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Total Recognition Discriminability in Huntington's and Alzheimer's Disease

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Abstract

Both the original and second editions of the California Verbal Learning Test (CVLT) provide an index of total recognition discriminability (TRD) but respectively utilize nonparametric and parametric formulas to compute the index. However, the degree to which population differences in TRD may vary across applications of these nonparametric and parametric formulas has not been explored. We evaluated individuals with Huntington's disease (HD), individuals with Alzheimer's disease (AD), healthy middle-aged adults, and healthy older adults who were administered the CVLT-II. Yes/no recognition memory indices were generated, including raw nonparametric TRD scores (as used in CVLT-I) and raw and standardized parametric TRD scores (as used in CVLT-II), as well as false positive (FP) rates. Overall, the patient groups had significantly lower TRD scores than their comparison groups. The application of nonparametric and parametric formulas resulted in comparable effect sizes for all group comparisons on raw TRD scores. Relative to the HD group, the AD group showed comparable standardized parametric TRD scores (despite lower raw nonparametric and parametric TRD scores), whereas the previous CVLT literature has shown that standardized TRD scores are lower in AD than in HD. Possible explanations for the similarity in standardized parametric TRD scores in the HD and AD groups in the present study are discussed, with an emphasis on the importance of evaluating TRD scores in the context of other indices such as FP rates in an effort to fully capture recognition memory function using the CVLT-II.

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Keywords

California Verbal Learning Test; California Verbal Learning Test – Second Edition; recognition discriminability; Huntington's disease; Alzheimer's disease

Introduction

The California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987, 2000) is a standardized neuropsychological test that provides a multitude of verbal learning and memory indices. The original and second editions of the CVLT (CVLT-I and CVLT-II, respectively) are widely used in research and clinical settings and have been utilized in efforts to characterize memory function and decline in various populations.

Total Recognition Discriminability (TRD) on the CVLT

Both versions of the CVLT include a TRD index, which is a single score that reflects the ability of the examinee to endorse target items *and* reject distractor items. The CVLT-I used the following nonparametric formula (see Underwood, 1974) to compute a TRD index that was interpreted as a percentage, with 100 (%) set as the maximum possible score:

$$\mathrm{TRD}_{\mathrm{CVLT\text{-}\,I,\,nonp}} = [1 - (\text{total FPs} + \text{total misses})/44] \times 100.$$

Thus, the nonparametric TRD index incorporates an examinee's total number of FPs into a ratio or percentage TRD score. In addition to differentiating patient and control populations, this index has been useful in distinguishing patients with different profiles of memory loss, particularly those with primarily cortical (e.g., AD) versus subcortical (e.g., HD) degeneration (see Delis et al., 2000 for review).

The CVLT-I was developed between 1979 to 1981, prior to the availability of personal computers. As was discussed in the CVLT-II manual (Delis et al., 2000), the nonparametric measure of TRD was employed in the CVLT-I because it allowed for a relatively quick, convenient calculation of recognition discriminability by hand and still correlated strongly with more complex parametric signal-detection measures such as *d'*. However, as noted by Corwin (1994), the nonparametric formula was less able than other measures to account for response bias on recognition memory tasks with an unequal number of target and distractor items, such as the yes/no recognition memory task on the CVLT-II. Alternatively, *d'* is calculated independently of response bias, rendering it better suited for tests with an unequal number of target and distractor items. By the time the CVLT-II was developed, personal computers were widely available and facilitated the efficient application of more complex mathematical methods for assessing recognition memory function, further strengthening the rationale for employing the parametric *d'* measure to compute the TRD index on the CVLT-II.

A raw *d'* score reflects the absolute difference in standard deviation units between an examinee's hit rate and FP rate and is therefore analogous to a contrast *z* score (Delis et al., 2000; Macmillan & Creelman, 1991):

$$\mathrm{TRD}_{\mathrm{CVLT\text{-}II},d'} = z\,(\text{hit rate}) - z\,(\text{FP rate})\,.$$

Thus, in contrast to the nonparametric TRD score, which more generally reflects an examinee's percentage of correct responses, the parametric TRD score more specifically reflects an examinee's hit rate relative to their FP rate. In this regard, the parametric formula for TRD might better capture recognition memory function in cases where there are unequal numbers of target and distractor items. However, whether the parametric formula for TRD sufficiently captures the full magnitude of FP errors, particularly in individuals who are susceptible to committing very high FP rates (e.g., those with AD) is not entirely clear and warrants further consideration. Additional distractor items were included on the CVLT-II relative to the CVLT-I to increase test difficulty and lower the ceiling effect that is often found on recognition memory tests, including that on the CVLT-I (Dean C. Delis, personal communication, December 5, 2015). Specifically, the CVLT-II includes all 16 List B distractor items, whereas the CVLT-I included only 8 List B distractor items. Thus, the proportion of distractor items that are from List B is larger on the CVLT-II (16/32) than on the CVLT-I (8/28). In shifting from the use of a nonparametric TRD formula in the CVLT-I to the use of a parametric TRD formula in the CVLT-II, it is unclear whether an attempt to accommodate the imbalance between the number of target and distractor items on the yes/no recognition memory test comes at the cost of not fully capturing the true possible range of FP rates that may occur in certain neurodegenerative populations.

HD, AD, and Profiles of Memory Loss

HD is a neurodegenerative disorder caused by expanded repetitions of the cytosine-adenine-guanine (CAG) trinucleotide on the huntingtin gene located on the short arm of chromosome 4 (Huntington's Disease Collaborative Research Group, 1993). HD is characterized by an array of motor, cognitive, and psychiatric changes. Motor changes include chorea in addition to bradykinesia, rigidity, and ataxia (Ross et al., 2014). Cognitive deficits associated with HD include impaired episodic memory, executive functioning, attention, and visuospatial processing (Dumas, van den Bogaard, Middelkoop, & Roos, 2013). On the other hand, AD is characterized by early deficits in episodic memory followed by later decline in other cognitive domains including language, executive functioning, and visuospatial processing (Salmon & Bondi, 2009). In contrast to HD, motor functioning is relatively preserved in the context of AD.

The classic profile of episodic memory loss in AD is thought to be one of poor encoding and retention of information, which lead to rapid forgetting and result in impaired recall and recognition (Budson & Kowall, 2013; Dickerson & Atri, 2014; Salmon & Bondi, 2009). Conversely, earlier evidence suggests that individuals with HD exhibit what has been referred to as a "subcortical profile" of episodic memory decline that includes poor recall and improvements in recognition. This profile is thought to reflect impaired retrieval processes but relatively intact encoding and maintenance mechanisms and is particularly evident in earlier stages of the disease (Butters, Wolfe, Martone, Granholm, & Cermak, 1985; Butters, Delis, & Lucas, 1995; Delis et al., 1991). More recent evidence suggests that recognition memory is indeed compromised in HD, but to a lesser extent than recall (see

Montoya et al., 2006 for review). Indeed, the extant literature strongly suggests that, although individuals with HD and AD have both been shown to exhibit recall deficits, recognition memory is thought to be less impaired in HD, at least in the earlier stages of the disease.

Studies using the CVLT-I and CVLT-II have generally shown that individuals with HD and AD are impaired in various aspects of verbal learning and memory, and that they differ from other populations (both healthy and impaired) and from each other in their profiles of memory loss (see Elwood, 1995 for review of CVLT-I literature).

HD and AD performance on the CVLT—Research suggests that individuals with HD perform worse than a demographically similar comparison group on multiple measures of verbal learning and recall on the CVLT-I (Kramer et al., 1988; Massman, Delis, Butters, Levin, & Salmon, 1990; Massman, Delis, Butters, Dupont, & Gillin, 1992; Massman, Delis, & Butters, 1993). Some studies have shown that those with HD demonstrate worse recognition discriminability (Kramer et al., 1988; Lundervold, Reinvang, & Lundervold, 1994; Massman et al., 1990), and other evidence suggests that they exhibit greater improvement on recognition discriminability relative to Trial 5 recall (Massman et al., 1992). Various studies also have indicated that individuals with AD perform worse than healthy older adults on multiple indices of verbal learning and recall on the CVLT-I (Delis et al., 1991; Deweer et al., 1994; Kramer et al., 1988; Massman et al., 1993; Mendez & Ashla-Mendez, 1991; Simon, Leach, Winocur, & Moscovitch, 1994). Additionally, those with AD have been shown to demonstrate higher FP rates or a positive response bias (Delis et al., 1991; Deweer et al., 1994; Kramer et al., 1988), worse recognition discriminability (Delis et al., 1991; Deweer et al., 1994; Kramer et al., 1988), and no improvement on recognition testing relative to free recall (Delis et al., 1991).

No prior studies to the authors' knowledge have examined CVLT-II performance in individuals with HD relative to a demographically similar comparison group (i.e., cognitively healthy middle-aged adults). One study investigated the effects of rivastigmine treatment on cognitive function in early stage HD and included a group of healthy controls to account for practice effects between baseline and follow-up assessments (Sesok, Bolle, Kobal, Bucik, & Vodusek, 2014). However, no direct comparisons between patients and controls in performance on neuropsychological measures (including the CVLT-II) were made. Consistent with CVLT-I findings, studies using the CVLT-II have shown that individuals with AD perform worse than healthy older adults on most measures of recall (Delis et al., 2005; Duarte et al., 2006; Sherod et al., 2009) as well as recognition discriminability (Duarte et al., 2006).

HD/AD comparisons on the CVLT—In general, studies using the CVLT-I have shown that deficits in verbal learning and recall are less severe in individuals with HD relative to those with AD (Delis et al., 1991; Kramer et al., 1988; Kramer, Levin, Brandt, & Delis, 1989). Additionally, evidence suggests that individuals with HD – particularly in milder stages of the disease – demonstrate better recognition discriminability than those with AD on the CVLT-I (Delis et al., 1991; Kramer et al., 1988) that is reflected by lower FP rates in the absence of differences in hit rates (Kramer et al., 1988). Also, compared to individuals

with AD, those with HD have shown greater improvement on recognition discriminability relative to Trial 5 recall (Delis et al., 1991). Some evidence suggests that individuals with mild HD have a smaller positive response bias than those with AD on the CVLT-I (Kramer et al., 1988), whereas other findings have not found such group differences (Delis et al., 1991).

Only two studies have examined the relative performance of individuals with HD and AD on the CVLT-II. The first study revealed that whereas those with HD and AD do not differ on immediate and delayed recall measures when using the traditional measure of target recall, those with AD perform significantly worse than those with HD on short-delay free recall, short-delay cued recall, and long-delay cued recall when using a new index called "recall discriminability" that analyzes target recall relative to intrusion rate (Delis et al., 2005). The second study revealed that those with AD perform significantly worse than those with HD on CVLT-II measures of total and novel recognition discriminability, but comparably on measures of source recognition discriminability (Fine et al., 2008). These studies were based on the same sample of 16 individuals with HD and 17 individuals with AD.

Although the two versions of the CVLT utilize different formulas to compute the TRD index, no prior study has directly assessed the degree to which population differences in TRD vary across applications of these nonparametric and parametric methods. Insight into whether or not such variation occurs would inform efforts to interpret and compare CVLT-I and CVLT-II findings regarding recognition memory function in HD and AD in particular. Additionally, insight into whether the nonparametric and parametric formulas for TRD differ in the extent to which they capture FP errors would be helpful in improving efforts to accurately characterize recognition memory function in these populations in research and clinical settings. Moreover, limited evidence exists regarding HD performance relative to a demographically similar comparison group on the CVLT-II, and what is available is based on relatively small samples. Therefore, the purpose of the present study was to compare nonparametric and parametric assessments of TRD using the CVLT-II in a relatively large sample of individuals with HD and AD and two demographically similar comparison groups.

Method

Participants

Participants included 66 individuals with HD, 33 individuals with AD, 68 healthy middle-aged adults (comparison sample for the HD group), and 35 healthy older adults (comparison sample for the AD group). Individuals with HD were recruited from the Huntington's Disease Clinical Research Program (HDCRP) at the University of California, San Diego (UCSD), which follows a cohort of individuals with HD who have participated in longitudinal clinical studies and undergone annual evaluations of cognitive and motor symptoms (a portion of the HD group came from the same sample used in the studies by Delis et al., 2005 and Fine et al., 2008). The HD group was administered the Unified Huntington's Disease Rating Scale (UHDRS; Huntington Study Group, 1996) by a senior staff neurologist at the HDCRP. Individuals with HD were diagnosed with definite HD on the basis of unequivocal motor signs on the UHDRS and a positive family history of HD. In

addition, all HD participants had a CAG repeat length greater than 39, indicating that all carried the fully penetrant genetic mutation for HD. Exclusionary criteria for individuals with HD and healthy middle-aged adults included the following: a diagnosis of any neurological disorder (with the exception of HD in the HD group), a diagnosis of any major medical condition (e.g., cancer), a diagnosis of any psychiatric disorder (with the exception of a mood or anxiety disorder in the HD group, for which any current symptoms were managed with medication), a history of traumatic brain injury, and a history of substance abuse. All participants provided informed written consent and this portion of the study was approved by the Institutional Review Boards of San Diego State University (SDSU) and UCSD.

CVLT-II data from the 33 individuals with AD and 35 healthy older adults were extracted from an archival database that included data from a larger battery of neuropsychological tests administered at the Shiley-Marcos Alzheimer's Disease Research Center (ADRC) in La Jolla or the Veterans Affairs San Diego Healthcare System (VASDHS) (a portion of the AD group came from the same sample used in the studies by Delis et al., 2005 and Fine et al., 2008). Participants at both sites were administered a standardized battery of tests by trained research assistants or psychometrists. Diagnoses of individuals with probable AD were consistent with the criteria established by the National Institute of Neurological and Communicative Disorders and Stroke–Alzheimer's Disease and Related Disorders Association (ADRDA) workgroup (McKhann et al., 1984; McKhann et al., 2011).

Healthy middle-aged and older adults were recruited from the San Diego community by the HIV Neurobehavioral Research Center (HNRC) and the Bondi Laboratory at UCSD, respectively, using flyers (posted with approval by public sites/institutions) and outreach to senior centers. Efforts were made to target healthy populations with demographic characteristics similar to those of the patient groups.

Measures

Dementia Rating Scale-2 (DRS-2)—Individuals with HD and AD completed the DRS-2 (Jurica, Leitten, & Mattis, 2001), a measure of global cognitive functioning, as part of a larger neuropsychological battery.

CVLT-II and TRD Indices—The CVLT-II was administered as part of a larger neuropsychological battery to all participants using standard administration procedures outlined by Delis and colleagues (Delis et al., 2000). CVLT-II data were collected between May 2002 and July 2013. The CVLT-II involves the presentation of word-lists and provides a multitude of verbal learning and memory indices, including immediate recall, free and cued recall over short and long delays, and recognition memory. The TRD indices that were of primary interest to the present study were derived from the yes/no recognition memory portion of the CVLT-II. In the present study, short- and long-delay tests of recall were separated by an interval of approximately 20 minutes, during which other nonverbal neuropsychological measures were administered. CVLT-II data were scored using CVLT-II scoring software (Delis & Fridlund, 2000).

Nonparametric and parametric TRD scores were calculated using CVLT-II data. Raw nonparametric TRD scores were computed using the following formula:

$$\mathrm{TRD}_{\mathrm{CVLT\text{-}\,II,\,nonp}} = [1 - (\text{total FPs} + \text{total misses})/48] \times 100.$$

Note that the CVLT-II contains 48 total items in the yes/no recognition memory test, whereas the CVLT-I contained 44 items. Raw and standardized parametric TRD scores were computed by CVLT-II software. Raw nonparametric and parametric TRD scores in addition to standardized parametric TRD scores were analyzed. An analysis of standardized nonparametric TRD scores could not be conducted, as the normative data that would be required to do so have not been published or made available otherwise.

Statistical Analyses

Analyses were conducted in Statistical Package for the Social Sciences (SPSS) Version 22. Prior to examining group differences in TRD scores, chi-square analyses were conducted to determine whether groups differed in gender. In addition, analysis of variance (ANOVA) tests were conducted to determine whether groups differed in age, education, or DRS-2 scores.

Shapiro-Wilk tests of normality revealed that TRD scores were non-normally distributed in the present sample ($p < .05$). Therefore, Mann-Whitney U tests were conducted to examine differences in raw nonparametric and parametric TRD scores in the comparison of the HD group to healthy middle-aged adults and in the comparison of the AD group to healthy older adults. For the HD and AD group comparisons on raw nonparametric and parametric TRD scores, nonparametric and parametric TRD scores were ranked, and two-way ANOVA tests were conducted to examine group differences in the ranked TRD scores, while including gender as a second between-subjects factor (Akritas, 1990; Baguley, 2012). Mann-Whitney U tests were conducted to examine group differences in standardized parametric TRD scores in all comparisons of interest.

Effect size values for each group comparison in each analysis of TRD scores were calculated. Following Mann-Whitney U tests, r values for the group effect were computed by dividing the Z value associated with the U statistic by the square root of N (Fritz, Morris, & Richler, 2012). Following two-way ANOVA tests on ranked data, r values for the group effect were computed manually using sum of squares (SS) error terms from the SPSS output and the following formula: $r_{effect} = \sqrt{(SS_{effect}/SS_{total})}$. All r values were converted to Cohen's d effect size estimates using the following formula: $d = 2r/\sqrt{(1-r^2)}$. Fisher's r to z transformation analyses were conducted to determine whether group differences in TRD scores significantly differed between applications of nonparametric and parametric methods. Spearman rank correlation analyses and Fisher's r to z transformation analyses also were conducted in a set of exploratory analyses involving FP rates, TRD scores, and source recognition discriminability (SoRD; the endorsement of List A target items and rejection of List B distractor items) scores.

Although a comparison of standardized nonparametric and parametric TRD scores could not be made, standardized parametric TRD scores were still analyzed to provide researchers and clinicians with the opportunity to make relevant inferences with the present data, as the norms for standardized TRD scores are available in the CVLT-II manual and are widely utilized in research and clinical settings.

Results

Demographic information for the HD and AD groups and their respective comparison groups is provided in Table 1. A chi-square analysis revealed that there were no differences in the percentage of men versus women between the HD group and healthy middle-aged adults or between the AD group and healthy older adults (ps > .05). However, compared to the HD group, the AD group had a significantly greater percentage of men relative to women, χ^2 (N = 91) = 9.06, p < .01. Thus, subsequent analyses examining differences in raw nonparametric and parametric TRD scores between the HD and AD groups included gender as a between-subjects factor.

A one-way ANOVA test revealed that there were no differences in age between the HD group and healthy middle-aged adults or between the AD group and healthy older adults (ps > .05). However, individuals with AD were significantly older than those with HD, t(89) = 14.15, p < .001, which was expected given known differences in the age of disease onset. This highlights that age is systematically confounded with group in the comparison of HD and AD, which renders including age as a covariate in subsequent analyses examining differences in raw TRD scores between the HD and AD groups a statistically invalid method for parceling out age effects on raw TRD scores. This issue is inherently present in studies involving the comparison of raw scores between groups of individuals with HD and AD. Accordingly, age was not included as a factor in ANOVA tests examining differences in raw TRD scores between the HD and AD groups in the present study. Moreover, the size of the present sample would not accommodate alternative analyses that might otherwise address this issue.

A one-way ANOVA test revealed no differences in education between the HD and AD groups; the HD group and healthy middle-aged adults; or the AD group and healthy older adults (ps > .05). The HD and AD groups did not differ in mean DRS-2 scores (p > .05), suggesting that the groups were comparable in terms of overall cognitive impairment. Moreover, the variation in DRS-2 scores within each of the patient groups was minimal.

As shown in Table 2, Mann-Whitney U tests revealed that the HD and AD groups performed significantly worse than their respective comparison groups on all TRD indices. According to Fisher's r to z transformation analyses, the effect sizes associated with the nonparametric and parametric formulas were comparable in all comparisons of patient groups to their respective comparison groups (ps > .05; see Table 3).

As shown in Table 2, ANOVA tests on ranked data revealed that the AD group performed significantly worse than the HD group on *raw* nonparametric and parametric TRD indices. In the comparison of the HD and AD groups using raw scores, the difference in effect sizes

associated with the nonparametric and parametric formulas was negligible and was not statistically significant according to a Fisher's *r* to *z* transformation analysis ($p > .05$; see Table 3). However, a Mann-Whitney *U* test revealed that the AD group performed comparably to the HD group on *standardized* parametric TRD, despite the observation that the AD group had significantly lower *raw* parametric TRD scores than the HD group. Table 2 displays the inferential and descriptive statistics for all planned group comparisons on TRD scores.

Exploratory analyses were conducted in an attempt to elucidate the observation that the AD group had standardized parametric TRD scores that were comparable to those in the HD group, despite lower raw nonparametric and parametric TRD scores. Specifically, additional analyses involving FP rates, TRD scores, and SoRD scores were conducted.

Mann-Whitney *U* tests were conducted to examine differences between the HD and AD groups in raw and standardized FP rates. The Mann-Whitney *U* tests revealed that the AD group ($Mdn_{FPraw} = 14.00$; $Mdn_{FPz} = 2.50$) had significantly higher raw, $U = 339.50$, $p < .001$, and standardized FP rates, $U = 611.50$, $p < .01$, than the HD group ($Mdn_{FPraw} = 5.00$; $Mdn_{FPz} = 1.00$). Spearman rank correlation analyses then were conducted to examine correlations between raw FP rates and raw nonparametric and parametric TRD scores in the HD and AD groups. The analyses revealed significant negative correlations between raw FP rates and raw nonparametric and parametric TRD scores in the HD ($r_{s\_FP(nonp)} = -.73$, $p < .001$; $r_{s\_FP(d')} = -.57$, $p < .001$) and AD ($r_{s\_FP(nonp)} = -.91$, $p < .001$; $r_{s\_FP(d')} = -.64$, $p < .001$) groups. Moreover, Fisher's *r* to *z* transformation analyses revealed that the correlation between raw FP rates and raw nonparametric TRD scores was significantly larger than the correlation between raw FP rates and raw parametric TRD scores in the AD group ($z = 2.99$, $p < .01$) but not the HD group ($z = 1.46$, $p = .14$). However, it is important to note that because FP errors are incorporated in the calculation of the TRD index, the reported correlations between FP rates and TRD scores may be influenced by a certain degree of circularity.

Additionally, exploratory analyses were conducted to examine differences between the HD and AD groups in SoRD scores. A Mann-Whitney *U* test revealed that the AD group ($Mdn = 0.80$) had significantly lower raw SoRD scores than the HD group ($Mdn = 1.75$), $U = 370.50$, $p < .001$. However, the HD ($Mdn = -1.50$) and AD ($Mdn = -2.00$) groups were comparable on standardized SoRD scores, $U = 874.50$, $p = .49$.

Discussion

In the present study, nonparametric and parametric formulas were applied in the assessment of TRD using the CVLT-II in a relatively large sample of individuals with HD and AD and healthy adults. As expected, the HD and AD groups performed worse than their respective comparison groups on nonparametric (raw) and parametric (raw and standardized) indices of TRD. It is worth noting that the effect size for the comparison of AD and healthy older adults on standardized parametric TRD scores was larger than the effect size for the HD and healthy middle-aged adults comparison. However, this difference is consistent with empirical evidence suggesting that individuals with HD exhibit rather heterogeneous

cognitive abilities, with memory deficits that are typically less severe than those observed in individuals with AD.

Relative to the HD group, the AD group had comparable standardized parametric TRD scores despite lower raw nonparametric and parametric TRD scores (even after adjusting for gender, which is corrected for in the standardization of scores on the CVLT-II). The examination of raw scores in research may be informative, yet clinical judgments about the nature of recognition memory abilities and dysfunction by default rely on the analysis and interpretation of standardized scores, as did previous efforts to characterize and distinguish profiles of memory loss in neurodegenerative populations using the CVLT. Interpreting standardized TRD scores from the present study in isolation would lead to the conclusion that individuals with AD show comparable deficits in TRD relative to those with HD. This is in contrast with findings from previous studies in which the CVLT-I (which employs the nonparametric formula) was used to assess TRD. These studies showed that individuals with AD exhibited worse recognition discriminability than those with HD (Delis et al., 1991; Kramer et al., 1988). Additionally, Fine et al. (2008) used the CVLT-II to assess TRD in individuals with HD and AD and also found that those with AD performed worse than those with HD based on standardized scores, albeit using a smaller sample than the present study sample.

A possible explanation for the similarity in standardized parametric TRD scores in the HD and AD groups in the present study, despite earlier evidence for individuals with AD performing worse than those with HD on standardized TRD scores using the CVLT, may involve the extent to which the nonparametric and parametric formulas for TRD capture high FP rates. Namely, the unequal number of target and distractor items on the CVLT-II (although better accounted for by the use of the parametric *d'* formula to calculate the TRD index) may be an important factor to consider when assessing TRD in individuals with a tendency to commit high FP rates, such as individuals with AD. Consistent with previous findings (Kramer et al., 1988), the AD group in the present study committed significantly more FP errors than the HD group. In addition, exploratory analyses revealed significant negative correlations between raw FP rates and raw nonparametric and parametric TRD scores in both the HD and AD groups. Moreover, Fisher's *r* to *z* transformation analyses revealed that the correlation between raw FP rates and raw nonparametric TRD scores was significantly larger than the correlation between raw FP rates and raw parametric TRD scores in the AD group but not the HD group. These observations highlight that the nonparametric TRD formula may more fully capture the contribution of FP errors to a TRD score and, as a result, provide important information regarding an examinee's recognition memory function that may otherwise be lost in the application of the parametric TRD formula and the standardization of parametric TRD scores. The present data and findings suggest that TRD scores may be somewhat overestimated (i.e., the impact of FP errors on TRD scores may be inadvertently reduced) in individuals with AD, leading them to appear to perform comparably to individuals with HD. However, as previously noted, it is important to note that because FP errors are incorporated in the calculation of the TRD index, the reported correlations between FP rates and TRD scores may be influenced by a certain degree of circularity. This point should be taken into consideration when interpreting the present findings.

Another potentially important factor when considering the similarity in standardized parametric TRD scores in the HD and AD groups in the present study involves the greater number of List B distractor items included in the yes/no recognition memory test on the CVLT-II relative to the CVLT-I. Research has shown that individuals with HD and other individuals with frontal system pathology are susceptible to source memory deficits (Baldo et al., 2002; Fine et al., 2008; Pirogovsky et al., 2007). On the CVLT, these deficits may manifest in the endorsement of List B distractor items on the yes/no recognition memory test in particular (see Fine et al., 2008). Consequently, it may be argued that individuals with HD (including those in the present study) are likely to exhibit lower TRD scores on the CVLT-II than they would on the CVLT-I given the opportunity to endorse more List B distractor items on the CVLT-II, which could potentially result in comparable TRD scores to individuals with AD. However, an exploratory analysis of SoRD scores (i.e., the ability to endorse List A target items and reject List B distractor items) in the present study revealed that although the AD group had significantly lower raw SoRD scores than the HD group, the groups were comparable on standardized SoRD scores, which is consistent with previous findings (Fine et al., 2008). This suggests that the discrepancy between the present findings and those reported in previous CVLT studies regarding standardized parametric TRD scores in HD and AD is not likely due to differences in the number of List B distractor items included in the yes/no recognition memory test across the two versions of the CVLT.

Taken together, the primary and exploratory findings of the present study highlight the importance and utility of examining nonparametric TRD scores and other recognition memory indices (e.g., FP rates) in addition to (not instead of) standardized parametric TRD scores when using the CVLT-II to characterize recognition memory function.

Limitations

There are some limitations to the present study that deserve acknowledgement and discussion. First, age was systematically confounded with group in the comparison of HD and AD. The mean ages of the two patient groups differed by more than three standard deviations. This rendered including age as a covariate an insufficient method for parceling out the effects of age on raw TRD scores in subsequent analyses examining differences in raw TRD scores between the HD and AD groups. Age was therefore not included in ANOVA tests examining differences in raw TRD scores between the HD and AD groups. Moreover, the size of the present sample would not accommodate alternative analyses that might otherwise address this issue. Although this limits the interpretation of direct comparisons between the HD and AD groups, it reflects an inherent issue in studies involving the comparison of raw scores between individuals with HD and AD because of the known difference in the average age of disease onset. In light of the issue, it is important to emphasize that the HD and AD groups were equivalent in terms of overall cognitive impairment based on DRS-2 scores, which are commonly used in neuropsychological studies to evaluate and compare the severity of disease in neurological populations. Second, CVLT-II data were collected between May 2002 and July 2013, and individuals were diagnosed with probable AD in alignment with the criteria established by the National Institute of Neurological and Communicative Disorders and Stroke–Alzheimer's Disease and Related Disorders Association (ADRDA) workgroup (McKhann et al., 1984; McKhann

et al., 2011). More specifically, some individuals were diagnosed with AD using the criteria established in 1984, while other individuals were diagnosed with AD using the criteria that were updated in 2011. Although the general framework of probable AD dementia from the 1984 criteria were retained in the 2011 criteria, the 2011 criteria emphasize documenting cognitive decline in persons who meet the core clinical criteria for probable AD dementia to increase the certainty of diagnosis. We believe it is important to acknowledge that the present study sample consists of individuals with AD who were diagnosed using either the 1984 or 2011 criteria, and to encourage readers to take this into consideration in the evaluation of the present findings. Third, the size of the AD group in the present study was relatively small compared to the HD group. However, compared to previously published studies involving the CVLT-II, the AD group in the present study was substantially larger. Fourth, the study sample was relatively well educated and may not fully represent the population. However, it could be hypothesized that the observed magnitude of deficits in TRD in the patient groups actually may be increased in a sample of individuals with less cognitive reserve. Finally, we would like to acknowledge that although it would have been helpful to include an analysis and discussion of performance validity data derived from the forced-choice recognition test, these data are not available for all participants in the study sample.

Conclusion

The present study found that, relative to individuals with HD, individuals with AD had comparable standardized parametric TRD scores despite lower raw nonparametric and parametric TRD scores, which is in contrast with what has been previously reported in the CVLT literature. A possible explanation for this difference in findings between the present and previous studies involves potential differences in the extent to which the nonparametric and parametric formulas for TRD capture high FP rates. A comprehensive approach to evaluating recognition memory function that includes the examination of other indices in addition to (not instead of) standardized TRD scores, which are relied upon by default for making clinical judgments about the nature of recognition memory abilities and dysfunction, is encouraged. The present findings may have important implications when making comparisons between CVLT-I and CVLT-II findings regarding TRD in HD and AD and in improving efforts to accurately characterize recognition memory function in these populations.

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Table 1

Gender distribution and mean values (standard deviations) of age and education for individuals with Huntington's disease (HD), healthy middle-aged adults (MA), individuals with Alzheimer's disease (AD), and healthy older adults (OA).

Variable	HD	MA	AD	OA
n	58	68	33	35
% Female	57%	47%	24%	46%
Age (years)	48.03 (9.58)	43.63 (15.56)	76.55 (8.60)	75.80 (8.82)
Education (years)	14.33 (2.15)	15.15 (2.17)	15.00 (2.69)	16.06 (1.86)
DRS-2 (total score)	123.78 (12.94)	N/A	119.55 (7.61)	N/A

Note: DRS-2 = measure of global cognitive functioning.

Table 2

Inferential and descriptive statistics for all planned group comparisons on TRD indices.

	Index	HD	MA	*Test Statistic*	*p*	*r*	*d*
HD vs MA	Nonp	76.90 (12.40)	94.67 (7.91)	$U = 386.50$	<.001	.70	1.94
	d'	1.71 (0.88)	3.40 (0.73)	$U = 328.00$	<.001	.72	2.08
	$z\,d'$	−1.78 (1.25)	0.44 (0.95)	$U = 354.50$	<.001	.71	2.02

	Index	AD	OA	*Test Statistic*	*p*	*r*	*d*
AD vs OA	Nonp	58.96 (12.24)	90.65 (6.50)	$U = 0.50$	<.001	.86	3.37
	d'	0.68 (0.61)	2.83 (0.68)	$U = 7.50$	<.001	.85	3.21
	$z\,d'$	−2.14 (0.89)	0.34 (0.79)	$U = 19.00$	<.001	.84	3.04

	Index	HD	AD	*Test Statistic*	*p*	*r*	*d*
HD vs AD	Nonp	76.90 (12.40)	58.96 (12.24)	$F(1,88) = 37.41$	<.001	.28	0.16
	d'	1.71 (0.88)	0.68 (0.61)	$F(1,88) = 34.27$	<.001	.27	0.15
	$z\,d'$	−1.78 (1.25)	−2.14 (0.89)	$U = 807.50$	.21	.13	0.26

Note: Nonp = raw nonparametric TRD score; d' = raw parametric TRD score; $z\,d'$ = standardized parametric TRD score.

Table 3

Fisher's r to z transformations of group effects on raw nonparametric versus parametric TRD scores.

		Nonp	*d´*		
Comparison	**n**	***r1***	***r2***	***z***	***p***
HD vs MA	126	.70	.72	0.32	.75
AD vs OA	68	.86	.85	0.21	.83
HD vs AD	91	.28	.27	0.07	.94