Construct validity of Hopkins Verbal Learning Test—Revised component process measures in an HIV-1 sample

Steven Paul Woods *, J. Cobb Scott, Matthew S. Dawson, Erin E. Morgan, Catherine L. Carey, Robert K. Heaton, Igor Grant, The HIV Neurobehavioral Research Center (HNRC) Group

Abstract

Executive dyscontrol of episodic verbal learning and memory secondary to prefrontostriatal circuit neuropathophysiology is a common feature of HIV-1 infection. Prior research indicates that standard clinical learning and recall indexes from Hopkins Verbal Learning Test—Revised (HVLT-R) are among the most sensitive indicators of HIV-associated neurocognitive disorders. Emerging data support the validity of qualitative component process measures derived from the HVLT-R (e.g., Semantic Clustering); however, no prior studies have examined these particular indices of performance in an HIV-1-infected population. In the present study, we examined the construct validity of HVLT-R component process indices in a sample of 42 persons with HIV-1 infection and 29 demographically similar seronegative comparison participants. The HIV-1 sample performed significantly below the seronegative group on Total and Delayed Recall, Semantic Clustering, and the Retrieval Index. No between-group differences were observed on Serial Clustering, Pair Frequency, Learning, Repetitions, Semantic False Positive Recognition Errors, or the Recognition Discrimination Index. In addition, the HVLT-R component process measures demonstrated evidence of convergent and divergent validity with standard clinical tests in the HIV-1 sample. Findings support the construct validity of HVLT-R component pro-

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cess measures and are commensurate with prior literature indicating that HIV-1 disease is associated with deficient executive control of encoding and retrieval within verbal episodic memory.

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The Hopkins Verbal Learning Test—Revised (HVLT-R; Brandt & Benedict, 2001; Benedict, Schretlen, Groninger, & Brandt, 1998) was originally designed to provide a brief and user-friendly measure of episodic verbal memory in clinical and research settings. The literature generally supports the reliability (Benedict et al., 1998) and construct validity of the standard learning and recall measures on the HVLT-R, including evidence of their convergent (e.g., Lacritz, Cullum, Weiner, & Rosenberg, 2001), concurrent (e.g., Shapiro, Benedict, Schretlen, & Brandt, 1999), predictive (e.g., Kuslansky et al., 2004), and discriminant (e.g., De Jager, Hogervorst, Combrinck, & Budge, 2003) validity.

Emerging evidence also supports the construct validity of the HVLT-R for the purpose of examining more specific component process aspects of encoding, consolidation, and retrieval (e.g., Bruce & Echemendia, 2003; Woods, Rippeth, et al., 2005), which are indices more commonly associated with the California Verbal Learning Test (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000). Examination of the HVLT-R component process indices can reveal the underlying cognitive mechanisms of observed memory deficits, which might facilitate differential diagnosis and remediation efforts (Delis, Jacobson, Bondi, Hamilton, & Salmon, 2003; Poreh, 2000). For example, Bruce and Echemendia (2003) utilized the HVLT-R semantic clustering index as a measure of the executive aspects of memory recovery in mild traumatic brain injury (Bruce and Echemendia, 2003). More recently, Woods, Rippeth, et al. (2005) used the HVLT-R in the context of Moscovitch’s (1992, 1994) component process model to elucidate the learning and memory deficits in persons with methamphetamine dependence. The latter study also supported the convergent validity of the HVLT-R component process measures in healthy comparison subjects (e.g., semantic clustering was associated with HVLT-R Total and Delayed Recall, as well as with measures of executive functions).

Standard clinical learning and recall indexes from the HVLT-R are among the most sensitive indicators of neuropsychological impairment in persons with HIV-1 infection (Carey et al., 2004). However, no prior studies have used the HVLT-R to examine the profile of memory deficits in HIV-1 infection; accordingly, the present study was initiated to examine the construct validity of the HVLT-R component process measures in an HIV-1 sample. Consistent with a prefrontostriatal neuropathogenesis, prior research in HIV-1 using the CVLT has revealed deficits in free recall, inconsistent recall across learning trials, repetition errors, and diminished semantic clustering (Becker et al., 1995; Delis et al., 1995; Peavy et al., 1994). Such impairments are contrasted with deficits in consolidation (i.e., forgetfulness) that are not common in HIV-1 (e.g., Delis et al., 1995). Thus, the profile of memory deficits in HIV-1 infection is thought to reflect deficient executive control of encoding and retrieval (Murji et al., 2003).

In light of this prior literature, we hypothesized that persons with HIV-1 would demonstrate impairment on HVLT-R component process measures of semantic clustering, repetitions, and
a retrieval index (i.e., recognition discrimination minus delayed free recall), but not on mea-
sures of retention, intrusions, or recognition discrimination. We also hypothesized that the
three HVLT-R component process measures that were expected to discriminate HIV-1 from
seronegative comparison subjects would correlate with putative clinical measures of executive
functions, but would not correlate with non-executive tasks (e.g., constructional praxis).

1. Method

1.1. Participants

The study sample was comprised of 29 healthy comparison (HC) participants and 42 indi-
viduals with HIV-1-infection (HIV-1) as indicated by enzyme-linked immunosorbent assays
(ELISA) and a Western blot confirmatory test. Note that, an a-priori power analysis indicated
adequate power to detect medium-to-large univariate effect sizes (power > 0.8; Erdfelder, Faul,
& Buchner, 1996). Potential participants were excluded if they reported any history of head
injury with loss of consciousness greater than 30 min, or a history of neurological or psychiatric
illness that would adversely impact cognitive functioning (e.g., seizure disorder, toxoplasmo-
sis, or schizophrenia). Participants also were excluded if they met Diagnostic and Statistical
Manual of Mental Disorders (fourth edition) (DSM-IV; American Psychiatric Association,
1994) criteria for any current substance-related disorder (e.g., cocaine or methamphetamine
dependence).

As evident in Table 1, the groups were comparable for age, years of education, sex, and
handedness. Approximately 79% of the HIV-1 sample met Centers for Disease Control cri-

Table 1
Demographic and disease characteristics of the HIV-1 and healthy comparison samples

<table>
<thead>
<tr>
<th>Variable</th>
<th>HIV-1 (n=42)</th>
<th>HC (n=29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>44.4 (8.4)</td>
<td>44.1 (12.2)</td>
</tr>
<tr>
<td>Education (years)</td>
<td>13.9 (2.6)</td>
<td>14.5 (2.4)</td>
</tr>
<tr>
<td>Sex (men, %)</td>
<td>80.9</td>
<td>72.4</td>
</tr>
<tr>
<td>Handedness (right, %)</td>
<td>90.5</td>
<td>79.3</td>
</tr>
<tr>
<td>Ethnicity (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>59.0</td>
<td>79.3</td>
</tr>
<tr>
<td>Hispanic</td>
<td>14.2</td>
<td>10.3</td>
</tr>
<tr>
<td>Black</td>
<td>21.4</td>
<td>6.9</td>
</tr>
<tr>
<td>Other</td>
<td>5.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Beck Depression Inventory (BDI)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| BDI Total Score           | 6.8 (7.2)    | 3.0 (3.5)$^*$
| BDI Cognitive-Affective Scale | 3.3 (3.7)  | 1.9 (2.3)$^*$
| POMS Tension-Anxiety Scale | 6.9 (5.5)   | 5.0 (5.3)$^*$

Note. HC: healthy comparison group; POMS: Profile of Mood States.

$^*$ P = .005.
$^*$ P < .10.
Criteria for a diagnosis of AIDS; however, only 19% were immunosuppressed and the median CD4 lymphocyte count within this group was 450 (interquartile range = 263, 608). Seventy-nine percent of participants in the HIV-1 sample were prescribed highly active antiretroviral therapy (HAART). The HC sample ($M = 105.2$; $S.D. = 9.5$) scored higher on a measure of premorbid verbal intelligence, the oral reading portion of the Wide Range Achievement Test (third edition) (WRAT-3; Wilkinson, 1993), than the HIV-1 sample ($M = 99.3$; $S.D. = 9.45$; $p < .05$). In addition, the HIV-1 group endorsed a greater number of depressive and anxious symptoms on the Beck Depression Inventory (BDI; Beck & Steer, 1987) and Profile of Mood States (McNair, Lorr, & Droppleman, 1981), respectively (see Table 1).

1.2. Procedure

After providing informed written consent to participate in the study, all participants were administered the Hopkins Verbal Learning Test—Revised (HVLT-R; Benedict et al., 1998; Brandt & Benedict, 2001) as part of a larger neuropsychological battery. The neuropsychological battery in use at the HIV Neurobehavioral Research Center (HNRC) was designed in accordance with National Institute of Mental Health AIDS workgroup guidelines (Butters et al., 1990) to provide a brief, but nonetheless robust evaluation of the fronto-striatal cognitive domains impacted by HIV-1 infection (see Woods & Grant, 2005). Briefly, the HVLT-R consists of three groups of four (non-consecutive) semantically related words, which are read aloud at approximately 2-s inter-stimulus intervals. The HVLT-R includes three consecutive learning trials, a 20- to 25-min delayed free recall trial (trial 4), and a recognition trial, which contains 24 words consisting of 12 target words from the original list and 12 non-target words. Six of the 12 non-target words are semantically related to words on the original list.

A psychometrist who was blind to participants’ HIV-1 status scored the HVLT-R for the following primary dependent variables of interest: (1) Total Recall (i.e., total number of correct words recalled per trial); (3) Semantic Clustering (see Stricker, Brown, Wixted, Baldo, & Delis, 2002); (4) Serial Clustering (see Stricker et al., 2002); (5) Pair Frequency Recall Across Trials (see Sternberg & Tulving, 1977); (6) Total Intrusion Errors (i.e., words generated that were not HVLT-R stimuli); (7) Total Repetitions (i.e., HVLT-R words that were repeated during the same recall trial); (8) Delayed Free Recall (i.e., total words correct on trial 4); (9) Percent Retained (trial 4 divided by the higher of trials 2 or 3); (10) Response Bias (Br; Snodgrass & Corwin, 1988); (11) Recognition Discrimination; (12) Retrieval Index (i.e., delayed free recall versus recognition discrimination; Delis et al., 2000); and (13) Semantic False Positive Recognition Errors (i.e., endorsement of any of the six non-target words on the recognition trial that are semantically related to words on the HVLT-R list). In contrast to the good reliability of the HVLT-R primary measures, the test–retest reliability of the HVLT-R component process measures is generally more modest (Woods, Scott, et al., 2005).

For those variables that were normally distributed (Kolmogrov–Smirnov $P$-values > .05), we conducted a series of independent-samples $t$-tests to examine potential between-group differences. Non-normally distributed data were analyzed using a Wilcoxon test of ranked sums. The Cohen’s $d$ statistic was used to measure the effect sizes of the group comparisons: by convention, $d$-values of .2, .5, and .8 correspond to small, medium, and large effect sizes,
respectively (Cohen, 1988). Finally, a composite “executive functioning \( z \) score” was created from \( z \) scores on putative cognitive measures of fronto-striatal functioning, which were selected on an a priori conceptual basis for an examination of convergent validity. The specific measures included in the composite index were the Halstead Category Test (CT total errors; Reitan & Wolfson, 1985), the Wisconsin Card Sorting Test—64 Card Version (WCST-64 perseverative responses; Kongs, Thompson, Iverson, & Heaton, 2000), the Trail Making Test (TMT difference score [B–A]; Reitan & Wolfson, 1985), and Stroop Color–Word Test (incongruent trial; Golden, 1978). Spearman’s rank order correlation coefficients were used to examine the associations between this composite \( z \) score and several key HVLT-R component process indices to provide evidence of convergent validity in the HIV-1 group. Divergent validity was evaluated by conducting correlations between the HVLT-R indices, WRAT-3 Reading, and the Brief Visuospatial Memory Test—Revised (BVMT-R copy trial; Benedict, 1997). To minimize the risk of Type I error, the critical alpha level was set at .01 value for the convergent and divergent correlational analyses.

2. Results

Table 2 displays the means, standard deviations, and effect sizes for all of the HVLT-R-dependent measures of interest. The HIV-1 group performed significantly worse than the HC.

<table>
<thead>
<tr>
<th>HVLT-R variable</th>
<th>HIV-1 (n = 42)</th>
<th>HC (n = 29)</th>
<th>Cohen’s ( d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Recall (^*^)</td>
<td>26.69 (4.69)</td>
<td>29.59 (3.48)</td>
<td>−0.71</td>
</tr>
<tr>
<td>Learning Slope</td>
<td>1.49 (0.90)</td>
<td>1.34 (0.96)</td>
<td>0.16</td>
</tr>
<tr>
<td>Delayed Recall (^*^)</td>
<td>9.19 (2.38)</td>
<td>10.76 (1.60)</td>
<td>−0.79</td>
</tr>
<tr>
<td>Percent Retained (^*)</td>
<td>0.89 (0.13)</td>
<td>0.95 (0.08)</td>
<td>−0.57</td>
</tr>
<tr>
<td>Pair Frequency</td>
<td>1.85 (1.68)</td>
<td>2.20 (1.82)</td>
<td>−0.20</td>
</tr>
<tr>
<td>Semantic Clustering</td>
<td>1.22 (1.26)</td>
<td>1.88 (1.36)</td>
<td>−0.50</td>
</tr>
<tr>
<td>Serial Clustering</td>
<td>−0.08 (0.59)</td>
<td>0.17 (1.07)</td>
<td>−0.31</td>
</tr>
<tr>
<td>Intrusions (^\dagger)</td>
<td>0.60 (1.21)</td>
<td>1.14 (1.27)</td>
<td>−0.44</td>
</tr>
<tr>
<td>Semantic Intrusions (^*^)</td>
<td>0.29 (0.74)</td>
<td>1.07 (1.33)</td>
<td>−0.75</td>
</tr>
<tr>
<td>Subordinate Intrusions</td>
<td>0.02 (0.15)</td>
<td>0.03 (0.19)</td>
<td>−0.06</td>
</tr>
<tr>
<td>Unrelated Intrusions</td>
<td>0.21 (0.87)</td>
<td>0.07 (0.26)</td>
<td>0.25</td>
</tr>
<tr>
<td>Repetitions</td>
<td>0.88 (1.35)</td>
<td>0.90 (1.18)</td>
<td>−0.02</td>
</tr>
<tr>
<td>Semantic False Positives</td>
<td>0.55 (0.71)</td>
<td>0.69 (0.76)</td>
<td>−0.19</td>
</tr>
<tr>
<td>Response Bias (Br)</td>
<td>−0.08 (0.13)</td>
<td>−0.07 (0.08)</td>
<td>0.10</td>
</tr>
<tr>
<td>Recognition Discrimination Index</td>
<td>11.10 (1.14)</td>
<td>11.14 (0.99)</td>
<td>−0.04</td>
</tr>
<tr>
<td>Retrieval Index (^*^)</td>
<td>1.90 (2.00)</td>
<td>0.38 (1.42)</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Note. HC: healthy comparison group.

\(^\dagger\) \( P < .10 \)
\(^*\) \( P < .05 \)
\(^*^\) \( P < .01 \)
\(^*^*\) \( P < .001 \)
Table 3
Correlations between key HVLT-R indexes and standard clinical tests in the HIV-1 sample

<table>
<thead>
<tr>
<th>HVLT-R index</th>
<th>Executive functions*</th>
<th>WRAT-3 reading</th>
<th>BVMT-R copy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantic Clustering</td>
<td>0.43**</td>
<td>0.05</td>
<td>0.13</td>
</tr>
<tr>
<td>Retrieval Index</td>
<td>-0.46**</td>
<td>-0.08</td>
<td>0.02</td>
</tr>
<tr>
<td>Serial Clustering</td>
<td>0.00</td>
<td>-0.08</td>
<td>-0.17</td>
</tr>
<tr>
<td>Intrusions</td>
<td>-0.23</td>
<td>-0.24</td>
<td>-0.22</td>
</tr>
<tr>
<td>Percent Retained</td>
<td>0.29</td>
<td>-0.10</td>
<td>-0.13</td>
</tr>
<tr>
<td>Recognition Discrimination</td>
<td>0.42**</td>
<td>0.08</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Note. Data represent Spearman’s rho correlations. WRAT-3: Wide Range Achievement Test-3; BVMT-R: Brief Visuospatial Memory Test-Revised. **P ≤ .01.

* A composite z score derived by averaging scores from the Halstead Category Test (total errors), Stroop Test (incongruent trial), Trail Making Test (Part B – Part A), and Wisconsin Card Sorting Test—64 Card Version (perseverative responses).

As shown in Table 3, correlational analyses within the HIV-1 group revealed significant relationships between the executive functions composite z score and the HVLT-R Semantic Clustering (P = .005) and Retrieval Index (P = .002) variables. As predicted, these two HVLT-R variables did not significantly correlate with the WRAT-3 Reading subtest or the BVMT-R copy trial (P > .05). No other significant correlations were observed, with the exception of a modest association between Recognition Discrimination and the executive function composite (P = .005).

3. Discussion

The aim of the present study was to examine the construct validity of the HVLT-R component process measures in persons with HIV-1 disease. Consonant with prior research (e.g., Carey et al., 2004), the HIV-1 sample demonstrated poorer overall performance on the HVLT-R Total and Delayed Recall measures relative to a demographically comparable group of seronegative comparison subjects. A closer examination of the HVLT-R component process measures indicates that deficient strategic (i.e., executive) control of episodic verbal encoding/retrieval mechanisms likely underlies this omnibus deficit (Moscovitch, 1994). For instance, the HIV-1 group evidenced ineffective utilization of the semantic organizational structure of the HVLT-R word list, which prior research indicates is associated with poorer learning and retrieval per-
formance (e.g., Gershberg & Shimamura, 1995; Woods, Rippeth, et al., 2005). In fact, in a post hoc analysis, we observed a significant positive correlation between Semantic Clustering and Total Recall (Spearman’s rho = .78, \( P < .0001 \)) among HIV-1-infected persons, which suggests that greater use of semantic clustering encoding and retrieval strategies was associated with better free recall performance. This finding is consistent with those of Peavy et al. (1994) and Delis et al. (1995), both of whom observed deficits in the Semantic Clustering Index—but not Serial Clustering—of the CVLT in persons with HIV-1. The convergent validity of Semantic Clustering was further supported by a series of planned correlational analyses in the HIV-1 sample, which revealed significant associations with well validated clinical measures of executive functions. Evidence of divergent validity was provided by the minimal associations between Semantic Clustering and measures of semantic memory (i.e., WRAT-3 Reading) and constructional praxis (i.e., BVMT-R copy trial).

Although the HIV-1 group displayed poorer performance on the HVLT-R Percent Retained measure, it is unlikely that this finding stems from deficient memory consolidation since the groups performed comparably on Recognition Discrimination. Instead, this HVLT-R profile more likely reflects deficient retrieval mechanisms—a hypothesis supported by the observed group differences on the Retrieval Index. Thus, even though the HIV-1 group recalled fewer words than HC on the delayed free recall trial, they were successfully able to identify the list items when demands on self-initiated search and retrieval processes were minimized with a forced-choice recognition format. Prior research supports the notion that HIV-1 is associated with deficient effortful search and retrieval strategies within both lexical-semantic (White et al., 1997; Woods et al., 2004) and episodic (e.g., Becker et al., 1995; Delis et al., 1995; Peavy et al., 1994) memory stores. Moreover, the Retrieval Index (along with Recognition Discrimination) was negatively correlated with the executive functioning composite score, which similarly indicates that better episodic verbal retrieval was associated with better performance on tests of executive functions (i.e., novel problem solving and cognitive flexibility).

Perhaps the most unexpected finding in the current study was the trend towards a higher rate of intrusion errors in the HC sample than in the HIV-1 group. No prior studies have observed differences between HIV-1 and seronegative comparison subjects on verbal list learning intrusions (in either direction). One possible explanation for this curious finding is that it is a result of the HC group’s greater utilization of the semantic structure of the HVLT-R. This contention is supported by post hoc analyses that revealed a higher rate of semantically related intrusions in the HC group, but no differences in subordinate or unrelated intrusions. Moreover, semantically related intrusions were modestly correlated with semantic false-positive recognition errors (Spearman’s rho = 0.36, \( P = .06 \)); however, there was no association between semantic clustering and semantically related intrusions (\( P > .10 \)).

Another surprising finding was the absence of group differences on the Repetitions and Pair Frequency variables. In particular, prior research in lesioned and clinical disease samples demonstrates that Pair Frequency is a reliably sensitive indicator of prominent fronto-striatal circuit neuropathophysiology (e.g., Alexander, Stuss, & Fansabedian, 2003). Of note, however, one recent study using Pair Frequency from the HVLT-R did not observe any differences between persons with methamphetamine dependence and healthy comparison subjects (Woods, Rippeth, et al., 2005). The lack of observed differences in these studies may be an artifact of the subtle memory deficits associated with HIV-1 infection and methamphetamine
dependence, or it may reveal problems with the sensitivity of this specific HVLT-R component process measure.

It is unlikely that the study results can be attributed to demographic factors, including age, education, or sex, as the groups were comparable on these characteristics. Nevertheless, the generalizability of our findings is limited by the demographic and disease characteristics of our sample, which largely consisted of Caucasian men with well-managed HIV-1 disease (median CD4 lymphocyte count = 450.0). Moreover, 79% of the current sample was prescribed HAART, which prior research shows may be associated with improved episodic verbal memory performance (e.g., Suarez et al., 2001). Future research involving a larger range of disease severity would allow for analyses regarding the associations between the HVLT-R component process measures and HIV-1 disease and treatment variables (e.g., RNA viral load in plasma and cerebrospinal fluid). It is also not likely that between-group differences in premorbid verbal intelligence or depressive symptoms can explain the results of this study. Post hoc analyses revealed that neither the WRAT-3 reading score nor measures of affective distress (i.e., POMS Tension-Anxiety scale, BDI Total score, and BDI Cognitive-Affective scale) were significantly correlated with the variables of interest within the HIV-1 group (all P > .10). Furthermore, the significant between-group findings on the HVLT-R variables of interest did not change when co-varied for WRAT-3, BDI, or POMS scores. Finally, although the lack of association between the WRAT-3 score (and BVMT-R copy trial) and the HVLT-R process measures provides preliminary evidence of divergent validity, future research should examine the association of these process indices with a broader range of validated tests of temporolimbic function (e.g., confrontation naming).

It is important to highlight the potential clinical implications of the study findings. In a subset of persons with HIV-1 infection, deficits in episodic verbal memory adversely impact performance of instrumental (and sometimes fundamental) activities of daily living (ADLs), including vocational functioning (e.g., van Gorp, Baerwald, Ferrando, McElhiney, & Rabkin, 1999) and medication management (e.g., Hinkin et al., 2002). Consistent with prior research (e.g., Delis et al., 1995), our data indicate that, as a group, persons with HIV-1 infection are able to retain and recognize information that is effectively encoded. Moreover, the limited reliance on semantic clustering strategies should not be taken as evidence that persons with HIV-1 disease are incapable of using such encoding and retrieval strategies. Rather, the use of a more passive, concrete serial approach to encoding/retrieval may limit the extent to which higher level strategies are utilized. In fact, we observed a negative association between Semantic and Serial Clustering in the HIV-1 sample (Spearman’s rho = −0.33, P < .05), which is commensurate with previous studies (e.g., Woods, Rippeth, et al., 2005). Thus, remedial techniques that focus on the use of active organizational strategies (e.g., clustering techniques), as well as salient external reminders (e.g., electronic reminding devices) might temper the impact of HIV-1-associated memory deficits on ADLs (e.g., Gershberg and Shimamura, 1995; van den Broek, Downes, Johnson, Dayus, & Hilton, 2000).

In summary, findings from the present study provide support for the construct validity of HVLT-R component process indices in persons with HIV-1 infection. Commensurate with prior investigations that have used the CVLT (e.g., Delis et al., 1995; Peavy et al., 1994), HVLT-R measures of semantic clustering and retrieval differentiated persons with and without HIV-1 infection. Moreover, HVLT-R Semantic Clustering and Retrieval Index scores demonstrated
evidence of convergent and divergent validity with other, well-validated clinical measures in the HIV-1 group. Further research is needed to solidify the construct validity of the HVLT-R component process variables, including demonstrations of: (1) criterion-related validity (e.g., associations with functional and structural neuroimaging data); (2) predictive validity (e.g., sensitivity to clinical disease samples with temporolimbic dysfunction); (3) incremental validity (e.g., relative to summary scores of recall); and (4) ecological validity (e.g., associations with performance of activities of daily living).

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