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A Neuropsychological Investigation of Multitasking in HIV Infection: Implications for Everyday Functioning

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Abstract

Objective—A subset of individuals with HIV-associated neurocognitive impairment experience related deficits in “real world” functioning (i.e., independently performing instrumental activities of daily living [IADL]). While performance-based tests of everyday functioning are reasonably sensitive to HIV-associated IADL declines, questions remain regarding the extent to which these tests’ highly structured nature fully captures the inherent complexities of daily life. The aim of this study was to assess the predictive and ecological validity of a novel multitasking measure in HIV infection.

Method—Participants included 60 individuals with HIV infection (HIV+) and 25 demographically comparable seronegative adults (HIV−). Participants were administered a comprehensive neuropsychological battery, questionnaires assessing mood and everyday functioning, and a novel standardized test of multitasking, which involved balancing the demands of four interconnected performance-based functional tasks (i.e., financial management, cooking, medication management, and telephone communication).

Results—HIV+ individuals demonstrated significantly worse overall performance, fewer simultaneous task attempts, and increased errors on the multitasking test as compared to the HIV− sample. Within the HIV+ sample, multitasking impairments were modestly associated with deficits on standard neuropsychological measures of executive functions, episodic memory, attention/working memory, and information processing speed, providing preliminary evidence for convergent validity. More importantly, multivariate prediction models revealed that multitasking deficits were uniquely predictive of IADL dependence beyond the effects of depression and global neurocognitive impairment, with excellent sensitivity (86%), but modest specificity (57%).

Conclusions—Taken together, these data indicate that multitasking ability may play an important role in successful everyday functioning in HIV+ individuals.

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Keywords

HIV; cognition; neuropsychology; activities of daily living; executive functions

A convergence of multidisciplinary scientific evidence indicates that HIV-1 infection is associated with neuropathological changes in frontostriatal systems (e.g., Everall, Hansen, & Masliah, 2005) and corresponding neurocognitive impairment in approximately 30 to 50% of cases (e.g., Heaton et al., 1995). A subset of HIV-infected individuals with cognitive impairment experience related deficits in a range of everyday, “real world” functions (i.e., instrumental activities of daily living [IADLs]). While both standard clinical tests and direct, performance-based functional tests are reasonably sensitive to HIV-associated IADL declines (e.g., Heaton et al., 2004), questions remain regarding the extent to which these tests’ highly structured nature fully captures the various cognitive abilities involved in successful everyday functioning. For example, it has long been noted that IADL functioning can still be impaired despite normal performance in the laboratory, even on objective measures of functional ability (e.g., Burgess, Alderman, Evans, Emslie, & Wilson, 1998). This discrepancy may be due to, among other possibilities (e.g., psychiatric factors), impairment in the ability to prioritize, organize, and structure a course of action in the face of competing alternatives in daily life situations. This ability, also known as “multitasking,” is not readily measured by standard neurocognitive and functional tests, despite its potential relevance to everyday functioning.

Although research regarding the cognitive and neuroanatomical architecture of multitasking has increased in recent years, studies have suffered from divergent (but at times overlapping) operationalizations of the construct. Many studies have used the term multitasking to describe simultaneously performing multiple tasks (e.g., utilizing dual-task paradigms; Meyer & Kieras, 1997) or allocating attention to multiple streams of sensory input (e.g., media multitasking; Ophir, Nass, & Wagner, 2009). In the present study, we operationalize multitasking as an individual’s ability to plan and carry out multiple, separate tasks within a specific timeframe where switching between tasks is required. In this context, the simultaneous performance of tasks *can* occur and may be advantageous in some circumstances, but individuals are not *required* to simultaneously perform tasks. Although this definition of multitasking is straightforward, it is clear that a number of cognitive processes are required for successful execution. Multitasking requires an individual to not only plan and organize based on temporal and conditional associations between actions but also to maintain these associations in working memory, along with other information such as the immediate environmental stimuli, goals, and sub-goals (Burgess, Veitch, de Lacy Costello, & Shallice, 2000). In fact, a number of deficits, including planning, set shifting, and output monitoring, could potentially lead to impairment in multitasking ability (Burgess, 2000; Schwartz, 2006).

Considering the cognitive demands of multitasking, it is not surprising that the prefrontal cortex and basal ganglia are thought to be critical in its execution (e.g., Dreher, Koechlin, Tierney, & Grafman, 2008). Studies have shown that patients with prefrontal lobe lesions who evidence everyday functioning difficulties also have profound deficits on measures of multitasking (Gouveia, Brucki, Malheiros, & Bueno, 2007; Shallice & Burgess, 1991). These individuals characteristically display an elevated number of rule-violations and a low number of tasks attempted within the context of a normal work rate, suggesting a tendency to get “stuck in set,” plan inefficiently, or both. Similar results have also been reported in patients with selective vascular lesions of the basal ganglia (Thoma et al., 2008) and individuals with traumatic brain injuries (Levine, Stuss, Milberg, Alexander, Schwartz, & McDonald, 1998). It is notable that these multitasking deficits often occur despite minimal

impairment on a range of traditional tasks of executive functions (e.g., Alderman, Burgess, Knight, & Henman, 2003). These findings suggest that multitasking may make demands upon different cognitive processes than those assessed by traditional executive functioning tests and may provide a novel contribution to the prediction of everyday functioning.

The most commonly used assessment of multitasking is the Six Elements Test (SET), developed by Shallice & Burgess (1991), and its shortened version, the Modified Six Elements Test, which is included in the Behavioral Assessment of the Dysexecutive Syndrome (BADS) battery. These tests, however, are comprised of tasks that may have limited ecological relevance in neurological populations (e.g., bead counting). Moreover, the rules of these tests are set up such that participants are not likely to complete any of the subtasks unless they get ‘stuck in set’ and do not switch to any other subtasks. Thus, the optimal performance on the SET entails spending approximately one-sixth of the allotted time on each subtask. While this assesses one’s ability to plan his or her time accordingly and carry out one’s formulated plan, it does not assess an individual’s ability to work efficiently towards a goal within time constraints or evaluate the ability to set priorities, strategies theoretically critical to successful everyday functioning. In addition, it does not present the opportunity to perform multiple tasks simultaneously, which, although detrimental in certain situations (e.g., Foerde, Knowlton, & Poldrack, 2006), is nonetheless a skill often required in everyday life. Thus, the multitasking test developed for this study improves upon these previous versions by employing tasks shown to be relevant to the everyday functioning of individuals with HIV (e.g., Heaton et al., 2004), while also allowing more participant-initiated task switching, prioritization, and time management.

The primary aim of the present study was to develop and validate a novel performance-based test of multitasking in HIV infection. It was hypothesized that: 1) HIV-infected individuals would show worse performance on a measure of multitasking relative to demographically comparable HIV seronegative comparison participants, with a lower overall summary score, increased errors, and fewer simultaneous task attempts; 2) performance on the measure of multitasking would be associated with traditional measures of executive functions, episodic memory, attention/working memory, and processing speed in both HIV-infected and seronegative comparison participants; and 3) worse performance on the multitasking test would be associated with increased self-reported IADL dependence in HIV-infected participants.

Methods

Participants

The present study examined 60 persons with HIV-1 infection (HIV+), as determined by enzyme linked immunosorbent assays (ELISA) and a Western Blot confirmatory test, and a comparison sample of 26 healthy, HIV seronegative volunteers (HIV–). Individuals were excluded who: (1) were not fluent in English; (2) reported histories of major neuromedical confounds (e.g., seizure disorders, stroke) or severe psychiatric disorders (e.g., psychosis); (3) evidenced a substance use disorder within one year of evaluation; and/or (4) tested positive for recent illicit drugs or alcohol on the day of evaluation. The demographic and clinical characteristics of the study samples are displayed in Tables 1 and 2.

Materials and Procedure

After providing written informed consent, each participant was administered the measure of multitasking along with a neuropsychological, psychiatric, and neuromedical research evaluation.

Multitasking Test—The assessment of multitasking required participants to complete as much of four separate tasks as possible within a 12-minute time limit. The task parameters were modified from the SET (Shallice and Burgess, 1991) to include components with face validity of relevance to the daily functioning of individuals living with HIV. The tasks included: (1) Cooking (meal preparation); (2) Advanced Finances (paying bills and balancing a checkbook); (3) Medication Management (pill dispensing); and (4) Telephone Communication. The first three tasks were adapted from Heaton et al. (2004), and their scoring and administration were similar to what was described in that publication. Telephone Communication is a new functional measure created for this study in which participants were asked to make three phone calls: one to a pharmacy, one to their doctor, and one to a credit card company. Participants were required to look up the number in a fictional address book, dial the number, and leave a message with the required information. In each call, points were awarded for dialing the number correctly, leaving a message, and stating the three pieces of correct information (provided to participants) for each call. Each call took approximately one minute.

Overall instructions for the test were based on those of the SET, which consisted of the following that participants read through with the examiner:

“Over the next 12 minutes, you will have 4 different tasks to try to complete. These tasks will involve different things that you might do in your everyday life. Look at the task sheet in front of you and we will go through each task together.”

After explaining each of the individual tasks to participants, the examiner then provided the rules and overall instructions:

“You must attempt at least part of each of these four tasks. You can do the tasks in any order, and you can return to tasks as often as you like. Your job is to try to complete as much of the tasks as possible. You will receive points for each step you successfully take in each task. However, it is unlikely that you will be able to complete all 4 tasks in the 12-minute time limit.

Your ultimate goals are to cook a meal and manage your finances. Before doing the financial task, however, you will need to call your credit card company.

You can use this stopwatch or that clock to help you organize your time if you like.”

In order to minimize demands on episodic memory for task instructions, the instructions for all parts of the multitasking test remained visible on cue cards. As mentioned above, participants were instructed to complete the phone call to the credit card company before beginning the financial task. In addition, they were told that they would run out of pills for one medication in the medication management task, and that when they figured out which medication it was, they would need to call the pharmacy with the information to request a refill. Thus, two required switches were built into the test itself, while other switches between tasks were participant initiated, which made it so that participants could not accurately complete any task from beginning to end without switching to another.

Points were awarded for correct execution at each step of each of the four tasks. The examiner assigned the cooking and advanced finances tasks explicit importance by informing the participant that these tasks were their ultimate goals, and that they would receive more credit for completing them. Thus, if these tasks were completed, participants received bonus points. There were no significant differences ($p > .10$) between the number of HIV+ and HIV– participants who attempted the cooking (50 [83%] HIV+ vs. 22 [88%] HIV– participants) and advanced finances (41 [68%] HIV+ vs. 21 [84%] HIV– participants) tasks. However, as suggested in the instructions, no participants were able to complete all

four tasks in this study (although 87.1% of participants were able to complete at least one task).

The lead author and a trained psychometrist administered and scored the multitasking test in accordance with standardized procedures. The examiner was blinded to the participant's HIV status. Each administration was double-scored to ensure accuracy, and any discrepancy in scoring was resolved with the assistance of a third rater. One HIV+ participant was excluded from analysis due to administration error, leaving 25 participants for analysis. Participants received one point for each step they completed in each task, creating an Overall Score that assessed how much of the total test they were able to complete (out of 70 possible points). In addition to the Overall Score, a number of qualitative variables and error types were examined in secondary analyses, including number of: (1) Repetitions (repeating task steps); (2) Intrusions (performing irrelevant task steps); (3) Omissions (leaving out tasks or relevant task steps); (4) Sequencing Errors (performing task steps in the wrong order); (5) Total Errors (sum of 1-4); (6) Task Switches; (7) Tasks Attempted (out of four); and (8) Simultaneous Task Attempts. Inter-rater reliability was established prior to the start of the study with 10 healthy, HIV seronegative participants who were not included in the study sample. Two-way random-effects intraclass correlations for consistency (Shrout & Fleiss, 1979) revealed good-to-excellent inter-rater reliability, with intraclass correlations of .97 for Overall Score and ranging from 0.84 to 0.96 for error types.

Neuropsychological Battery & Questionnaires

Participants also completed a comprehensive neurocognitive battery designed in accordance with NIH Working group recommendations (Antinori et al., 2007). Full details regarding this battery are available in Rippeth et al. (2004). Raw scores for each test were converted to demographically adjusted T-scores, which were subsequently converted to deficit scores and combined to calculate a Global Deficit Score (GDS; see Carey et al., 2004) as a summary score of overall NP impairment. For the planned correlational analyses, population-based Z scores were created from raw scores of measures within each neurocognitive domain, selected on an *a priori* conceptual basis, which were then averaged to generate putative composite measures of cognitive functioning within that domain. For speed of information processing, the measures used were: (a) WAIS-III Digit Symbol; (b) WAIS-III Symbol Search; and (c) the Trailmaking Test, Part A. For memory, the specific measures used were: (a) HVLIT-R Delayed Recall; and (b) BVMT-R Delayed Recall. For attention/working memory, the measures used were: (a) PASAT number correct (2.4 second inter-stimulus interval); and (b) WMS-III Spatial Span total. For executive functions, the measures used were: (a) WCST-64 perseverative responses; (b) the Trail Making Test, Part B; and (c) the Stroop Color-Word Test (incongruent trial).

Participants also completed the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996), the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1981), and the modified version of the Lawton & Brody (1969) ADL questionnaire (see Heaton et al., 2004). Consistent with prior research, individuals were classified as *IADL-dependent* if their self-rated current level of functioning was reported to be lower than their highest level of functioning for at least two functional domains (see Heaton et al., 2004, and Woods et al., 2006).

RESULTS

All variables except the Overall Score on the multitasking measure were non-normally distributed (Kolmogorov-Smirnov p -values $< .01$), and Wilcoxon Rank Sums tests were therefore used to conduct between-group comparisons for all other variables, with Cohen's d providing a measure of effect sizes. Results for the Multitasking test are presented in Table

3. As shown in this table, HIV+ participants demonstrated a significantly lower overall score, switched between tasks less frequently, and had significantly fewer simultaneous task attempts. Moreover, HIV+ participants exhibited a greater number of total errors, which primarily consisted of omission errors. In contrast, the groups did not differ in the number of intrusions, repetitions, sequencing errors, or tasks attempted (p values $> .10$). Effect sizes for the significant results were medium-to-large, ranging from 0.54 to 0.93. However, no HIV disease variables were associated with any variable from the multitasking measure.

As shown in Table 4, correlational analyses within the HIV- group revealed significant associations between the speed of information processing z score and multitasking task switches ($p = .020$) and simultaneous task attempts ($p = .005$). In addition, the executive functions z score was associated with multitasking overall score ($p = .020$), task switches ($p = .006$), and simultaneous task attempts ($p = .006$). Finally, the attention/working memory z score was associated with multitasking overall score ($p = .007$) and simultaneous task attempts ($p = .048$).

Overall score on the multitasking test was associated with the global neuropsychological summary score (i.e., GDS) at a trend level ($r = -.24$; $p = .06$) in the HIV+ group. As displayed in Table 5, within the HIV+ group, correlational analyses revealed significant relationships between the speed of information processing z score and multitasking overall score ($p = .005$) and simultaneous task attempts ($p = .004$). Significant correlations were found for the memory z score and multitasking overall score ($p = .001$), intrusions ($p = .031$), omissions ($p = .005$), total errors ($p = .0004$), and simultaneous task attempts ($p = .004$). The attention/working memory z score was significantly associated with multitasking overall score ($p = .037$), simultaneous task attempts ($p = .006$), total errors ($p = .002$), and omission errors ($p = .008$). Significant relationships were found between the executive functions z score and multitasking intrusions ($p = .032$), omissions ($p = .046$), and total errors ($p = .008$). Multitasking repetitions and task switches were not associated with any cognitive domain z score in the HIV+ group.

Table 6 displays the Spearman's ρ intercorrelations between the various indices of interest from the multitasking measure in the HIV+ group. Multitasking overall score was positively associated with task switches and simultaneous task attempts and negatively associated with total, omission, and sequencing errors. Multitasking total errors were strongly and positively associated with all other multitasking error types, while multitasking task switches were strongly and positively associated with simultaneous task attempts.

Based on the responses of the 60 HIV+ participants on the IADL questionnaire, 14 participants (23.3%) met criteria for IADL-dependence, while 46 (76.7%) were deemed IADL-independent. The IADL-dependent and IADL-independent subgroups were comparable for demographic characteristics, HIV disease severity, and estimated premorbid verbal IQ (as measured with the WRAT; all $ps > .10$). As might be expected from previous research (e.g., Heaton et al., 2004), the IADL-dependent group had a significantly higher rate of NP impairment ($p = .039$), endorsed greater affective distress on the BDI-II ($p < .001$), and had a higher proportion of current major depression diagnoses ($p = .007$), although they did not differ in proportion of individuals with lifetime substance dependence diagnoses ($p > .10$). The groups also did not differ in their "best" prior level of IADL functioning across domains.

Consistent with our hypotheses, the IADL-dependent individuals displayed a lower overall score on multitasking [$t(58) = 2.35$, $p = .022$], but no other variables from the measure were significantly different between the groups. Given this result, a hierarchical logistic regression was conducted to predict IADL status among HIV+ participants from the overall

score from the multitasking test while also accounting for the effects of neuropsychological impairment (GDS) and depression (current diagnosis). Given previous research in HIV (e.g., Heaton et al., 2004), depression diagnosis and GDS were entered together in the first step, followed by multitasking overall score in the next step. Depression and GDS were both significantly predictive of IADL status and together resulted in a nonsignificant Hosmer and Lemeshow test [$\chi^2(7) = 6.46; p = .49$], which indicates adequate model fit. In the next step, adding multitasking overall score increased the fit of the model (Hosmer and Lemeshow $\chi^2(7) = 10.992; p = .14$), with depression ($p = .001$) and multitasking overall score ($p = .019$) significantly predicting IADL status, although this resulted in GDS becoming a nonsignificant contributor to the model ($p = .152$). Of note, there were no significant differences on the multitasking test in HIV+ individuals with and without a current diagnosis of depression [$t(58) = 0.16, p = .870$], and the BDI-II Total Score was not significantly correlated with the overall score on the multitasking test ($r = -.039, p = .769$).

An ROC curve revealed that overall score on the multitasking test was superior to chance in classifying IADL status (area under the curve [AUC] = 0.69, $SE = 0.07, p = .03$). A cut-point of 27 on the multitasking test was chosen as providing a reasonable balance between sensitivity and specificity for predicting IADL status. The overall hit rate for this cutoff was 65%, with excellent sensitivity (i.e., the proportion of IADL-dependent participants with overall scores on multitasking below this cutoff = 86%) and negative predictive power (i.e., the proportion of multitasking overall scores above cutoff produced by the IADL-independent sample = 88%). However, the specificity (i.e., the proportion of IADL-independent participants with multitasking overall scores above this cutoff = 57%) and positive predictive power (i.e., the proportion of multitasking overall scores below cutoff produced by the IADL-dependent sample = 38%) values were somewhat more modest. Generating odds ratios using the cut-point of 27 to indicate impairment in multitasking showed that HIV+ individuals with multitasking overall scores below this cut-point were over 8 times more likely to be classified as IADL-dependent than those who were unimpaired on this measure ($OR = 8.1$).

Given its utility in predicting IADL status, a *post hoc* exploratory analysis was also conducted to examine potential differences between unemployed and employed individuals on the multitasking overall score. Individuals who were less than one-half time employed were considered unemployed, while individuals who were more than half time employed were considered employed (Heaton et al., 1994). Two participants reported a work status that was ambiguous, with one classified as employed and one unemployed after further review. Individuals who identified as “retired” were not included in analyses due to classification ambiguity, leaving 56 HIV+ participants for analysis. Unemployed participants displayed lower overall scores on the multitasking test compared to employed participants [$M = 26.2, SD = 7.2$ vs. $M = 31.8, SD = 9.4; t(53) = -2.37, p = .02$]. A nominal logistic regression was conducted that attempted to predict employment status from the overall score from the multitasking test while also including variables upon which the groups differed. The model was significant [$\chi^2(4) = 18.42, p = .001$], with current depression diagnosis ($p = .006$), AIDS status ($p = .015$), and overall score on the multitasking test ($p = .019$) each providing significant, unique contributions to the prediction model.

DISCUSSION

Impact of HIV Disease on Multitasking

Previous research has indicated that tests of multitasking may be particularly sensitive to prefrontal-striatal dysfunction in a range of clinical disorders (e.g., Burgess et al., 2006). Extending these findings, the present study revealed medium-to-large effect sizes in

multitasking errors and overall multitasking performance between HIV-infected and healthy comparison samples, generally consistent with the proposed hypotheses. In other words, individuals with HIV infection demonstrated problems with the complex cognitive processes involved in organizing, structuring, and executing a series of goal-related behaviors, evidencing a reduced overall score, a lower number of task switches, increased omission and total errors, and fewer attempts at performing tasks simultaneously. These results are generally commensurate with the multitasking performance that has been reported in prefrontal lobe lesion patients, who characteristically display an elevated number of task errors and a low overall score (e.g., Burgess, 2000). HIV+ individuals in this study, however, evidenced a low number of task switches in the context of an equivalent number of task attempts, which is somewhat distinct from the pattern of low task attempts *and* low switches reported in individuals with prefrontal lesions. While switching tasks more frequently is not necessarily the optimal way to complete the most tasks because of the difficulty this switching creates in attentional allocation, task switching as displayed in this study may indicate a level of confidence in one's abilities to allocate attention in the face of competing demands. On the other hand, HIV+ individuals still switched between tasks an average of five times; thus, the decreased number of task switches may have resulted from a slower approach to the tasks and a deficiency in progressing through the tasks. Relatedly, HIV+ individuals also attempted fewer simultaneous task attempts overall, which may reflect either a lack of confidence in one's skills in simultaneous and divided attention or a decreased rate of achievement in each task, wherein opportunities for simultaneous task performance presented themselves less often.

An analysis of error types in the multitasking measure showed that most of the errors observed in HIV+ participants were omission errors (e.g., forgetting to dispense medications on a day), which were somewhat surprising, as they occurred despite the instructions being readily available for participants. Omission errors have traditionally been conceptualized as suggesting a breakdown in the encoding of an intended action (i.e., weak or inaccurate associations are initially formed) or a faulty retrieval process in accessing the intended response (Shallice, 1988). In this instance, given that the task was time-pressured, these errors may have also resulted from participants becoming overwhelmed with the management of a number of tasks, limiting the cognitive resources available for the monitoring of task execution. Considered in the context of Norman and Shallice's (1986) "supervisory attentional system" (SAS) theory, the complex, novel nature of the task likely required increased modulation from prefrontal networks, but damage from HIV infection may have resulted in decreased efficiency in frontal-subcortical systems, leading to errors in execution. To this end, omission errors were moderately associated with both executive functions and memory performances in the HIV+ group, supporting the contention that such errors were driven by difficulties with executive modulation and retrieval failures.

Consistent with the study hypotheses, performance on the multitasking measure was moderately associated with memory, executive functions, attention/working memory, and speed of information processing domains. However, there were discrepancies between the HIV- and HIV+ samples in these relationships that did not appear to be solely a function of different sample sizes. In the HIV- sample, the strongest correlations were with measures of executive functions, attention/working memory, and speed of information processing. In the HIV+ group, multitasking overall score and simultaneous task attempts were both moderately associated with episodic memory, attention/working memory, and speed of information processing, while error types were associated with memory, attention/working memory, and executive functions. Yet the correlations between executive functions and multitasking overall score and simultaneous task attempts were lower than expected in the HIV+ sample, especially given the hypothesized demands of the measure on planning, set-shifting, and flexibility. One possibility for the modest associations is that neurocognitive

tests like the Trailmaking Test, Part B and Stroop Color-Word Interference Test often involve set-shifting and flexibility within seconds, whereas multitasking measures entail a deferral of task execution that predominantly occurs over longer periods of time (Burgess et al., 2000). Another possibility is that the skills used by HIV+ participants on the multitasking sub-tasks predominantly reflected more slowing and difficulties with memory, a contention that may be supported by the decreased simultaneous task attempts and task switches of the HIV+ group. Interestingly, previous studies utilizing measures of multitasking have often shown variable associations with traditional measures of executive functions in their participant groups, perhaps for similar reasons (e.g., Tranel, Hathaway-Nepple, & Anderson, 2007).

An alternative hypothesis is that the multitasking measure, by virtue of being a test of everyday action organization (and a potential proxy for everyday functioning), may correspond to a number of cognitive skills, making neurocognitive classification difficult. In other words, participants could perform poorly on the measure secondary to a variety of cognitive deficits (e.g., strategic planning, retrieval of one's plan, sustained attention to follow a plan), a possibility that may be even more pronounced in HIV infection because the profile of cognitive deficits is highly variable across individuals (e.g., Dawes et al., 2008). In addition, because of its use of relatively unstructured, open-ended situations with multiple goals and sub-goals, this specific measure of multitasking may access individual strategies that patients use in their everyday lives to compensate for their cognitive deficits. However, some individuals, aware of their cognitive weaknesses, may structure their everyday behavior to limit the cognitive resources required in some areas, and correspondingly may have done so during this test. For example, a number of individuals wrote down a plan/strategy before the task and monitored the time with timers, which may have helped them compensate for cognitive problems. Future studies should evaluate the effectiveness and utilization of such compensatory strategies in multitasking performance and everyday functional ability.

Of greater clinical relevance, HIV+ individuals who were IADL dependent or unemployed demonstrated a significantly lower overall score on the multitasking test. Moreover, the overall score on multitasking uniquely contributed to the prediction of IADL dependence, even when a global measure of neuropsychological functioning was included in multivariate models. In other words, the multitasking measure demonstrated incremental validity in predicting IADL functioning above and beyond what was accounted for by global neuropsychological impairment. Similarly, multitasking performance uniquely contributed to the prediction of employment status, even when depression, age, and AIDS status were included in models. Thus, the correspondence between the multitasking measure and IADL outcome measures not only provides preliminary evidence for the predictive validity of this construct in HIV infection, but also points to its potential incremental ecological relevance (i.e., validity) for important clinical outcomes in the daily lives of persons living with HIV infection.

Confounding Factors

It is unlikely that the differences observed between the HIV+ and HIV- groups in this study were due to demographic factors that might influence task performance, as the two groups were equivalent in age, education, sex, ethnicity, and estimated premorbid verbal intelligence. Similarly, the IADL-dependent and IADL-independent samples were comparable in demographic and disease variables. Results were also likely not dependent on affective status, as self-reported depressive symptoms and depression diagnoses were not associated with performance on the multitasking measure. To further ensure that depression did not confound our results, we conducted *post hoc* correlations between all multitasking

variables and self-reported depressive symptoms (i.e., BDI-II) in the HIV+ sample, which revealed small and nonsignificant ($p > .15$) associations for all variables.

One question that could be raised is whether multitasking represents a construct distinct from overall general intellectual functioning. In order to address this question, we conducted *post hoc* Pearson product-moment correlations between Overall Score on the multitasking test and WRAT Reading Scaled Score. The WRAT Scaled Score was significantly correlated with multitasking overall score in both the HIV- ($r = .64$; $p = .0006$) and HIV+ ($r = .29$; $p = .025$) groups, although the association was notably weaker in the HIV+ group. Thus, in neurologically healthy individuals, general intellectual functioning appears to be strongly associated with multitasking performance, while in HIV+ individuals, it is associated with multitasking at a lesser level, and other factors may be more contributory (i.e., neuropsychological performance in speed of processing, attention/working memory, and episodic memory). It should be noted, however, that the effects of the associations between intellectual functioning and multitasking were diminished in the between-group comparisons, as all groups were well matched on WRAT Reading Scaled Scores.

It is also unlikely that inexperience with the tasks comprising the multitasking measure among the HIV+ participants can explain these results, as *post hoc* analyses revealed that a large majority of participants reported significant current and/or past everyday experience with these tasks. Questionnaires assessing familiarity with the tasks used in the multitasking test showed that similar percentages of HIV+ and HIV- participants (86% vs. 72%, respectively) reported currently using a checkbook, although HIV+ participants unsurprisingly took medications and used a medication organizer more frequently. Similar proportions of HIV+ and HIV- participants reported using the phone at least once per day (85% vs. 95%, respectively). A large majority of the 59 HIV+ participants (78%) reported that they currently cooked over twice per week, while 92% of HIV- individuals reported cooking this frequently. The HIV+ participants who did not currently cook frequently did not differ in demographic characteristics from those who cooked frequently, although they evidenced higher levels of neurocognitive deficits ($p = .025$).

Limitations, Summary, and Future Directions

This study is not without its limitations. The test of multitasking used has limited data regarding its psychometric properties, and clearly, further research on its reliability and construct validity in healthy and clinical samples is needed. In addition, future studies should examine potential demographic influences on multitasking performance, including age, gender, and education, especially given the often strong effect of these variables on other neuropsychological measures. Moreover, one has to consider the amount of time and effort that the multitasking test requires when considering its clinical utility. In general, the multitasking measure took approximately 10 minutes to set up, 5-8 minutes to explain and answer questions to assure examinee understanding, and 12-15 minutes to administer (including the average planning time used by participants). In addition, a large testing room with a number of props is required to properly administer the test, which may not be feasible in many hospital, clinic, or even laboratory settings where space and time are at a premium. To enhance the everyday clinical applicability of this measure, a briefer, more portable version should be developed. If a multitasking measure could be set up in a virtual environment and run on a computer within the confines of a typical neuropsychological testing room, the everyday utility of the test might be vastly improved.

Importantly, the reliability of our findings may have been hampered by the absence of performance-based tests that individually assessed the specific functional skills used in the multitasking test (e.g., cooking, medication management; Heaton et al., 2004), which may have been helpful in determining whether individual deficits were due to multitasking skills,

difficulties with the individual functional tests, or both. Thus, future studies should attempt to parcel out the influence of single task ability on multitasking performance. Furthermore, the use of a self-report measure of IADL functioning might have also introduced some bias because of mild anosognosia, which may be evaluated more directly by future studies that incorporate proxy, significant other, or observational report. Moreover, this cross-sectional study did not evaluate the longitudinal predictive validity of impairment in multitasking in HIV but rather provided evidence of concurrent ecological validity. Finally, the generalizability of these data is restricted by the demographic (i.e., largely well-educated, Caucasian, and male) and HIV disease characteristics (i.e., relatively immunocompetent) of the study sample. In particular, extrapolation of these results to HIV-infected individuals with substance use disorders may be problematic given the often-discrepant demographic and psychiatric characteristics of this population.

Although no HIV disease variables were associated with multitasking performance in the present study, future studies might examine the relationship of other disease factors such as cART regimen penetration and peak viral loads with multitasking performance and everyday functioning outcomes. Longitudinal studies are also needed to determine if antiretroviral treatment that results in improved HIV disease outcomes, such as reduced HIV viral load or increased CD4 count, can translate to improvement in multitasking and IADL independence. Another direction for future study might be to examine the usefulness of cognitive remediation and rehabilitation strategies that attempt to compensate for multitasking deficits in HIV-associated neurocognitive disorders, including incorporation of individualized environmental adaptations (e.g., cues, workspace changes; Giovannetti et al., 2007) or using autobiographical memories to facilitate planning (e.g., Hewitt, Evans, & Dritschel, 2006).

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Table 1

Demographic and psychiatric characteristics of the study sample

	HIV+ (n = 60)	HIV- (n = 25)	<i>t</i> / χ^2	<i>p</i>
Demographic Characteristics				
Age (years)	49.9 (9.4)	47.1 (12.6)	1.14	.259
Education (years)	14.3 (2.7)	14.3 (2.2)	-0.02	.983
WRAT Reading SS	108.3 (9.8)	105.1 (10.2)	-0.09	.130
Sex (% male)	83.6%	69.2%	2.18	.130
Ethnicity ^a			3.22	.489
% Caucasian ^b	75.0%	65.4%	0.92	.338
% Hispanic	8.3%	7.7%	--	--
% Black	15.0%	19.2%	--	--
% Other	1.7%	7.7%	--	--
Percent Employed	33.3%	69.2%	8.07	.005
Psychiatric Characteristics				
Lifetime Major Depression (%)	58.3%	34.6%	3.78	.052
Lifetime Substance Dependence (%)	34.3%	35.0%	0.00	.973
Current Major Depression (%)	10.0%	3.9%	0.88	.347
BDI-II ^c	9.6 (8.6)	3.9 (5.5)	3.10	.003
POMS Total ^d	53.2 (39.2)	32.5 (23.5)	2.41	.018
Neuropsychological Characteristics				
Global Deficit Score	0.4 (0.4)	0.2 (0.3)	1.79	.064
% Neuropsychologically Impaired	31.7%	16.0%	2.22	.127

Note: WRAT = Wide Range Achievement Test; SS = Standard Score; BDI-II = Beck Depression Inventory-II; POMS = Profile of Mood States.

^a Chi-square analysis compares all ethnic groups.

^b Chi-square analysis compared Caucasian versus all other ethnic groups.

^c Fifteen HIV+ participants received the Beck Depression Inventory.

^d N = 80.

Table 2

HIV disease and medical characteristics of the HIV+ sample (n = 60)

	<i>Median or P</i>	<i>IQR</i>
Estimated HIV Duration (years)	15.3	6.6
Current ART Regimen Duration (months)	32.6	27.7
Nadir CD4 ^a (cells/ μ l)	70.0	9.0, 202.0
Current CD4 ^a (cells/ μ l)	413.5	242.0, 748.3
Plasma HIV RNA ^{a,b} (log ₁₀)	1.7	1.7, 1.8
CSF HIV RNA ^{a,b,c} (log ₁₀)	1.7	1.7, 1.7
Detectable Plasma HIV RNA ^b (%)	31.4%	--
Detectable CSF HIV RNA ^b (%)	16.7%	--
Proportion with AIDS	73.3%	--
Proportion Immunosuppressed ^d	16.7%	--
Antiretroviral Therapies (%)		
cART	86.7%	--
Non-cART ART	3.3%	--
No ART	10.0%	--
Disease Stage (%)		
CDC A	23.3%	--
CDC B	23.3%	--
CDC C	53.3%	--

Note: AIDS = Acquired Immune Deficiency Syndrome; ART = antiretroviral therapy; cART = combination antiretroviral therapies.

^aData represent medians with interquartile ranges.

^bThe nominal lower detection limit of the viral load assay is 50 copies per milliliter (1.7 log copies per milliliter).

^c $n = 38$.

^dImmunosuppression was defined as CD4 lymphocyte count < 200 cells μ L.

Table 3

Multitasking performance in the HIV+ and HIV- healthy comparison samples

	HIV+ (n = 60)	HIV- (n = 25)	t / χ^2	p	d
Overall Score ^a	28.1 (8.1)	32.4 (7.5)	-2.24	.028	-0.54
Task Switches	5.1 (2.1)	7.1 (3.5)	5.89	.015	-0.67
Tasks Attempted	3.2 (0.5)	3.4 (0.6)	1.11	.293	-0.23
Simultaneous Task Attempts	2.1 (1.5)	3.7 (2.9)	4.82	.028	-0.70
Total Errors	2.7 (1.5)	1.6 (0.8)	13.99	.0002	0.93
Repetitions	0.2 (0.4)	0.2 (0.4)	0.54	.463	-0.12
Intrusions	0.4 (0.6)	0.2 (0.4)	1.97	.160	0.39
Omission Errors	1.5 (1.0)	0.8 (0.6)	10.24	.001	0.84
Sequencing Errors	0.5 (0.6)	0.4 (0.5)	0.38	.537	0.17

^aIndicates a t test value.

Table 4

Spearman's *rho* correlations between neuropsychological performance and Multitasking variables in the HIV-group (n = 25)

Variable	SIP Z Score	Memory Z Score	Attention/WM Z Score	Executive Functions Z Score
Overall Score ^a	.31	.29	.65**	.50*
Task Switches	.46*	.24	.32	.53**
Simultaneous Task Attempts	.55**	.34	.49*	.53**
Total Errors	-.37 [^]	-.09	-.34	-.29
Repetitions	.08	.18	.19	.08
Intrusions	-.36 [^]	-.32	-.14	-.26
Omission Errors	-.13	.01	-.42 [^]	-.05
Sequencing Errors	-.15	-.06	-.34	-.19

Note. SIP = Speed of Information Processing; WM = Working Memory

^a Indicates a Pearson product-moment correlation coefficient.

[^]
 $p < .10$.

*
 $p < .05$.

**
 $p < .01$.

Table 5

Spearman's *rho* correlations between neuropsychological performance and Multitasking variables in the HIV+ group (n = 60)

Variable	SIP Z Score	Memory Z Score	Attention/WM Z Score	Executive Functions Z Score
Overall Score ^a	.36**	.39**	.27*	.20
Task Switches	.17	.19	.24 [^]	.05
Simultaneous Task Attempts	.37**	.37**	.35**	.23
Total Errors	-.21	-.48***	-.39**	-.33**
Repetitions	.03	-.07	.06	.12
Intrusions	-.24 [^]	-.32*	-.18	-.32*
Omission Errors	-.22 [^]	-.36**	-.34**	-.26*
Sequencing Errors	-.08	-.23 [^]	-.14	-.18

Note. SIP = Speed of Information Processing.

^a Indicates a Pearson product-moment correlation coefficient.

[^]
p < .10.

*
p < .05.

**
p < .01.

p < .001.

Table 6

Intercorrelations between variables of the Multitasking test in the HIV+ group (n = 60)

Multitasking Variable	1	2	3	4	5	6	7	8
1. Overall Score	--							
2. Task Switches	.30*	--						
3. Simultaneous Task Attempts	.39**	.69***	--					
4. Total Errors	-.29*	-.01	-.07	--				
5. Repetitions	.07	.21	.17	.38**	--			
6. Intrusions	-.22	.07	-.05	.36**	.16	--		
7. Omissions	-.32*	-.01	-.17	.73***	.21	.15	--	
8. Sequencing Errors	-.25*	-.07	-.08	.36**	-.19	.14	.03	--