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The Dementia Apraxia Test can detect early-onset Alzheimer's disease.

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**Abstract**

**Objective**: Limb apraxia is a common early sign of Alzheimer's disease (AD) and is thought to occur specifically in early-onset (before the age of 65) AD. The Dementia Apraxia Test (DATE), a test of limb and face praxis developed to support the differential diagnosis of dementia, has shown good diagnostic accuracy in detecting AD in older patients but it has not been validated for younger age groups. We investigated how accurately DATE can detect AD in middle-aged individuals and whether apraxia is a distinctive feature in early-onset AD.

**Method**: A sample of mild-stage AD patients ($n$ = 24; $M_{age}$ = 61, $SD$ = 4) was drawn from a prospective consecutive series of individuals referred to our neurology clinic for dementia investigations. A healthy comparison group (HC) of comparable age ($n$ = 22; $M_{age}$ = 61, $SD$ = 7), sex distribution, and education was recruited. DATE was administered as a blinded experimental measure, and a receiver operating characteristic analysis was used to define the optimal diagnostic cut-off point.

**Results:** The DATE classified 93% of the participants correctly as AD or HC (sensitivity 0.88, specificity 1.00, area under curve 0.968). The optimal diagnostic cut-off point was higher (49 points) than in a previous sample of older patients (45 points). Early onset did not seem to be associated with worse praxis performance in AD.

**Conclusions**: DATE is an accurate tool for detecting early-onset AD within two years of symptom onset. The diagnostic cut-off point should be higher for middle-aged populations than for late-onset AD.

Keywords: Alzheimer's disease, apraxia, cognitive marker, diagnostic tests, neuropsychological assessment

**Keypoints:**

- We investigated whether a brief apraxia test could help detect early Alzheimer's disease in middle-aged individuals.
- The Dementia Apraxia Test correctly classified 93% of participants as AD and healthy participants.
- Limb apraxia is a cognitive marker that may reveal early AD.
- The Dementia Apraxia Test deserves further study in preclinical Alzheimer's disease, other dementias, and non-dementing conditions with cognitive symptoms.

Early detection of Alzheimer's disease (AD) continues to challenge clinicians, particularly in cases of atypical, non-amnestic presentation. AD rarely develops before age 65, but when it does, two thirds of these early-onset cases debut atypically with prominent dysexecutive or language deficits or with posterior cortical signs such as visuospatial impairment or apraxia (Mendez et al., 2012). Being able to rapidly exclude or confirm AD in middle-aged people may decrease stress caused by uncertainty, enable early treatment of AD-related symptoms and aid affected individuals and their families in planning for the future.

Apraxia, the loss of skilled movement not due to a primary motor deficit, can be an early feature of AD (as reviewed in Lesourd et al., 2013) and possibly an early diagnostic sign of dementia (Ahmed et al., 2016; Johnen, Tokaj, et al., 2015). Apraxia is commonly observed in moderate or severe disease stages of dementia, as individuals have difficulties with limb movements, handling objects and tools, and completing domestic tasks. These impairments may be detected earlier, in milder forms, with certain novel, abstract tasks during clinical testing. Individuals can be asked to show how they use tools, communicate with gestures, pantomime tool use, produce or imitate familiar gestures, meaningless hand postures and movements (Osiurak & Le Gall, 2012; Osiurak & Rossetti, 2017) as well as facial expressions and oral movements.

Reported prevalence and severity of apraxia depends on which type of task is used in the assessment and how advanced the disease is (Lesourd et al., 2013). Limb apraxia was suggested to characterize early-onset AD more distinctly than late-onset AD based on clinical observations and small patient series (as reviewed in Mendez et al., 2012). However, a majority of apraxia research in AD has been based on older participants (>70 years), with experimental support for this hypothesis still limited.

The Dementia Apraxia Test (DATE; Johnen, Frommeyer, et al., 2015) is a clinical tool developed to detect limb and face apraxias associated with early AD and frontotemporal dementia. Johnen, Frommeyer and colleagues (2015) reported that the DATE differentiated individuals with dementia (mean age of AD participants was 71 years) from healthy participants with 91% sensitivity and 71% specificity. The test measures both the production and conceptual system of praxis, and includes items for limb and face imitation, tool pantomimes, and verbal and oral production. The limb scale stresses bimanual imitation, a visually and executively demanding task type valuable in detecting early AD (Sanin & Benke, 2017). As one of the few apraxia tests validated among dementia

populations, the DATE has been recommended for research use globally by a specialist work group (Costa et al., 2017); however, reference data for younger individuals with dementia does not exist.

The aim of this study was to investigate (1) the diagnostic properties of the DATE among mild-stage individuals with early-onset AD and same-age healthy participants and (2) the hypothesis that apraxia is a distinctive feature in individuals with early-onset AD.

## Method

This study complied with the ethical principles of the Declaration of Helsinki and was approved by the Ethical Committee of [*City*] University Hospital (19/2019). All participants gave their informed written consent.

### Transparency and openness

Participants were included in the study according to predefined criteria. All data exclusions, manipulations, and measures in the study are reported. This study's design and its analysis were not pre-registered. All analyses were run on R 4.0.0 using the following packages: tableone v.0.13.0 (Yoshida & Bartel, 2021), pROC (Robin et al., 2011), cutpointr (Thiele & Hirschfeld, 2021), ggplot2 (Wickham, 2016), yardstick v.0.0.9 (Kuhn & Vaughan, 2021), psych v.2.1.9 (Revelle, 2021), irr v.0.84.1 (Gamer & Lemon, 2019), Hmisc v.4.6-0 (Harrell, 2021) and rstatix v.0.7.0 (Kassambar, 2021). The data and program code are available upon request from the corresponding author.

### Participants

The clinical source population comprised the individuals ages 50 to 70 years who were referred to our neurology clinic between August 2019 and January 2022 for cognitive or affective symptoms suggestive of a neurodegenerative disease, with symptom onset within the past 36 months.

A senior neurologist screened referrals for the following pre-defined exclusion criteria: previous neurological or psychiatric diagnosis, diagnostic intracerebral abnormalities, current excessive alcohol consumption, a history of alcohol-related medical complications, current or previous drug abuse, and intellectual disability. Exceptions included migraine, transient ischemic attack, chronic traces of simple traumatic injuries, single lacunes, Fazekas grade 1 for white matter lesions, non-diagnostic small anomalies (*e.g.*, small cysts), and mild mood disorders.

The healthy comparison (HC) participants were volunteers from various areas of the hospital district. Included HC participants had never received neurological or psychiatric diagnoses, and had

no neurological or cognitive symptoms or restrictions in activities of daily living (ADL). Participants included hospital workers (unfamiliar with dementia investigations), their family members and acquaintances, and acquaintances of the family members.

**Procedure**

All clinical participants were administered a neuropsychological test battery that included standardized tests for verbal learning and memory, visual memory, auditory working memory, processing speed, visual attention, visuoconstruction, visual and verbal intelligence, naming and verbal fluency, academic skills, visual perception, and inhibitory control (Table 1). The HC participants performed a limited set of tests.

Descriptive data is reported for the following measures from the battery: Mini-Mental State Examination (MMSE; Folstein & McHugh, 1975) is a brief screen of general cognitive impairment that assesses orientation, attention, recall, calculation and language. The Visual Object and Space Perception Battery subtest Number Location (VOSP7; Warrington & James, 1991) is used to evaluate spatial ability by asking the participant to match stimuli in corresponding locations. The Rey–Osterrieth Complex Figure Test (ROCFT; Osterrieth, 1944) is a measure of visuoconstructive ability and visual memory. The participant is asked to copy a complex figure and shortly after that draw the same figure from memory. The Boston Naming Test (Finnish version, Laine et al., 1997) is a test of confrontation naming with 60 drawings. The Apraxia Screen of Test of Upper Limb Apraxia (TULIA-AST; Vanbellingen et al., 2011) is a bedside measure that assesses the production of pantomimes and simple meaningless limb positions and movements.

The DATE was administered and scored at the beginning of the neuropsychological assessment by a neuropsychologist blinded to all background information and imaging findings at the time of testing. An informant, if available, was interviewed separately to document changes in the patient's ADL functions.

The DATE assesses limb imitation, finger imitation, object pantomimes, facial imitation, oral gestures on verbal command, and pseudoword repetition. The imitation items are presented using photographs. The test is organized into separate sum scales for limb items and face items and produces a Limb subscore, a Face subscore, and a Total sum score. Each task type is initially practiced, and the test items are scored from 0 (*unrecognizable*/ *erroneous*) to 3 (*fluent*) The protocol, scoring principles and psychometric properties are detailed in the original publication of this measure

(Johnen, Frommeyer, et al., 2015). The test was administered in a standardized fashion. For a subgroup of 10 participants, performance was video-recorded and rated independently by another neuropsychologist blinded to participant status to ensure reliability of administration and scoring.

The diagnosis of probable AD was made according to the NIA-AA criteria (McKhann et al., 2011) and based on observed cognitive changes in the workplace or personal life and a minimum of three of the following supportive findings: (a) the profile of neuropsychological deficits in the traditional test battery, (b) cortical atrophies, (c) CSF analysis, and (d) follow-up assessment at 12 months. The experimental praxis results were not included in the clinical decision-making. Participants diagnosed with amnestic mild cognitive impairment and the participant who had a MMSE score below 18 were excluded from the analyses.

Global and focal atrophies were graded by radiologists using 1.5T magnetic resonance imaging scans. Our neurologists conducted a detailed neurological status examination to exclude signs of movement disorders. Finally, if necessary to ensure the diagnosis, a cerebrospinal fluid (CSF) analysis on tau and beta-amyloid (BAm) 1–42 pathology was ordered from an accredited biomarker laboratory.

**Statistical methods**

Group differences in sex distribution were analyzed with Chi-square (with continuity correction). For continuous demographic variables and traditional test scores either one-way analysis of variance or, in case of non-normal distribution, Kruskal-Wallis tests were conducted. **T**he DATE scores were compared between groups with generalized linear model and the analyses were repeated after adjusting for age and years of education. Age and education were included in the model because they are potential confounders. Welch's t-test was used to compare DATE scores between sexes and Pearson correlations examined the association between age and years of education with DATE scores in the whole sample. For the AD group, correlations between DATE scores and symptom onset, MMSE, and traditional test results were computed. Krippendorff's alpha was used to define inter-rater reliability. A receiver operating characteristic analysis was used to define the optimal cutpoint score and its discrimination ability on the DATE Total sum and Limb subscore.

## Results

### Samples and diagnoses

Of the 177 screened participants, 118 were assessed according to the protocol and 94 of them excluded for reasons detailed in Figure 1. Twenty-four consecutive patients who could be reliably diagnosed with probable AD were included in the analyses. A CSF analysis was necessary and not contraindicated for 17 patients, of whom three exhibited abnormal $BAm_{1\text{-}42}$ (<715pg/ml), two exhibited abnormal tau (>260pg/ml) and 12 exhibited abnormal BAm and tau. The tau-positive participants' clinical phenotypes were defined as posterior and amnestic variants of AD after one year follow-up. All included participants showed mediotemporal/ hippocampal atrophy grade 1–2 and 14 participants showed additional general, central, Sylvian, parietal or fronto-parietal atrophies.

Severe neuropsychological test impairment (at least 2.5 *SD* below the normative mean or scaled score 1–3) in at least one cognitive domain was found for all but two patients, and these two had an isolated moderate memory impairment across three tests (approximately 2 *SD* below the normative mean or scaled score 4-5). Those with severe impairments also always had mild or moderate dysfunction in other domains. Nineteen patients exhibited one or more of the following select deficits: amnesia, disorientation, visuoperceptual disorder, acalculia, alexia or agraphia. Eleven patients were predominantly amnestic in this mild stage, five had a predominantly parietal/posterior presentation, two a dysexecutive presentation and two a language presentation. Four patients exhibited a wide-ranging clinical picture without a clear predominance.

The AD participants' mean age was 61 years and mean symptom duration 18 months (Table 2). Our oldest AD participants were ages 67 and 69 and reported symptom onset at ages 65 and 67, respectively; all others had onset before age 65. Women were overrepresented in both groups (62% in AD, 60% in HC). Table 2 shows that the groups did not differ statistically in terms of age or sex. The HC group had a higher mean for years of education but the difference did not reach significance. HC performed significantly better than AD on MMSE and on all traditional neuropsychological tests.

### Dementia Apraxia Test

The DATE Total sum scores were comparable between men and women, [$t(43) = -1.18$, $p = .25$] and did not correlate with age [$r(44) = .04$, $p = .79$] or education [$r(44) = .15$, $p = .33$]. HC scored significantly higher on all DATE task types except for oral emblems (Table 3). Generalized linear model showed that group status explained most of the variance on DATE Total sum [$R^2 = .64$, $F(1, 44) =$

79.06, $p$ <.001] and on Limb subscore [$R^2$ = .66, $F$(1, 44) = 84.82, $p$ <.001], but not on Face subscore [$R^2$ = .35, $F$(1, 44) = 23.69, $p$ <.001]. Adjusting for age or years of education did not improve the model (Table 4).

For AD participants, Limb subscore showed a strong positive correlation with ROCFT copy [$r$(22) = .70, $p$ < .001] and moderate correlations with VOSP7 [$r$(20) = .50, $p$ = .018] and TULIA-AST [$r$(20) = .55, $p$ = .008]. Face subscore correlated moderately with Limb subscore, [$r$(22) = .45, $p$ = .026] and VOSP7 [$r$(22) = .45, $p$ = .034]. DATE Total sum correlated moderately with TULIA-AST [$r$(20) = .47, $p$ = .028]. Scatterplots depicting these significant correlations are found in Supplement Figure 1. All other correlations between DATE scores and the traditional tests and MMSE were nonsignificant. Symptom duration did not correlate with DATE Total sum, Limb subscore, or Face subscore (all $p$s > 0.09). Inter-rater agreement was high for Limb subscore (α = .91), Face subscore (α = .93) and Total sum (α = .96).

The ROC analysis suggested that a score of 49 was the optimal cutpoint for Total sum to classify participants as AD or HC, resulting in .88 sensitivity and 1.00 specificity (Youden Index .88). The area under the curve (AUC) was .968 (Figure 2). Limb subscore displayed comparable discriminating abilities at a cut-off score of 22 points (sensitivity .92, specificity 1.00, Youden .92, AUC .969). As shown in Figure 3, three AD patients reached the level above 49 points (*i.e.*, the test would have misclassified them as healthy). Applying the previous cutpoint of 45 resulted in a lower sensitivity (.71) and no false positives.

## Discussion

Varying degrees of praxic difficulties were evident in most of the young AD participants who were within three years of symptom onset. The DATE correctly classified early-onset AD and HC in 93% of cases, and only three (13%) patients achieved normal performance level. The Limb subscale (limb imitation and pantomime items) alone also obtained the same diagnostic accuracy. The previously suggested diagnostic Total sum cut-off of 45 points would be too low for middle-aged participants: in our sample a score of ≤ 49 points was indicative of AD. Had we applied the lower cut-off score, 29% of the AD group would have achieved a normal result.

Whether apraxia is more pronounced in early-onset AD than in late-onset AD can be indirectly inspected by comparing the present results with those of Johnen, Frommeyer and colleagues (2015). In their mild-stage AD group, the mean age was 71 years, and the mean disease

duration was two years. The early-onset AD group performed better than the late-onset AD group on all DATE scales. Considered in relation to the same-age HC groups, the AD groups were comparably impaired in their performance.

As measured with TULIA-AST (Vanbellingen et al., 2011), 63% of our AD participants could be defined as mildly to severely apraxic. We found only one previous report on older advanced AD participants (mean MMSE score = 17) suggesting a 32% apraxia rate (Ozkan et al., 2013). The authors did not specify the cut-off score they used, but as the group mean score was much lower than that of our sample, they may have considered individuals apraxic only if they exhibited severe deficits. Defined this way, only one (5%) of our patients would be considered to be apraxic.

Prospective cohort studies comparing mild early-onset AD and late-onset AD have found statistically significant but clinically irrelevant 0.5–1.0 test point differences between large patient groups (Sá et al., 2012; Smits et al., 2014). Retrospective studies based on patient records have identified limb apraxia as a prominent feature in 5–12% of early-onset patients (Koedam et al., 2010; Mendez et al., 2012; Stopford et al., 2008). In sum, earlier onset in AD does not seem to be associated with worse praxis, but younger patients should perform better than older patients.

No statistical association between praxis scores and age or education was observed in this study, possibly due to the small sample sizes or the narrow ranges for age and years of education. Some studies of healthy illiterate or low-educated individuals and more diverse age groups have reported better performances in more highly educated and younger participants (Mantovani-Nagaoka & Ortiz, 2016; Rodrigues Cavalcante & Caramelli, 2009; Tessari et al., 2015); although others find no such relationships (Bartolo et al., 2008).

The fact that our AD participants tended to be less educated than the HC participants and were predominantly female may not have been a coincidence, as both factors may increase the likelihood of disease onset in people at risk (Dubois et al., 2021). Based on previous literature (Mantovani-Nagaoka & Ortiz, 2016; Rodrigues Cavalcante & Caramelli, 2009; Tessari et al., 2015), sex differences in praxis were neither expected nor found.

**Limitations**

The limitations of this work include concern regarding the generalizability of our results, in that, ”early onset” was a clinical descriptor and did not address potential genetic inheritance. In the absence of a genetic testing opportunity, it is unknown whether our sample included cases of

autosomal dominant inheritance, which often presents before the age of 65 years but differs pathogenetically from other early-onset cases (Jagust, 2018).

Stringent criteria in the selection of both AD and HC participants were used, as biomarker testing or more extensive imaging was not available for all patients. AD participants whose condition remained unresolved were excluded, thus, the sample represents more certain cases. This could have resulted in an overestimation of the discriminating ability of the test.

In addition, the HC participants represented an active, well-functioning group that did not experience cognitive deficits, which is possibly not a generalizable sample for the late middle-aged population and certainly atypical of individuals being assessed in a memory clinic. Other neurological and possibly even psychiatric conditions met in a clinical flow obscure the boundary between normal and pathological performance. Impairment on DATE is not specific to AD as it also appears in frontotemporal dementia (Johnen et al., 2018). Additionally, praxic deficits are characteristic of movement disorders (Zadikoff & Lang, 2005) and have been described in schizophrenia (Dutschke et al., 2018).

**Conclusion and Future directions**

Based on our results, DATE is a clinical tool that can accurately differentiate healthy middle-aged individuals from those developing early-onset AD. A higher cut-off score should be applied for middle-aged populations than for older populations.

Future studies should explore the test's performance among presymptomatic gene carriers and other at-risk populations, across various degenerative diseases, and among individuals with non-degenerative cognitive deficits and other health challenges.

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**Table 1** The neuropsychological battery in the initial assessment

| |
|---|
| *Boston Naming Test, Finnish version (Laine et al., 1997) |
| Frontal Assessment Battery (Dubois et al., 2000) |
| Geriatric Depression Scale 15 (Sheikh & Yesavage, 1986) |
| Modified Frontal Behavior Inventory, Finnish version (Suhonen et al., 2017) |
| *Rey-Osterrieth Complex Figure Test (Osterrieth, 1944) |
| Stroop Test (Stroop, 1935) |
| *Token Test, 12-item Finnish version, (De Renzi & Faglioni, 1978) |
| Trail Making Test, Finnish standardization (Poutiainen et al., 2010) |
| *Test of Upper Limb Apraxia - Apraxia Screen (Vanbellingen et al., 2011) |
| *Visual Object and Space Perception Battery (subtests 7, 8) (Warrington & James, 1991) |
| Wechsler Adult Intelligence Scale - Fourth Edition, Finnish version (subtests Block Design, Similarities, Coding) (Wechsler, 2012) |
| Wechsler Memory Scale - Third Edition, Finnish version (subtests Logical Memory I & II, Word Lists I & II, Digit Span) (Wechsler, 2007) |
| Tasks of form and shape discrimination, *three-dimensional copying, clock faces, tapping speed, *word fluency, reading, writing, arithmetics (references not available) |

*Note*. * The tests completed by the healthy participants.

**Table 2** Demographic characteristics and descriptive test scores

| | Alzheimer's disease ($n$ = 24) | Healthy comparison ($n$ = 22) | Statistic | $p$ |
|---|---|---|---|---|
| Age, years | 61 (4)<br>53 – 69 | 61 (7)<br>50 – 69 | $F(1, 44) = 0.01$ | 0.912 |
| Sex (F:M) | 15:9 | 13:9 | $X^2(1, N = 44) = 0.00$ | 1.000 |
| Education, years | 12 (3)<br>6 – 17 | 14 (3)<br>6 – 18 | $F(1, 44) = 3.76$ | 0.059 |
| Symptom onset, months | 18 (8)<br>6 – 36 | not available | not available | not available |
| MMSE (max. 30) | 23.3 (2.3)<br>19 – 28 | 29.6 (0.7)<br>28 – 30 | $H = 34.60$ | <.001 |
| VOSP subtest 7 (max. 10) | 8.0 (1.9)[a]<br>4 – 10 | 9.6 (0.7)<br>8 – 10 | $H = 11.70$ | .001 |
| ROCFT copy (max. 36) | 23.3 (12.2)<br>2 – 36 | 35.9 (0.4)<br>35 – 36 | $H = 33.41$ | <.001 |
| ROCFT immediate recall (max. 36) | 6.3 (6.2)[a]<br>0 – 24 | 20.3 (6.1)<br>8 – 29 | $H = 23.88$ | <.001 |
| Boston Naming Test (max. 60) | 47.8 (7.6)<br>23 – 60 | 56.5 (2.4)<br>50 – 60 | $H = 23.36$ | <.001 |
| TULIA-AST (max. 24) | 17.6 (3.6)[a]<br>9 – 24 | 23.0 (1.1)<br>20 – 24 | $H = 24.85$ | <.001 |

Abbreviations: MMSE, Mini-Mental State Examination; ROCFT, Rey–Osterrieth Complex Figure Test; TULIA-AST, Apraxia Screen of Test of Upper Limb Apraxia; VOSP, Visual Object and Space Perception Battery.

*Note*. Data presented as mean (*SD*) and range except for sex. [a] Two random missing values. The screen and test scores follow a non-normal distribution.

**Table 3** Dementia Apraxia Test scores

| | AD (*n* = 24) | HC (*n* = 22) | *F(1, 44)* | *p* | Difference in means HC–AD [95% CI] |
|---|---|---|---|---|---|
| Limb imitation (max. 21) | 11.5 (4.1)<br>4 – 19 | 19.4 (1.5)<br>16 – 21 | 71.36 | <.001 | 7.8<br>[6.0 – 9.7] |
| Finger imitation (max 3) | 1.9 (1.1)<br>0 – 3 | 2.9 (0.5)<br>1 – 3 | 13.16 | 0.001 | 1.0<br>[0.4 – 1.5] |
| Object pantomime (max. 6) | 2.7 (1.4)<br>0 – 6 | 4.7 (1.0<br>3 – 6 | 29.25 | <.001 | 2.0<br>[1.3 – 2.8] |
| Face imitation (max. 18) | 14.7 (2.2)<br>11 – 18 | 17.0 (1.5)<br>12 – 18 | 16.70 | <.001 | 2.3<br>[1.2 – 3.4] |
| Oral emblems (max. 6) | 5.5 (1.0)<br>3 – 6 | 5.9 (0.6)<br>3 – 6 | 2.18 | 0.147 | 0.4<br>[-0.1 – 0.9] |
| Pseudowords (max. 6) | 4.5 (1.9)<br>1 – 6 | 5.7 (0.6)<br>4 – 6 | 8.42 | 0.006 | 1.2<br>[0.4 – 2.1] |
| Limb subscore (max. 30) | 16.1 (5.1)<br>7 – 28 | 26.9 (2.2)<br>23 – 30 | 84.82 | <.001 | 10.8<br>[8.4 – 3.1] |
| Face subscore (max. 30) | 24.7 (3.3)<br>19 – 30 | 28.6 (1.8)<br>24 – 30 | 23.69 | <.001 | 3.9<br>[2.3 – 5.5] |
| Total sum (max. 60) | 40.8 (7.2)<br>30 – 56 | 55.5 (2.9)<br>50 – 60 | 79.06 | <.001 | 14.7<br>[11.3 – 18.0] |

Abbreviations: AD, Alzheimer's disease group; HC, healthy comparison group; CI, confidence interval.

*Note*. Scores presented as mean (*SD*) and range.

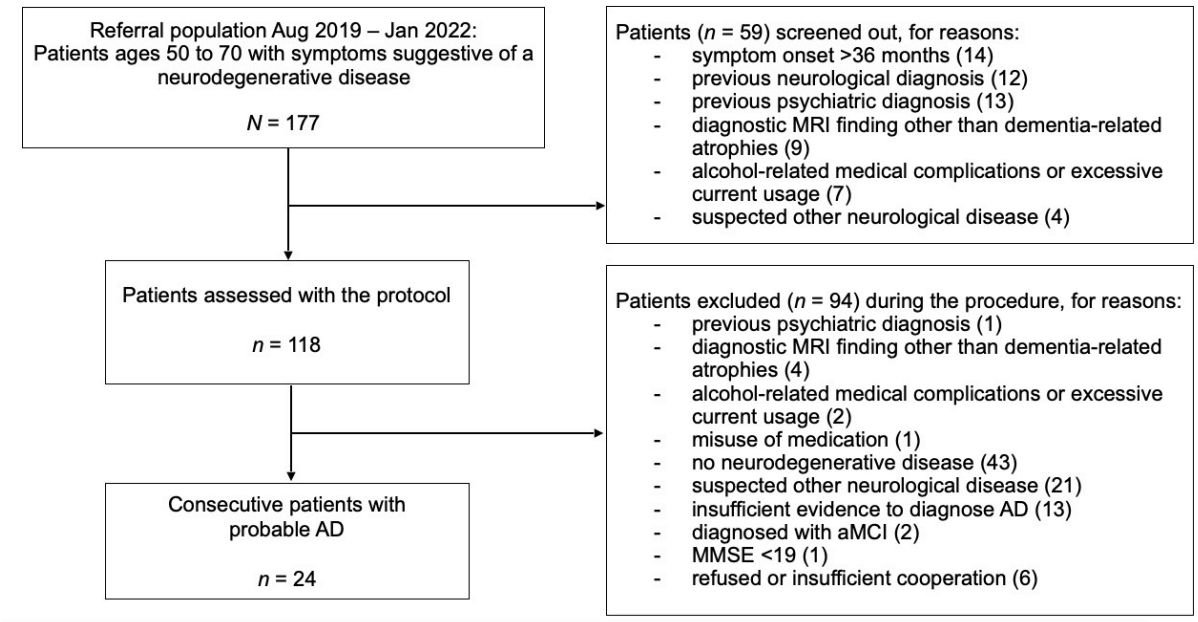
**Table 4** Results of generalized linear model: Dementia Apraxia Test sum score differences (HC–AD) adjusted for age and years of education

| | Group | Age | Education | *F(3, 42)* | $R^2$ adjusted |
|---|---|---|---|---|---|
| Limb subscore (max. 30) | 11.1*** | 0.1 | 0.2 | 28.06 | 0.64 |
| Face subscore (max. 30) | 4.0*** | 0.0 | 0.1 | 7.74 | 0.31 |
| Total sum (max. 60) | 15.1*** | 0.1 | 0.3 | 26.02 | 0.63 |

*Note*. Significance levels *<.05, **<.01, ***<.001

**Figure 1**

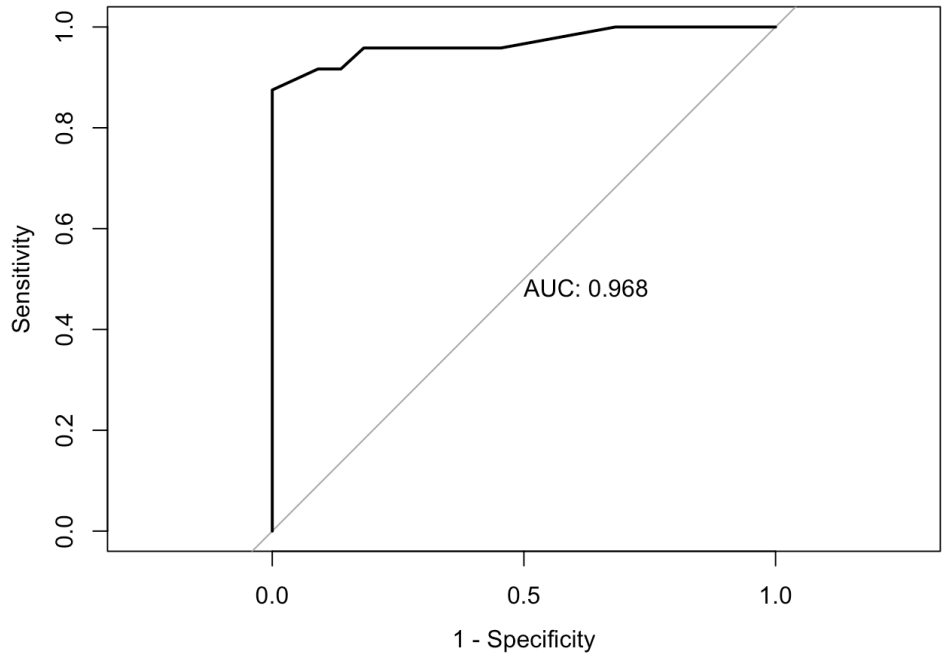
*Flow chart of patient selection*




Abbreviations: AD, Alzheimer's disease; aMCI, amnestic mild cognitive impairment; MMSE, Mini-Mental State Examination; MRI, magnetic resonance imaging.

**Figure 2**

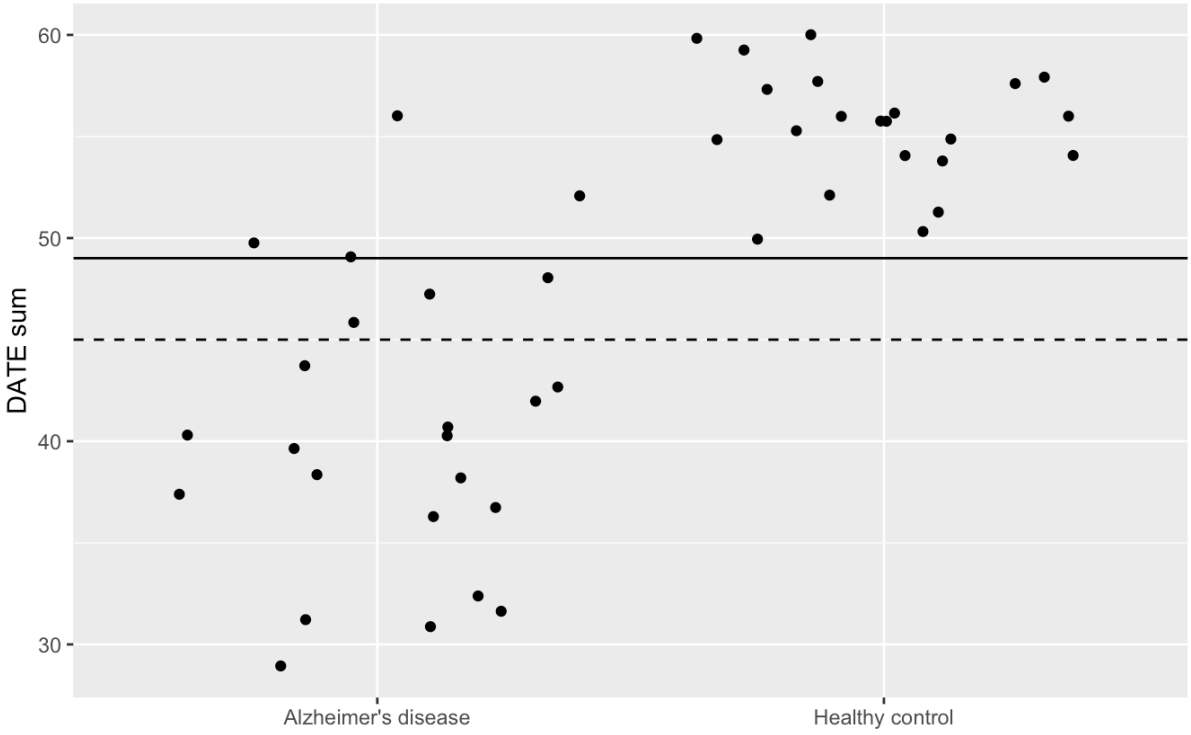
*The receiver operating characteristic curve of the Dementia Apraxia Test Total sum score as a classifier between groups*




*Note.* The 95% confidence interval is .907–1.

**Figure 3**

*Dementia Apraxia Test Total sum scores between groups*




*Note*. The solid line denotes the optimal diagnostic cut-off score in the present sample and the dotted line the cut-off score proposed previously (Johnen, Frommeyer, et al., 2015).

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**Supplement**

**Supplement Figure 1** *The significant correlations between Dementia Apraxia Test scores and selected traditional neuropsychological tests for Alzheimer's disease participants*