attention/ working memory, processing speed, verbal episodic memory, visual episodic memory, executive function, and motor skills (see Table 2 for listing of specific tests). For category and Wisconsin card sorting test computerized versions of the tests were used. Because oral reading skill may reflect quality of education (Manly, Touradji, Tang, & Stern, 2003), the levels of literacy based on the ZAT (O'Bryant et al., 2007; Ryan et al., 2005; Stemler et al., 2009) were included as potential supplements to years of education regarding academic achievement. The Reading (letter and word) Recognition subtest of the ZAT, which is an individually administered test constructed to quantify academic achievement in Zambian children of Grades 1 through 7 was included. Even though the test was made for children it can also be used for adults as the items contain words used in everyday language and the test is normed on grade level. As noted above, the WRAT-4 reading test also was administered; this is widely used in the United States and other Western, English speaking countries, but was not standardized with respect to item difficulty in Zambia. With the exception of the ZAT, virtually the same NP test battery has been used in ongoing and completed studies in the United States and several international sites (China, India, Brazil, Romania, Cameroon, South Africa), coordinated by the University of California-San Diego HIV Neurobehavioral Research Center (Kanmogne et al., 2010; Heaton et al., 2008; Heaton et al., 2010). The tests are well known NP instruments and have been widely used in neurobehavioral studies of HIV/AIDS (Gupta et al., 2011; Heaton et al., 2010; Heaton et al., 2008; Heaton et al., 2004; Hestad et al., 2012; Kanmogne et al., 2010; Woods et al., 2004). (Hestad et al., successfully used the tests in a pilot study in Zambia recruiting subjects from a HIV clinic in Lusaka.) However, in none of these sites has there been an effort to determine how the participants perform according to original U.S. norms. All participants in the current study were administered the neurobehavioral test battery in the same order, with standardized instructions. We made some accommodations of the HVLIT. All precious stones were changed to metals. For the learning trial, they were copper, iron, lead, and zinc. In the recognition trial, they were steel and bronze. The reason for this was that some of precious stones were not well known in Zambia. In addition, we used "Kwacha" (which is the currency used in Zambia) for the word "penny" in the Recognition Trial.

U.S. Norms

For some analyses the raw NP test scores were converted to normally distributed, uncorrected scaled scores ($M = 10$, $SD = 3$) and then demographically corrected T scores based on African American normative samples (Heaton et al., 2004; Norman et al., 2011). These T scores were corrected for age, education and gender, and in the U.S. normative samples had a mean of 50 and standard deviation of 10. A 1 standard deviation cutoff ($T < 40$) was used to determine "impairment" rates in the healthy Zambian sample based on the U.S. norms; expected, false positive error rates using this cutoff are approximately 16% (Heaton et al., 2004; Taylor & Heaton, 2001).

Development of Demographically Corrected Norms for Zambians

Two sets of norms were created. In the first set, scores were corrected for age (in years), education (in years), sex, and urban/ rural background. In the second set, ZAT was added to the list of demographic predictors. The development of Zambian norms essentially mirrored the process used to create the U.S. normative data. Specifically, raw test values were converted to normally distributed scaled scores by obtaining their standardized quantiles and scaling them to have a mean of 10 and standard deviation of 3, where higher values are always associated with better performance for comparability. Scaled scores were then regressed on demographic predictors listed above using fractional polynomials for numeric predictors (age, education, and ZAT). Fractional polynomials permit use of nonlinear terms (e.g., quadratic), if they show a statistically significant improvement ($p < .05$) over a simple straight line (Royston & Altman, 1994). The algorithm could choose between 36 linear combinations of power transformations: X^{-2} , X^{-1} , $X^{-0.5}$, $\log(X)$, $X^{0.5}$, X , X^2 , X^3 (where X is a numeric demographic predictor). Standardized residuals from the multivariable regressions were rescaled to form demographically corrected T scores ($M = 50$, $SD = 10$). Global scaled scores and T scores were calculated as averages of the relevant scores for individual tests. These analyses were performed with the statistical software R (R Core Team, 2013) and R package mfp (Ambler & Benner, 2010). Finally, in order to classify and quantify “impairment” on the total test battery, Global deficit scores (GDSs) were computed. These summary scores are based upon the demographically corrected T scores according to the procedure described in Heaton et al. (2004). Briefly, each NP Test T score was converted to a deficit score (DS) ranging from 0 to 5: DS 0 = $T > 40$, “normal”; DS 1 = $T 35-39$, “mild impairment”; DS 2 = $T 30-34$, “mild to moderate”; DS 3 = $T 25-29$, “moderate”; DS 4 = $T 20-24$, “moderate to severe”; DS 5 = $T < 20$, “severe.” The GDS is the average of these deficit scores, which reflects the number and severity of deficits on the total NP battery. The standard cutoff for impairment on the GDS is $> = 0.50$ (Carey et al., 2004; Heaton et al., 2004).

Ethical Consideration

At all stages of the study from data collection, data analysis and presentation of findings, ethical practices such as protecting confidentiality were carefully followed. Participants gave written consent after being explained and having read the study conditions, and after having been asked by the examiner if they understood the purpose of the study.

They were allowed to take breaks during the testing sessions if they felt fatigued. The participants were paid 50 Kwacha (about U.S.\$10.00) for the time spent undergoing the NP examination. The study was approved by the Research and Ethics Committee of the University of Zambia.

Results

Our first research question was whether the tests could be used in all the different Zambia study locations (rural and urban) without participants experiencing difficulty understanding and following the standard test instructions. The answer here was mainly yes. However, some participants in rural areas had difficulty repeating exact words from the Hopkins

Verbal Learning Test–Revised (HVLTR) list that had been read to them. As the list was being read, these participants seemed to associate the words they heard to other English words they knew, and did not seem to appreciate the instruction to remember the exact same words told to them. As a result, the examiners paid particularly close attention to the performance of these participants to ensure that the instructions were understood and followed. In addition, at times examiners had to give added instructions in nonstandard translations of vernacular or “revised English.” These observations and solutions were shared among the examiners and efforts were made to exclude any data that were considered invalid. Table 2 presents the NP test raw scores and their total variance accounted for by basic demographic variables, in combination.

Results on the U.S. *T* scores can be seen in Table 3, which range on average from 1 [1/2] standard deviation below the U.S. mean of 50 (Part A of Trail Making Test, $T = 34.0$) to about [1/2] standard deviation below for most tests, with the single exception of the WMS-III Spatial Span test of working memory that is close to the U.S. normative expectation ($T = 49.2$). Table 3 also compares the percentages of variance in the raw versus U.S. *T* scores that can be accounted for by the basic demographic variables of age, education and gender (column 3). Substantial demographic effects exist for the NP test raw scores, as expected, and that on most tests the R-squares are substantially reduced for the U.S. *T* scores. However, notable exceptions were present in which R-squares actually were higher for the *T* scores. Further analyses indicated that this tended to occur primarily on tests of processing speed (WAIS-III Digit Symbol and Symbol Search) and visual episodic memory (BVMTR Learning and Delayed Recall) on which African American women in the U.S. normative samples did better than their male counterparts, whereas the Zambian women did not. In effect, the U.S. norms “expected” women to have an advantage on these tests. The failure of Zambian women to surpass men on these tests resulted in a much larger “demographic effect” than existed in the raw scores. Finally, the last column in Table 3 indicates the percent of normal Zambian adults who would be classified as “impaired” ($T < 40$) by the U.S. norms. On virtually all tests, the false positive impairment rate greatly exceeded the expected 16% (actual median across tests = 40%, and the standard cutoff on the GDS based upon the U.S. norms classified 62% of healthy Zambians as impaired. Our data here clearly support a need for Zambian-specific norms.

We examined correlations between the raw NP test scores and each of the four demographic variables individually (i.e., age, education, gender, and rural/urban background), as well as educational quality (literacy) as indexed by ZAT versus WRAT-4. Urban background was associated with more years of education (mean years of education 11.67 urban vs. 10.28 rural, $t = -5.0$, $p < .001$) and younger age ($r = -.14$, $p = .01$). ZAT performance correlated strongly and positively with education ($r = .47$, $p < .0001$; vs. only $r = .14$, $p < .05$, for the WRAT-4), but ZAT’s association with urban/rural background was smaller ($r = .19$, $p = .001$) and even less with gender ($r = .13$, $p < .05$), with men performing somewhat better than women on the ZAT. The men had somewhat higher education as well, but not significantly so (mean years of education 11.21 vs. 10.84, $t = 1.3$, $p = .20$). Regarding the demographic background variables as predictors of Zambian NP performance, the results (all R-squares) are displayed in Table 4, both as univariable effects and combined effects of basic

demographics, urban/rural status, and ZAT literacy (last column in Table 4, based upon stepwise multiple regression analyses). The WRAT-4 was not included in the multivariable analyses because its univariable effects were much smaller than those of the ZAT and it never improved prediction achieved by ZAT alone. By contrast, the ZAT contributed significantly to the prediction of a majority of NP test results, even after effects of age, education, gender and urban/rural background were considered.

In every instance of a significant univariable demographic/ background effect on NP performance, better performance was associated with younger age, higher education, male gender, urban background and greater literacy (higher ZAT scores). On the overall NP test battery (uncorrected global mean scaled score) the strongest predictors of performance were age, education and ZAT, with much more modest (yet still statistically significant) effects of urban/rural status and gender. As expected, and consistent with findings in the United States and elsewhere (Heaton, Taylor, & Manly, 2003), the strongest age effects were seen on measures of processing speed (WAIS-III Digit Symbol and Symbol Search,) and visual episodic memory (BVM-T-R). Education and ZAT had rather widespread effects on NP performance, and were predictably strongest on the three verbal fluency tasks, followed by a math-related working memory task (PASAT 50), tests of processing speed (Trails A, digit symbol and symbol search) and a test of reading speed (Stroop Word reading subtest). Again, modest gender differences (favoring men) were seen, in particular on Animal Fluency and measures of working memory (the PASAT-50 and WMS-III Spatial Span). Participants from urban areas outperformed their rural counterparts on measures of processing speed (Trail Making Test A and WAIS-III Digit Symbol), even when all other demographic variables (age, education and gender) were statistically controlled. The last column in Table 4 indicates the amount of variance in each test's raw scores that can be accounted for by the demographic variables and ZAT reading in combination. Here the percentages are based upon the variance explained in a stepwise multiple regression analysis. Also the amounts of variance that can be accounted for by the predictors in various combinations are substantial, ranging from 8–38% on individual tests (median = 17%) and 50% on the total test battery (average scaled score). The formulas to convert the NP test raw scores to normalized scaled scores and then demographically corrected *T* scores are presented in Appendix. Two sets of demographic corrections are provided: one corrects for basic demographics (age, education, gender) and urban/rural status; the other also corrects for literacy and quality of education as indexed by the ZAT. All *T* scores from both sets of corrected norms have a mean of 50 and standard deviation of 10. Using a one standard deviation cutoff ($T < 40$) to classify “impairment” on the individual tests, the expected impairment rates for a normal sample is 16%. This cutoff is intended to provide a specificity of about 84% and optimize the balance between specificity and sensitivity to impairment that may be caused by central nervous system disorders (Taylor & Heaton, 2001). The actual “impairment” rates (false positive error rates) provided by the first set of Zambian *T* scores (without ZAT) across tests in our battery have a median of 16% (range 14–19%), and by the second set of *T* scores (with ZAT) also have a median of 16% (range 13–17%). These compare favorably with the much higher false positive error rates achieved by the U.S. *T* scores (see Table 3). When *T* scores on the NP battery were used to create global deficit scores for classifying overall impairment ($GDS \geq 0.50$), those impairment rates were 62%

for the U.S. norms (see Table 3) versus 14% and 12%, respectively, for the Zambian norms with and without ZAT.

Discussion

In this project a Western NP test battery was successfully used in a healthy adult population in Zambia. However, particularly with rural residents who have the lowest education levels (e.g., <8 years), examiners must be alert to test-takers who may not fully understand the test's requirements without violating the test instructions. In addition to language challenges among the least educated, people in Zambian rural areas may have little prior experience with standardized cognitive testing and may not fully appreciate the importance of what a test measures (e.g., processing speed or working memory). The effects of age and education on NP test performance were considerable, and generally consistent with prior findings from the U.S. and other international settings. Age and education typically have a stronger influence on these tests than gender. Age tends to have greatest influence on measures of so-called "fluid" abilities involving processing speed and episodic memory. Although education had its most salient effects on measures of verbal fluency, academic skills and processing speed, almost all NP scores had robust, positive correlations with education. In fact, processing speed showed comparable age and education effects in this sample of Zambian adults. The results presented here show that, overall, the U.S. norms are somewhat successful in correcting for demographic effects on NP testing in Zambia (see Table 3). These corrections are not entirely adequate, however, because statistically significant demographic effects remain on almost all tests. The practical ramifications of these effects, in addition to the excessively high false positive error rates seen with U.S. norms in Zambia, are that they support the need for Zambia specific norms, which we provide here in Appendix. An overall conclusion is that tests developed in the United States may be used in Zambia, but development and use of local cultural norms remains very important and is a must.

Of more general interest to international neuropsychology, however, may be the differential generalizability of specific demographic effects and normative corrections.

The U.S. norms generalized best for correcting the robust education effects apparent in Table 4. In most cases education effects were virtually eliminated on NP tests when the raw scores were converted to U.S. *T* scores; for example, while Table 4 shows that 25% of the variance in the total NP battery Global Mean Scaled Score is accounted for by years of education, this compares with zero percent for the mean U.S. *T* score. The success of the U.S. norms in correcting for education effects in Zambia may speak to the relative universality of basic years of education in enhancing peoples' abilities to perform standardized cognitive tests.

To index basic literacy and quality of education, we used an oral reading test developed in Zambia (the ZAT), in addition to the WRAT-IV that was developed in the United States. The fact that a performance-based measure of quality of education (i.e., ZAT) added significantly to basic demographics (including years of education) in predicting NP performance within this Zambian sample supports the importance of considering this factor

in NP test interpretation (Manly et al., 2002). Interesting the added, unique contribution of the ZAT in predicting NP performance was strongest on precisely those tests that showed the most robust effects of years of education completed (measures of verbal fluency, general processing speed, speed of simple reading, and working memory with a basic math component; Table 4). Performances on the Zambian, but not the United States, reading test were strongly correlated with years of schooling and, like education, explained large amounts of variance in results on the other NP tests (see Table 4). Moreover, the ZAT also explained unique amounts of variance in NP test scores beyond years of education and other demographic variables. A likely explanation for the superiority of the ZAT over the WRAT-IV in the Zambian (vs. United States) context is that, due to differences in cultural, linguistic (typically poly lingual) and educational backgrounds, English words have different frequencies of use, familiarity and degrees of difficulty for the persons included in the current study. Because there has been some variation in the quality of education the ZAT gave good additional information of the participants' formal reading levels, which hopefully to some degree controlled for some cultural disadvantages related to variation in the quality of education over time. To a small degree it mattered if people lived in urban or rural areas, which may also have to do with cultural disadvantages related to less exposure to informal educational experiences typical of a westernized society. However, as in the United States and Europe the two major demographic variables related to neuropsychological performance are age and education.

Age effects on Zambian NP test results were reduced by application of U.S. normative corrections as well; for example, age accounted for 18% of the variance in the uncorrected, global mean scaled score on the battery (see Table 4), versus only 8% for the United States demographically corrected global mean *T* score. However, the direction of the correlations was reversed (negative for uncorrected scaled scores, and positive for *T* scores), indicating that the U.S. norms overcorrected for the negative age effect in Zambia. This overcorrection was apparent on tests of most ability domains, including the Category and Stroop Incongruent tests of Executive Function, the PASAT-50 and WMS-III Spatial Span tests of Working Memory, the Trails A, Stroop Color Naming and Stroop Word reading tests of processing speed, the Grooved Pegboard test of Motor skills, and Verbal Episodic Memory (HVLIT-R Delayed Recall). One possible reason for this overcorrection is that the normative samples in the United States were somewhat older than the current Zambian sample (Heaton et al., 2004; Heaton, Taylor, & Manly, 2003; Norman et al., 2011), and a broader age range in the normative sample may increase the age effect. The best available African American norms for four tests in the current battery (i.e., HVLIT-R, BVMT-R, Stroop, WCST-64) were derived from the Norman et al. (2011) study, which included relatively few participants over the age of 60. Although the average ages of our total Zambian sample and the African American sample in Norman et al. (2011) were comparable (38.5 vs. 40.6 years), a possible concern is that the U.S. norms from Norman and colleagues might perform less well in the oldest Zambian subgroup (ages 56–65, $n = 41$). Given that all norms used in the current study are regression-based (i.e., not computed separately in each age cell), and age effects on neurocognitive tests tend to be quite linear (Heaton et al., 2003, 2009), we would not anticipate any major bias on this account. Nevertheless, to further address this possible concern we compared the older Zambian subgroup with their younger counterparts on mean

U.S. *T* scores for the four tests with Norman et al. norms, as well as on *T* scores from the rest of the test that were based upon African American samples with greater representation of older individuals.

The older subgroup had better performance than the younger group on both mean *T* scores (Norman: 46.6 (5.3) vs. 42.8 (6.6), $p < .001$; non-Norman: 43.7 (4.0) versus 41.5 (5.4), $p = .01$). The consistent finding that the older Zambians performed somewhat better, by U.S. standards, on tests having both types of U.S. norms, argues against a major problem with the Norman norms in the age ranges studied here.

Normative gender differences were the least generalizable between African Americans and Zambians. Whereas women in the United States tend to outperform men on tests of processing speed and episodic memory (Heaton et al., 2004; Heaton, Taylor, & Manly, 2003; Norman et al., 2011), Zambian women showed modest but statistically significant disadvantages versus their male counterparts. As a result, *T* scores based on the U.S. norms had an exaggerated gender effect in Zambia, and in the opposite direction, when compared to raw scores. Although female gender generally is associated with social and economic disadvantages worldwide, including in the United States, these disadvantages can be more pronounced in developing countries like Zambia, where greater gender inequalities in the forms of polygamy, subordination of women in families, increased poverty, discrimination and gender based violence (sometimes extending even to the school system) continue to exist (Bah, 2005; Hestad et al., 2012; Morna, Rama, Makamure, & Magarangoma, 2013). In this context a plethora of biological (e.g., access to optimal nutrition and health care) and psychological factors associated with female gender may influence development and expression of cognitive abilities. Thus, neuropsychologists should be alert that gender effects on NP tests may not generalize from Western, industrialized countries to the developing world. The women's more difficult situation can also be reflected in the serious HIV situation in the country. Almost all of the HIV transmission in Zambia is from heterosexual contacts. Thus women are more at risk for HIV-infection in Zambia than in United States and Europe. In fact, a majority of those infected with HIV in Zambia are females. This has led some researchers to say "the epidemic in Zambia has a female face" (Global Press Institute, 2012). Around 15% of Zambian adults are HIV+, with women accounting for almost 60% of these (Zambia Country Report, 2012; Zambia Demographic Health Survey, 2009), whereas in Latin America, Eastern Europe/Central Asia and Asia, only 30%–35% of those affected are women (Avert, 2012; Maki & Martin-Thormeyer, 2009).

The tests used in the present study were developed in the industrialized Western world among people with totally different cultural backgrounds from the Zambian experience (even though some of the schooling system in Zambia is inherited from England). We chose to compare the participants with African American norms. This was a pragmatic choice. It was expected that participants from Zambia would perform below the mean scores from the United States, whether they are based on Caucasians or African Americans. If we had used the "global U.S. norms" instead of the African American ones, the performance would have been worse relative to the norms used. The use of Western "reference" norms enhances the scope of the findings and makes it possible to assess effects of demographics across nations.

It could be debated whether African Americans are actually the best reference or if we should have used “global U.S. norms” with no ethnicity corrections. The ethnicity effects on neuropsychological data in the United States are influenced by “race” issues (Helms, 2012) with complex sociohistorical and socioeconomic effects specific to the United States and may not be relevant in the African context where the colonial history and current economies are quite different. But this is a complex discussion and we feel that there is no wrong or right answer at this stage, but an important issue for further research in international neuropsychology. The cultural contribution can also be seen on the two reading tests where the locally standardized ZAT was more relevant for the Zambian participants than the WRAT-IV.

The difference in test scores across countries with the same language can also be seen in different Spanish speaking countries even if age, education and gender distributions are similar in the participants examined (Buré-Reyes et al., 2013). The findings highlight the importance of cross-group differences between Spanish speakers. Overall, the norms used in cognitive testing should be relatively new. Performances on cognitive tests do not only vary between cultures, but also may vary within cultures across time. For instance, there has been a change reported in performance on IQ tests over time in many countries, which probably is related to cultural change and the length and quality of education (Sundet, 2010).

Because urban/rural status and the ZAT literacy measure enhanced prediction of NP test performance of normal Zambians, inclusion of these variables in the demographic corrections of Zambian NP test norms may increase their accuracy in evaluating people with possible brain disorders (e.g., neuroAIDS). We have chosen to develop separate normative corrections for future research and clinical work in Zambia, one set using only demographic variables (including urban/rural status) that will not be affected by brain disease or injury that is acquired in adulthood, and the other set using both demographics and the ZAT (which could be affected by some acquired neurological conditions such as certain dementing conditions; e.g., Ashendorf, Jefferson, Green, & Stern, 2009; Cockburn, Keene, Hope, & Smith, 2000; Roselli et al., 2009). Future work with neurological disease samples will determine which set of norms is best for which conditions, based upon demonstration of insensitivity of the ZAT to specific conditions of interest. Finally, the current norms might be studied for generalizability to populations in other African countries, especially those with similar, historic British colonial influences on language use and educational systems.

A limitation in our study could be that the participants were recruited from HIV-clinics and those who come there for testing may not be representative of the general Zambian population. However, one needs to understand the situation in Zambia regarding this devastating pandemic. The government has issued a general request for HIV-testing. Their argument is that, even if you yourself have not knowingly ever had a sexual practice that could have resulted in HIV-infection, your partner could have had such experiences.

In addition to governmental recommendations regarding HIV screening there are community meetings and cultural projects like big concerts related to being tested for HIV. Also, our subject sampling targeted appropriate age groups as well as education levels as represented in Zambia Demographic Health Survey. We included only participants who

were fluent English-speakers. Ardila et al., 2010 conclude in a literature review that literacy is strongly reflected in the performance of tasks used in psychological, as well as neuropsychological evaluations. The degree of literacy may in fact represent a crucial variable regarding validity of the neuropsychological performance (Ardila et al., 2010). On the basis of such conclusions, we elected not to include individuals with less than 5 years of formal education, so it is true that our results cannot be generalized to individuals with very low levels of education.

There are high drop out rates from school especially among girls. In Zambia, 6 million children under the age of 18 of which 4 million children are of the primary school age (7 to 14). Though Zambia made commendable progress in increasing access and gender parity, more than a quarter million children are out of school and 47% of those enrolled in school do not complete the primary cycle. (<http://www.unicef.org/zambia/education.html>). Significant progress has been registered by government in Zambian Basic Education between 2002 and 2009 mainly due to the declaration of free education from Grades 1 to 7 and the infrastructure development efforts. This has resulted in increased enrolment from 2.9 million children in 2004 to 3.6 million children in 2009 (Hamusunga et al., 2012). Adult education is the subsector for those adults who have not been able to attend any formal education or dropped out of school at an early stage. Only 68% of the Zambian population is literate. It is also estimated that of the 32% illiterate population, about 60% are women (Hamusunga et al., 2012).

With a sample size of 324 it is not possible to generalize to the Zambian population before more data is collected, but this is a start. Standardization samples from a population as diverse as Zambia for example, urban-rural, 10 different local dialects, educational changes in the recent past make this work difficult but not impossible. We have addressed that people who go to an HIV screening clinic in Zambia are not particularly unusual because they are encouraged to do so and virtually everyone who is sexually active has some potential risk for infection. Additionally, in anticipation of needing to create demographically corrected norms our recruitment strategy aimed to ensure adequate representation by age, education level and sex. Finally, because HIV infection is a common and important risk for central nervous system compromise in the Zambian population, recruitment of adults who have recently screened negative for HIV was considered a positive feature of the design.

The next step is to test out the test norms on patients with central nervous system dysfunctions (which we actually have started), and also perhaps translating the tests to local languages in similar age, education and gender samples to examine whether this will give different test results.

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Appendix. Zambian T-Score Formulas

Age/Education/Gender/Area

Gender: Male = 0; Female = 1

Area: Rural = 0; Urban = 1

Letter Fluency

$$[(\text{Letter Fluent scaled score} - ((-3.6680392 * (\text{age}/100)) + (4.7043701 * (\text{education}/100)) + (-0.2736719 * \text{gender}) + (0.3875785 * \text{area}) + 6.1371614)) / 2.631186] * 10 + 50$$

Animal Fluency

$$[(\text{Animal Fluency scaled score} - ((-2.9498905 * (\text{age}/100)) + (4.6226210 * (\text{education}/10)) + (-0.9650793 * \text{gender}) + (-0.3155616 * \text{area}) + 6.6404298)) / 2.567488] * 10 + 50$$

Action Fluency

$$[(\text{Action Fluency scaled score} - ((-1.291793 * (\text{age}/100)) + (4.4590152 * (\text{education}/10)) + (-0.144435 * \text{gender}) + (0.2362084 * \text{area}) + 5.6303680)) / 2.719982] * 10 + 50$$

Halstead Category Test Total Errors

$$[(\text{Category Total Errors scaled score} - ((-4.541264 * (\text{age}/100)) + (2.3591849 * (\text{education}/10)) + (-0.7701421 * \text{gender}) + (-0.1311255 * \text{area}) + 9.5923062)) / 2.858283] * 10 + 50$$

Color Trails 2

$$\begin{aligned} &[(\text{Color Trails 2 score} - ((-4.4832218 * (\text{age}/100) + (-5.5206012 * ((\text{education}/10)^{-2})) \\ &+ (-7.1477108 * (((\text{education}/10)^{-2}) * \ln(\text{education}/10))) + (-0.5797014 * \text{gender}) \\ &+ (0.4225714 * \text{area}) + 16.8753739)) / 2.710798] * 10 + 50 \end{aligned}$$

WCST-64 Total Errors

$$\begin{aligned} &[(\text{WCST- 64 Total Errors scaled score} - ((-6.7093954 * (\text{age}/100)) + (0.5632795 * (\text{education}/10)) \\ &+ (-0.7761147 * \text{gender}) + (0.3772005 * \text{area}) + 12.1441337) / 2.771825] * 10 + 50 \end{aligned}$$

PASAT

$$\begin{aligned} &[(\text{PASAT scaled score} - ((-3.156383 * (\text{age}/100)) + (3.6993606 * (\text{education}/10)) \\ &+ (-0.9348317 * \text{gender}) + (0.3927794 * \text{area}) + 7.4168364) / 2.716223] * 10 + 50 \end{aligned}$$

WMS-III Spatial Span Total

$$\begin{aligned} &[(\text{Spatial Span scaled score} - ((-37706216 * (\text{age}/100)) + (-5.4832244 * ((\text{education}/10)^{-2})) \\ &+ (-7.6263795 * (((\text{education}/10)^{-2}) * \ln(\text{education}/10))) + (-0.9821945 * \text{gender}) \\ &+ (-0.2839009 * \text{area}) + 17.0386891) / 2.83201] * 10 + 50 \end{aligned}$$

Trails A

$$\begin{aligned} &[(\text{Trails A scaled score} - ((-6.2434403 * (\text{age}/100)) + (3.0135120 * (\text{education}/10)) \\ &+ (-0.6295856 * \text{gender}) + (0.7254523 * \text{area}) + 9.0236729) / 2.650415] * 10 + 50 \end{aligned}$$

Color Trails 1

$$\begin{aligned} &[(\text{Color Trails 1 scaled score} - ((-4.75501419 * (\text{age}/100)) + (2.96685281 * (\text{education}/10)) \\ &+ (-0.38628064 * \text{gender}) + (-0.04603743 * \text{area}) + 8.78647943) / 2.784241] * 10 + 50 \end{aligned}$$

WAIS-III Digit Symbol Total

$$\begin{aligned} &[(\text{Digit Symbol scaled score} - ((-10.3408409 * (\text{age}/100)) * (3.3645982 * (\text{education}/10)) \\ &+ (-0.2459171 * \text{gender}) + (0.8511184 * \text{area}) + 9.9335611) / 2.428599] * 10 + 50 \end{aligned}$$

WAIS-III Symbol Search Total

$$\begin{aligned} &[(\text{Symbol Search scaled score} - ((-7.4482743 * (\text{age}/100)) + (3.3126273 * (\text{education}/10)) \\ &+ (-0.4657605 * \text{gender}) + (0.4060363 * \text{area}) + 9.1810352)) / 2.731799] * 10 + 50 \end{aligned}$$

Stroop Word Reading

$$\begin{aligned} &[(\text{Stroop Word scaled score} - ((-0.1727806 * (\text{age}/100)) + (-24.3670542 * ((\text{age}/100) \\ &* (\ln(\text{age}/100)))) + (3.3949336 * (\text{education}/10)) + (0.1120616 * \text{gender}) \\ &+ (0.277137 * \text{area}) - 2.3143198) / 2.819484] * 10 + 50 \end{aligned}$$

Stroop Color Naming

$$\begin{aligned} &[(\text{Stroop Word scaled score} - ((-14.822668 * (\text{age}/100)^3) + (1.1909431 * (\text{education}/10)) \\ &+ (0.6712742 * \text{gender}) + (0.6078574 * \text{area}) + 9.1401468) / 2.739282] * 10 + 50 \end{aligned}$$

Stroop Color-Word

$$\begin{aligned} &[(\text{Stroop Color- Word scaled score} - ((-3.5156999 * (\text{age}/100)) + (2.3378598 * (\text{education}/10)) \\ &+ (0.2835761 * \text{gender}) + (-0.4269484 * \text{area}) + 8.8589323) / 2.896093] * 10 + 50 \end{aligned}$$

HVLT Total Learning (Trials 1–3)

$$\begin{aligned} &[(\text{HVLT Total Learning scaled score} - ((-6.365841 * (\text{age}/100)) + (2.109299 * (\text{education}/10)) \\ &+ (-0.3104958 * \text{gender}) + (0.3971380 * \text{area}) + 10.0216279) / 2.730027] * 10 + 50 \end{aligned}$$

HVLT Delayed Recall

$$\begin{aligned} &[(\text{HVLT Delayed Recall scaled score} - ((-4.9617669 * (\text{age}/100)) + (2.8581991 * (\text{education}/10)) \\ &+ (-0.2800256 * \text{gender}) + (0.3777944 * \text{area}) + 8.6782526) / 2.88207] * 10 + 50 \end{aligned}$$

BVMT Total Learning (Trials 1–3)

$$\begin{aligned} &[(\text{BVMT Total Learning scaled score} - ((-9.1039079 * (\text{age}/100)) + (1.6409074 * (\text{education}/10)) \\ &+ (-0.6001684 * \text{gender}) + (0.5329455 * \text{area}) + 11.6656442) / 2.664311] * 10 + 50 \end{aligned}$$

BVMT Delayed Recall

$$\begin{aligned} &[(\text{BVMT Delayed Recall scaled score} - ((-7.5950457 * (\text{age}/100)) + (1.7130297 * (\text{education}/10)) \\ &+ (-0.6241801 * \text{gender}) + (0.5582945 * \text{area}) + 10.9211075)) / 2.715021] * 10 + 50 \end{aligned}$$

Grooved Pegboard Dominant Hand

$$\begin{aligned} &[(\text{Pegs Dominant scaled score} - ((-7.27232973 * (\text{age}/100)) + (2.76887705 * (\text{education}/10)) \\ &+ (-0.02025368 * \text{gender}) + (0.10307677 * \text{area}) + 9.7240779)) / 2.760837] * 10 + 50 \end{aligned}$$

Grooved Pegboard Non-Dominant Hand

$$\begin{aligned} &[(\text{Pegs Non- Dominant scaled score} - ((-5.9462873 * (\text{age}/100)) + (3.1366542 * (\text{education}/10)) \\ &+ (0.2253781 * \text{gender}) + (0.354455 * \text{area}) + 8.5237021)) / 2.755751] * 10 + 50 \end{aligned}$$

ZAT

$$\begin{aligned} &[(\text{ZAT scaled score} - ((1.4105772 * (\text{age}/100)) + (5.2811745 * (\text{education}/10)) \\ &+ (-0.6865138 * \text{gender}) + (0.3538396 * \text{area}) + 3.9645579)) / 2.558927] * 10 + 50 \end{aligned}$$

Zambian T-Score Formulas

Age/Education/Gender/Area/ZAT

Gender: Male = 0; Female = 1

Area: Rural = 0; Urban = 1

Letter Fluency

$$\begin{aligned} &[(\text{Letter Fluency scaled score} - ((-4.19971399 * (\text{age}/100)) + (2.91703441 * (\text{education}/10)) \\ &+ (0.02043121 * \text{gender}) + (0.25658015 * \text{area}) + (2.28677286 * (\text{ZAT}/10)) \\ &+ 4.78244778)) / 2.471446] * 10 + 50 \end{aligned}$$

Animal Fluency

$$\begin{aligned} &[(\text{Animal Fluency scaled score} - ((-3.5444249 * (\text{age}/100)) + (3.5039942 * (\text{education}/10)) \\ &+ (-0.9195234 * \text{gender}) + (-0.4846146 * \text{area}) + (2.0416356 * (\text{ZAT}/10)) \\ &+ 5.0714595)) / 2.576594] * 10 + 50 \end{aligned}$$

Action Fluency

$$\begin{aligned} &[(\text{Action Fluency scaled score} - ((-1.53473804 * (\text{age}/100)) + (3.17194124 * (\text{education}/10)) \\ &+ (-0.05205982 * \text{gender}) + (0.13395404 * \text{area}) + (1.70321373 * (\text{ZAT}/10)) \\ &+ 4.58846663)) / 2.597106] * 10 + 50 \end{aligned}$$

Halstead Category Test Total Errors

$$\begin{aligned} &[(\text{Category Total Errors scaled score} - ((-4.8397322 * (\text{age}/100)) + (0.4463110 * (\text{education}/10)^3) \\ &+ (-0.6761315 * \text{gender}) + (-0.1630125 * \text{area}) + (0.9109907 * (\text{ZAT}/10)) \\ &+ 10.2354966)) / 2.742551] * 10 + 50 \end{aligned}$$

Color Trails 2

$$\begin{aligned} &[(\text{Color Trails 2 scaled score} - ((-4.9974730 * (\text{age}/100)) + (-4.2210864 * (\text{education}/10)^{-2}) \\ &+ (-5.929742 * ((\text{education}/10)^{-2} * \ln(\text{education}/10)) + ((-0.434488 * \text{gender})(0.3430142 * \text{area}) \\ &+ (1.6574824 * (\text{ZAT}/10)) + 13.4497750)) / 2.647578] * 10 + 50 \end{aligned}$$

WCST-64 Total Errors

$$\begin{aligned} &[(\text{WCST- 64 Total Errors scaled score} - ((-6.8323806 * (\text{age}/100)) + (0.1456207 * (\text{education}/10)) \\ &+ (-0.7869193 * \text{gender}) + (0.3742284 * \text{area}) + (0.4244251 * (\text{ZAT}/10)) + 11.989286)) / 2.735508] \\ &* 10 + 50 \end{aligned}$$

PASAT

$$\begin{aligned} &[(\text{PASAT scaled score} - ((-3.6721994 * (\text{age}/100)) + (1.8860874 * (\text{education}/10)) \\ &+ -0.7318375 * \text{gender}) + (0.2342126 * \text{area}) + (2.5831592 * (\text{ZAT}/10)) \\ &+ 5.8884371)) / 2.547533] * 10 + 50 \end{aligned}$$

WMS-III Spatial Span Total

$$\begin{aligned} &[(\text{Spatial Span scaled score} - ((-3.9675172 * (\text{age}/100)) + (-4.9807419 * ((\text{education}/10)^{-2})) \\ &+ (-7.1455295 * (((\text{education}/10)^{-2}) * \ln(\text{education}/10))) + (-0.8383535 * \text{gender}) \\ &+ (-0.2734717 * \text{area}) + (0.6461047 * (\text{ZAT}/10)) + 15.5622007)) / 2.776151] * 10 + 50 \end{aligned}$$

Trails A

$$\begin{aligned} &[(\text{Trails A scaled score} - ((-6.6052518 * (\text{age}/100)) + (2.3452679 * (\text{education}/10)) \\ &+ (-0.5155693 * \text{gender}) + (0.7004568 * \text{area}) + (0.9861449 * (\text{ZAT}/10)) \\ &+ 8.4281262)) / 2.617884] * 10 + 50 \end{aligned}$$

Color Trails 1

$$\begin{aligned} &[(\text{Color Trails 1 scaled score} - ((-5.19964359 * (\text{age}/100)) + (2.16230983 * (\text{education}/10)) \\ &+ (-0.23785689 * \text{gender}) + (-0.09433938 * \text{area}) + (1.20585894 * (\text{ZAT}/10)) \\ &+ 7.85995502)) / 2.763519] * 10 + 50 \end{aligned}$$

WAIS-III Digit Symbol Total

$$\begin{aligned} &[(\text{Digit Symbol scaled score} - ((-10.53652110 * (\text{age}/100)) * (2.11861114 * (\text{education}/10)) \\ &+ (-0.07795244 * \text{gender}) + (0.71238325 * \text{area}) + (1.72066989 * (\text{ZAT}/10)) \\ &+ 8.67596973)) / 2.277676] * 10 + 50 \end{aligned}$$

WAIS-III Symbol Search Total

$$\begin{aligned} &[(\text{Symbol Search scaled score} - ((-7.5094508 * (\text{age}/100)) + (1.8936216 * (\text{education}/10)) \\ &+ (-0.2992734 * \text{gender}) + (0.3216508 * \text{area}) + (1.8660738 * (\text{ZAT}/10)) \\ &+ 8.0053263)) / 2.620382] * 10 + 50 \end{aligned}$$

Stroop Word Reading

$$\begin{aligned} &[(\text{Stroop Word scaled score} - ((-0.2434328 * (\text{age}/100)) + (-26.5491534 * ((\text{age}/100) \\ &* \ln(\text{age}/100))) + (1.9234559 * (\text{education}/10)) + (0.2059836 * \text{gender}) + (0.1437884 * \text{area}) \\ &+ (2.1183641 * (\text{ZAT}/10)) - 4.6399868)) / 2.656278] * 10 + 50 \end{aligned}$$

Stroop Color Naming

$$\begin{aligned} &[(\text{Stroop Word scaled score} - ((-15.38838574 * (\text{age}/100)^3) + (-0.01840777 * (\text{education}/10)) \\ &+ (0.80335610 * \text{gender}) + (0.43434863 * \text{area}) + (1.64315500 * (\text{ZAT}/10)) \\ &+ 7.94690169)) / 2.632398] * 10 + 50 \end{aligned}$$

Stroop Color-Word

$$\begin{aligned} &[(\text{Stroop Color- Word scaled score} - ((-3.6249634 * (\text{age}/100)) + (1.2921741 * (\text{education}/10)) \\ &+ (0.2677009 * \text{gender}) + (-0.4780440 * \text{area}) + (1.2153213 * (\text{ZAT}/10)) \\ &+ 8.1297669)) / 2.765723] * 10 + 50 \end{aligned}$$

HVLT Total Learning (Trials 1–3)

$$\begin{aligned} &[(\text{HVLT Total Learning scaled score} - ((-7.0135421 * (\text{age}/100)) + (1.3164819 * (\text{education}/10)) \\ &+ (-0.1791343 * \text{gender}) + (0.2885323 * \text{area}) + (1.2434030 * (\text{ZAT}/10)) \\ &+ 9.2296502)) / 2.794971] * 10 + 50 \end{aligned}$$

HVLT Delayed Recall

$$\begin{aligned} &[(\text{HVLT Delayed Recall scaled score} - ((-4.8842738 * (\text{age}/100)) + (1.7217325 * (\text{education}/10)) \\ &+ (-0.1720850 * \text{gender}) + (0.2769806 * \text{area}) + (1.3414290 * (\text{ZAT}/10)) \\ &+ 7.8606174)) / 2.699056] * 10 + 50 \end{aligned}$$

BVMT Total Learning (Trials 1–3)

$$\begin{aligned} &[(\text{BVMT Total Learning scaled score} - ((-9.3473297 * (\text{age}/100)) + (0.7514059 * (\text{education}/10)) \\ &+ (-0.4847848 * \text{gender}) + (0.4922592 * \text{area}) + (1.2219226 * (\text{ZAT}/10)) \\ &+ 10.8856273)) / 2.655178] * 10 + 50 \end{aligned}$$

BVMT Delayed Recall

$$\begin{aligned} &[(\text{BVMT Delayed Recall scaled score} - ((-7.7713469 * (\text{age}/100)) + (0.97952 * (\text{education}/10)) \\ &+ (-0.5489638 * \text{gender}) + (0.4944564 * \text{area}) + (1.0355204 * (\text{ZAT}/10)) \\ &+ 10.3148218)) / 2.693601] * 10 + 50 \end{aligned}$$

Grooved Pegboard Dominant Hand

$$\begin{aligned} &[(\text{Pegs Dominant scaled score} - ((-7.21917957 * (\text{age}/100)) + (2.68676398 * (\text{education}/10)) \\ &+ (0.04642314 * \text{gender}) + (0.08681296 * \text{area}) + (0.19684248 * (\text{ZAT}/10)) \\ &+ 9.28902213)) / 2.733832] * 10 + 50 \end{aligned}$$

Grooved Pegboard Non-Dominant Hand

$$\begin{aligned} &[(\text{Pegs Non-Dominant scaled score} - ((-6.1251701 * (\text{age}/100)) + (2.8743685 * (\text{education}/10)) \\ &+ (0.2666862 * \text{gender}) + (0.3718002 * \text{area}) + (0.3839779 * (\text{ZAT}/10)) \\ &+ 8.1902329)) / 2.786228] * 10 + 50 \end{aligned}$$

Table A1

	COWAT-FAS	Animals	Actions	
1		0–5		1
2	0–11		0–2	2
3	12	6	3–4	3
4	13		5	4
5	14–15	7	6	5
6	16–18	8–9	7	6
7	19–21	10	8	7
8	22–24	11	9	8
9	25–27	12	10	9

	COWAT-FAS	Animals	Actions	
10	28–30	13	11–12	10
11	31–34	14	13	11
12	35–37	15	14–15	12
13	38–41	16–17	16–17	13
14	42–45	18–19	18	14
15	46–50	20	19–20	15
16	51–54	21–22	21	16
17	55–56	23	22–23	17
18	57–63		24–25	18
19	64–80	24–80	26–80	19

Table A2

	Category errors	Color Trails 2	WCST total errors	
1	159–208		56–64	1
2	149–158		55	2
3	139–148		52–54	3
4	130–138		50–51	4
5	117–129	236–240	48–49	5
6	106–116	208–235	45–47	6
7	95–105	170–207	39–44	7
8	84–94	151–172	35–38	8
9	73–83	133–150	31–34	9
10	59–72	116–132	27–30	10
11	49–58	102–115	22–26	11
12	39–48	92–101	18–21	12
13	32–38	82–91	15–17	13
14	25–31	73–81	12–14	14
15	19–24	66–72	11	15
16	16–18	61–65	9–10	16
17	13–15	56–60	7–8	17
18	11–12	51–55	4–6	18
19	0–10	10–50	0–3	19

Table A3

	PASAT	Spatial Span	
1	0–1	0–2	1
2	2–4	3–6	2
3	5–6		3
4	7	7	4

	PASAT	Spatial Span	
5	8–9	8	5
6	10–12	9	6
7	13–14	10	7
8	15–17	11	8
9	18–20	12	9
10	21–22	13	10
11	23–26	14	11
12	27–30	15	12
13	31–34	16–17	13
14	35–39	18	14
15	40–41	19	15
16	42–47	20	16
17	48	21	17
18	49	22–27	18
19		28–32	19

Table A4

	Trails A	Color Trails 1	Digit Symbol	Symbol Search	
1			0–8	0	1
2		219–240	9–16	1	2
3		158–218	17–19	2–4	3
4	120+	139–157	20–22	5–6	4
5	102–119	119–138	23–25	7–9	5
6	90–101	107–118	26–30	10–11	6
7	78–89	90–106	31–35	12–13	7
8	66–77	75–89	38–40	14–15	8
9	57–65	67–74	41–45	16–18	9
10	50–56	57–66	46–50	19–20	10
11	43–49	51–56	51–56	21–23	11
12	38–42	45–50	57–65	24–26	12
13	34–37	40–44	66–72	27–29	13
14	31–33	35–39	73–76	30–31	14
15	28–30	31–34	77–84	32–33	15
16	25–27	25–30	85–93	34–39	16
17	23–24	23–24	94–103	40–42	17
18	21–22	18–22	104–116	43–44	18
19	10–20	5–17	117–133	45–60	19

Table A5

	Stroop Word	Stroop Color	Stroop Color-Word	
1	0–32	0–14	0–7	1
2	33–39	15–26	8–10	2
3	40–42	27–29	11–14	3
4	43–48	30–34	15–16	4
5	49–54	35–37	17–19	5
6	55–59	38–41	20–21	6
7	60–63	42–45	22–24	7
8	64–68	46–49	25–26	8
9	69–73	50–54	27–30	9
10	74–80	55–57	31–33	10
11	81–85	58–61	34–35	11
12	86–89	62–65	36–39	12
13	90–94	66–69	40–42	13
14	95–98	70–73	43–44	14
15	99–105	74–77	45–49	15
16	106–110	78–82	50–55	16
17	111–114	83–94	56–64	17
18	115–139	95–101	65–75	18
19	140–150	102–133	76–133	19

Table A6

	HVLT Total Recall	HVLT Delayed Recall	BVMT Total Recall	BVMT Delayed Recall	
1	0–4	0	0–1		1
2	5–10	1	2	0	2
3	11	2	3		3
4	12–13	3	4	1	4
5	14–15		5–6	2	5
6	16	4	7–8	3	6
7	17–18	5	9–10	4	7
8	19	6	11–13	5	8
9	20–21	7	14–17	6–7	9
10	22		18–19	8	10
11	23–24	8	20–23	9	11
12	25	9	24–26	10	12
13	26–27	10	27–28	11	13
14	28		29–30		14
15	29–30	11	31–32	12	15
16	31		33–34		16
17		12	35–36		17

	HVLT Total Recall	HVLT Delayed Recall	BVMT Total Recall	BVMT Delayed Recall
18	32–34			18
19	35–36			19

Table A7

	Pegs Dominant	Pegs Nondominant	ZAT	
1	255–301	295–301	0	1
2	213–254	273–294	1–2	2
3	169–212	245–272	3	3
4	145–168	178–244	4–5	4
5	134–144	145–177	6–7	5
6	115–133	127–144	8	6
7	105–114	115–126	9–10	7
8	93–104	104–114	11–12	8
9	81–92	94–103	13–14	9
10	76–80	87–93	15	10
11	72–75	82–86	16	11
12	68–71	77–81	17	12
13	65–67	73–76	18	13
14	61–64	70–72	19	14
15	58–60	66–69		15
16	53–57	64–65	20	16
17	49–52	57–63		17
18	39–48	33–56		18
19	0–38	0–32		19

Figure 1.
Education distribution (years completed).

Table 1
Demographic Characteristics of Zambian Adult Subject Sample (Percentage of Total Population, N = 324)

Age range in years (<i>n</i>)	Gender		Place of residence		Education				
	Male	Female	Rural	Urban	5–7 years (primary)	8–9 years	10–11 years	12 years (high school)	13+ years (college)
20–35 (129)	64 (19.8%)	65 (20.1%)	62 (19.1%)	67 (20.7%)	12 (3.7%)	26 (8.0%)	17 (5.3%)	44 (13.6%)	30 (9.3%)
36–45 (89)	47 (14.5%)	42 (13.0%)	37 (11.4%)	52 (16.1%)	2 (0.6%)	20 (6.2%)	20 (6.2%)	26 (8.0%)	21 (6.5%)
46–55 (65)	22 (6.8%)	43 (13.3%)	33 (10.2%)	32 (9.9%)	13 (4.0%)	11 (3.4%)	22 (6.8)	5 (1.5%)	14 (4.3%)
56–65 (41)	24 (7.4%)	17 (5.3%)	20 (6.2%)	21 (6.5%)	7 (2.2%)	14 (4.3%)	8 (2.5%)	1 (0.3%)	11 (3.4%)

Table 2

Neuropsychological Test Raw Scores (M, SD) in the Zambian Sample (N = 324)

Neuropsychological tests	Raw scores <i>M</i> (<i>SD</i>)
Letter fluency	29.10 (9.65)
Animal fluency	12.92 (3.65)
Action fluency	11.86 (4.05)
Category test	68.18 (30.46)
Color Trials 2	141.86 (72.53)
WCST-64, Total errors	28.94 (11.42)
PASAT 50	22.61 (9.33)
WMS-III Spatial Span	13.04 (3.17)
TMT-A	59.11 (26.16)
Color Trails 1	69.00 (34.49)
WAIS-III Digit Symbol	48.63 (16.83)
WAIS-III Symbol Search	19.72 (7.72)
Stroop Word	75.93 (15.11)
Stroop Color	54.73 (11.72)
Stroop Incongruence	31.29 (8.65)
HVLT-R Learning	21.71 (4.55)
HVLT-R Delayed Recall	7.33 (2.26)
BVMT-R Learning	18.26 (8.18)
BVMT-R Delayed Recall	7.39 (3.25)
Grooved Pegboard DH	87.80 (26.90)
Grooved Pegboard NDH	100.29 (34.40)
ZAT	14.31 (4.04)
WRAT-IV	39.50 (10.94)

Note. WCST-64 = Wisconsin Card Sorting Test–64 Card Version; PA-SAT = Paced Auditory Serial Addition Task; TMT-A = Trail Making Test–A; WAIS-III = Wechsler Adult Intelligence Test–3rd ed.; HVLT-R = Hopkins Verbal Learning Test–Revised; BVMT-R = Brief Visuospatial Memory Test–Revised; DH = dominant hand; NDH = nondominant hand; ZAT = Zambian Achievement Test; WRAT-IV = Wide-Range Achievement Test–4th Edition.

Table 3

Zambian Healthy Adults' (N = 324) Neuropsychological T-Scores Based Upon African American Norms, Percent Variance in Test Raw Scores vs. T-Scores Accounted for by Basic Demographics (Age, Education, and Gender), and Percentage "Impaired" According to U.S. norms ($T < 40$)

Neuropsychological test	U.S. <i>T</i> -score <i>M</i> (<i>SD</i>)	Basic demographic effects: Raw/U.S. <i>T</i> -score	Impaired by U.S. norms
Letter fluency	44.9 (8.2)	.23/.01	26%
Animal fluency	39.5 (8.1)	.22/.02	52%
Action fluency	40.7 (7.1)	.17/.01	49%
Category test	44.2 (12.1)	.10/.08	35%
WCST-64, Total errors	46.2 (10.2)	.12/.08	29%
Stroop Incongruence	43.2 (12.2)	.05/.30	39%
Stroop Word	40.0 (9.4)	.11/.18	47%
Stroop Color	39.4 (8.8)	.13/.18	52%
TMT-A	34.0 (10.2)	.18/.07	68%
WAIS-III Digit Symbol	40.7 (8.9)	.32/.18	52%
WAIS-III Symbol Search	41.7 (9.1)	.21/.07	40%
PASAT 50	40.0 (8.9)	.19/.06	48%
WMS-III Spatial Span	49.2 (9.8)	.09/.06	18%
HVLT-R Learning	41.7 (8.1)	.14/.11	43%
HVLT-R Delayed Recall	43.9 (7.7)	.12/.14	31%
BVMT-R Learning	45.4 (12.0)	.22/.07	34%
BVMT-R Delayed Recall	46.5 (13.6)	.17/.07	32%
Grooved Pegboard DH	42.6 (11.1)	.17/.04	40%
Grooved Pegboard NDH	42.2 (10.6)	.15/.08	40%
Global mean ^{a,b}	42.3 (5.3)	.37/.18	62%

Note.

^aFor "Global mean," the first R^2 in Column 3 used average of uncorrected, standardized scaled scores ($M = 10$, $SD = 3$, for all tests) instead of raw scores.

^bPercent impaired for U.S. norms for total test battery is based on global deficit score cutoff of $.50$.

Table 4

Percentage Variance in Neuropsychological Test Raw Scores Accounted for, Individually, by Basic Demographics (Age, Education, Gender) Rural vs. Urban Residence, ZAT Reading Score, and WRAT-IV Reading Score, and by the Combined Basic and Extended Demographics (Excluding the WRAT-IV)

Neuropsychological test	Age	Education	Gender	Urban/rural	ZAT	WRAT-IV	Combined ^a
Letter fluency	5%	20%	0%	4%	19%	5%	31%
Animal fluency	4%	18%	4%	0%	16%	2%	26%
Action fluency	1%	17%	0%	2%	13%	2%	20%
Category test	5%	5%	2%	0%	5%	0%	12%
Color Trails 2	3%	7%	1%	0%	9%	3%	14%
WCST-64, Total errors	10%	1%	3%	0%	1%	0%	14%
TMT-A	9%	11%	1%	2%	5%	1%	20%
WAIS-III Digit Symbol	23%	13%	1%	5%	12%	3%	39%
WAIS-III Symbol Search	12%	11%	1%	2%	12%	0%	27%
Stroop Word	1%	11%	0%	2%	13%	3%	18%
Stroop Color	9%	3%	1%	2%	5%	0%	18%
Stroop Incongruence	3%	3%	0%	0%	4%	0%	9%
HVLT-R Learning	10%	6%	0%	2%	6%	1%	17%
HVLT-R Delayed recall	5%	8%	1%	2%	8%	1%	15%
BVMT-R Learning	18%	6%	2%	2%	5%	0%	25%
BVMT-R Delayed recall	12%	5%	2%	2%	5%	0%	19%
PASAT 50	4%	14%	4%	3%	19%	2%	28%
WMS-III Spatial Span	4%	4%	3%	0%	3%	0%	11%
Grooved Pegboard DH	10%	9%	0%	0%	2%	0%	18%
Grooved Pegboard NDH	7%	10%	0%	1%	2%	0%	16%
Global mean scaled score	18%	25%	2%	4%	26%	2%	50%

Note.

^a Includes all basic and extended demographic variables except WRAT-IV reading score.