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RESEARCH ARTICLE

The Cognitive & Leisure Activity Scale (CLAS): A new measure to quantify cognitive activities in older adults with and without cognitive impairment

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Abstract

Introduction: Potentially modifiable dementia risk factors include diet and physical and cognitive activity. However, there is a paucity of scales to quantify cognitive activities. To address this, we developed the Cognitive & Leisure Activity Scale (CLAS).

Methods: The CLAS was validated in 318 consecutive individuals with and without cognitive impairment. Psychometric properties were compared with sample characteristics, disease stage, and etiology.

Results: The CLAS has very good data quality (Cronbach alpha: 0.731; 95% confidence interval: 0.67-0.78). CLAS scores correlated with gold standard measures of cognition, function, physical functionality, behavior, and caregiver burden. CLAS scores were positively correlated with other resilience factors (eg, diet, physical activity) and negatively correlated with vulnerability factors (eg, older age, frailty).

Discussion: The CLAS is a brief inventory to estimate dosage of participation in cognitive activities. The CLAS could be used in clinical care to enhance cognitive activity or in research to estimate dosage of activities prior to an intervention.

KEYWORDS
Alzheimer's disease, cognitive activity, cognitive impairment, dementia, dementia prevention

1 | INTRODUCTION

Alzheimer's disease and related dementias (ADRD) currently affect >5.7 million Americans[1] and >50 million people worldwide.[2] By the year 2050, the number of ADRD cases is expected to increase as the number of people older than 65 years of age grows by 62% and the number of people older than 85 years is expected to grow by 84%.[1,3] More than one in eight adults older than 65 years of age has dementia and current projections indicate a 3-fold increase by 2050.[1] In addition to cognitive impairment, >31 million adults age ≥50 years are physically inactive,[4] and impaired physical performance may interfere with activities of daily living (ADLs).[5] The extent to which older adults are mentally and cognitive active is unknown.

A large number of modifiable (eg, exposures, lifestyle, and social habits) and non-modifiable (eg, age, sex, genetics) risk factors have been identified.[6–8] Up to 30% of ADRD cases could be preventable through modification of risk factors and behavioral changes to mitigate the effect of unmodifiable risk factors.[6–9] Multiple lines of evidence from epidemiological and longitudinal observational studies exist that suggest that the risk of ADRD appears to be reduced in individuals who are physically[10–12] and cognitively active,[13] socially engaged,[14,15] who expand their life space,[16] practice mindfulness,[17]

RESEARCH IN CONTEXT

1. **Systematic Review**: The authors reviewed the literature (eg, PubMed) focusing on articles that describe the types of cognitive activities older adults participated in and scales available to capture this information. There are limited scales for capturing cognitive activities in older adults that can be used in individuals with and without cognitive impairment.
2. **Interpretation**: Our findings support that the Cognitive & Leisure Activity Scale (CLAS) can provide a brief, yet comprehensive assessment of the activities in which older adults participate and the frequency of their participation. This permits estimation of a baseline "dosage" of cognitive and leisure activities. The CLAS works well across different patient characteristics, cognitive stages, and dementia etiologies.
3. **Future Directions**: The CLAS could be used to estimate baseline cognitive and leisure activities in dementia prevention and intervention studies. The longitudinal properties of the CLAS still need to be studied, as well as studies across different racial, ethnic, and cultural groups.

have higher educational attainment and cognitive reserve,[18,19] and eat a heart- and brain-healthy diet.[20,21] For example, in a meta-analysis of 19 studies,[22] cognitive and leisure activities, including crossword puzzles, card games, computer use, arts and crafts, life-long learning, group discussions, and music had a protective effect for ADRD (odds ratio [OR] = 0.58). In addition, several large-scale, multi-modal interventions aimed at ADRD prevention are underway that focus more broadly on lifestyle[7,23–25] including cognitively stimulating activities.

However, a potential challenge in designing and implementing an intervention with cognitive and leisure activities is identifying and quantifying what activities older adults are engaging in before starting the intervention and how often they are doing them. This is important in group randomized trials in which an estimation of cognitive activities is important to establish a baseline, in order to determine if an intervention is effective.[13,26] It is equally important in clinical practice and precision medicine–type trials to personalize the intervention for maximal benefits.[27] In addition, cognitive decline can have a deleterious effect on the types of activities and the extent to which an individual participates. Thus it is a critical methodological challenge to measure cognitive activity.[28] However, there are few instruments available to capture and quantify cognitive activities in a standardized fashion.

To address this unmet need, we developed the CLAS, an inventory of activities in which older adults commonly participate and are supported by research as beneficial.[22] We had three overall goals: (1) conduct a descriptive study of the data quality and psychometric properties of the CLAS; (2) examine whether cognitive and leisure activities captured by the CLAS were positively correlated with other protective or resilience factors associated with ADRD such as physical activity, mindfulness, diet, and social engagement, and negatively correlated with risk or vulnerability factors associated with ADRD such as age, vascular risk factors, physical frailty, and multiple medical comorbidities; and (3) test the hypothesis that individuals with high levels of cognitive and leisure activities at baseline would perform better on neuropsychological tests and caregiver and patient ratings of function, and have less atrophy on magnetic resonance imaging (MRI) captured as hippocampal occupancy scores. We examined the utility of the CLAS to quantify cognitive leisure activities in cognitively normal controls, mild cognitive impairment (MCI), and ADRD.

2 | METHODS

2.1 | Study Participants

This study was conducted in 318 consecutive patient-caregiver dyads attending our center for clinical care or participation in cognitive aging research. During one 3-hour visit, each patient and caregiver underwent a comprehensive evaluation including the Clinical Dementia Rating (CDR) and its sum of boxes (CDR-SB),[29] physical and neurological examination; assessment of mood, physical performance, and falls risk; neuropsychological testing; and caregiver ratings of patient cognitive abilities, behavior, and function. Patients and caregivers independently completed rating scales; independent interviews with the patient and caregiver were conducted to generate the CDR; a psychosocial assessment was conducted with the caregiver while the patient underwent neuropsychological testing, physical, and neurologic examinations; and a feedback session was conducted with the patient and caregiver to review the results. All components of the assessment are part of standard of care at our center, and research and clinical data collection platforms are identical.[30] A waiver of consent was obtained for retrospective analyses of clinic patients, whereas prospective research participants provided written informed consent. This study was approved by the University of Miami Institutional Review Board.

Development and Scoring of CLAS : The CLAS (**Table 1**) was developed as part of a review of a comprehensive assessment of older adults and their caregivers by a collaborative care team including a cognitive neurologist, gerontologist, physical therapist, nurse practitioners, and social workers in conjunction with a review of the literature. Items incorporated into the CLAS were captured as part of semi-structured interviews with patients and caregivers or reported in the literature as offering protective benefits for ADRD. Final item selection was by consensus and included 16 items covering passive activities, games, social activities, the arts, and exercise with exemplars provided. Because participation in these activities may vary over time, respondents were asked to consider these cognitive leisure activities over the prior year. Frequency of activity was scored on a 0-5 scale collected as never (score 0), several times per year (score 1), several times per month (score 2), once per week (score 3), several times per week (score 4), and daily (score 5). Many activities may overlap, particularly with socialization. Some activities serve a specific purpose (eg, attendance of a reli-

TABLE 1 The Cognitive Leisure Activity Scale (CLAS)

INSTRUCTIONS: Please rate the patient's cognitive and leisure activities over the past year. Choose the *one best answer* that best fits the patient						
	How often do you participate in each activity (Check One)					
Type of Activity	Never	Several times per year	Several times per month	Once per week	Several times per week	Daily
Chess, Checkers, Backgammon						
Crossword puzzles, Jigsaw puzzles, Sudoku						
Playing cards or Board Games						
Socializing with friends						
Attending a club or group activity outside the home						
Volunteering						
Painting, drawing or other arts/crafts						
Singing or playing instrument						
Watching TV or listening to music						
Reading a newspaper, book or magazine						
Attending the theatre, concert, or symphony						
Going to a museum or exhibition						
Attending a conference, lecture, or course						
Attending a religious service						
Writing a letter, poem, journal or diary entry						
Exercise (any type)						

gious service, club meeting), whereas others are less defined (ie, meeting a friend for a conversation). The CLAS was designed to capture the full range of cognitive and leisure activities and relies on the respondent choosing which activity fits into which category. To ensure that all activity was accounted for, no specific instructions were given that would restrict multiple reporting. The CLAS also was designed to capture unique information rather than recapitulating tasks routinely captured in ADRD clinical care and research such as performance of ADLs. The total participation was then added together to give the CLAS score representing a "dose" of cognitive and leisure activities, ranging from 0 to 80. The CLAS took 2-3 minutes to complete.

Administration of CLAS : Prior to the in-person visit, a welcome packet was mailed to the patient and caregiver to collect demographics and medical history and included the CLAS completed by the caregiver. The caregiver was asked to rate the patient's cognitive and leisure activities over the past year. The packets including the CLAS were returned before the in-person assessment. The CLAS was not considered in the clinical evaluation, staging, or diagnosis of the patient.

2.2 | Clinical Assessment

The in-person clinical assessments are modeled on the Uniform Data Set (UDS) 3.0 from the National Institute on Aging (NIA) Alzheimer Disease Research Center program.[31,32] The clinician was not aware of the CLAS score. The CDR [Morris] was used to determine the presence or absence of dementia and to stage its severity: CDR 0 = no dementia; CDR 0.5 = MCI or very mild dementia; CDR 1, 2, or 3 correspond to mild, moderate, or severe dementia. The CDR-SB was calculated by adding up the individual CDR categories, giving a score from 0 to 18, with higher scores supporting more severe stages. Because CDR 0 includes individuals with and without subjective cognitive complaints and CDR 0.5 includes individuals with MCI and very mild dementia, we also staged each individual using the Global Deterioration Scale (GDS).[33] A GDS 1 indicates no cognitive impairment (NCI); GDS 2 indicates subjective cognitive impairment; GDS 3 corresponds to MCI; and GDS 4-7 corresponds to mild, moderate, moderate-severe, or severe dementia.[33] Diagnoses were determined in consensus conference using standard criteria for MCI,[34] AD,[35] dementia with Lewy bodies (DLB),[36] vascular contributions to cognitive impairment and dementia (VCID),[37] and frontotemporal degeneration (FTD).[38]

2.3 | Assessment of Resilience (Protective) Factors

Educational attainment was captured as years of formal schooling (range: 0-20), with any postgraduate training being capped at 20 years. The Quick Physical Activity Rating (QPAR)[39] was used to determine the dosage of physical activity in which the patient participates over a 4-week period. Scores range from 0 to 153, with higher scores representing greater participation in physical activity. The Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet scoresheet[40] was used to determine the extent to which the patient follows the Mediterranean-DASH diet (15 food categories and frequencies; score range: 0-15). Higher scores represent greater adherence to the MIND diet. Mindfulness was measured with the Applied Mindfulness Process Scale (AMPS).[41] Responses were reported on a 5-point Likert scale (score range: 0-60), with higher scores indicative of greater use of mindfulness practice. Social engagement was captured by an investigator-generated question that ask "How would you rate the participant's overall socialization?" scored on a Likert scale using anchors (poor, fair, good, excellent) with scores ranging from 1 to 4 with higher scores representing greater social engagement.

2.4 | Assessment of Vulnerability (Risk) Factors

Age was reported as years at time of assessment. Medical comorbidities were captured with the Charlson Comorbidities Index.[42] Vascular risk factors were captured with a modified version of the Cardiovascular Risk Factors, Aging, and Dementia (mCAIDE) scale,[43,44] which ranges from 0 to 14, with higher scores representing higher risk of vascular disease. A global assessment of physical functionality was captured with the mini Physical Performance Test (mPPT),[45] which measures flexibility, gait, strength, and balance, each ranging from 0 to 4, with 4 indicating the highest level of performance for a total score between 0 and 16. A score of < 12 represents impaired physical functionality.[45] Physical frailty was assessed with the Fried Frailty Phenotype,[46] with scores of 1-2 rated as pre-frailty and scores ≥ 3 supporting presence of frailty.[46]

2.5 | Cognitive Assessment

Each patient was administered an in-person 45-minute test battery to assess their cognitive status. The psychometrist was unaware of the diagnosis, CDR, or CLAS scores. Subjective cognitive complaints were captures with the AD8[47] and Quick Dementia Rating System (QDRS).[48] The Montreal Cognitive Assessment (MoCA)[49] was used for a global screen. The rest of the battery was modeled after the UDS battery used in the NIA Alzheimer Disease Centers[32] supplemented with additional measures: 15-item Multilingual Naming Test (naming)[32]; Animal naming fluency (verbal fluency)[32]; Hopkins Verbal Learning Task (episodic memory for word lists—immediate, delayed, and recognition)[50]; Number forward/backward tests (working memory)[32]; Trailmaking A and B (processing and visuospatial abilities)[51]; and the Number-Symbol Coding Test (executive function).[52] A composite z-score was generated to represent overall cognitive performance. Mood was assessed with the Hospital Anxiety Depression Scale,[53] providing subscale scores for depression (HADS-D) and anxiety (HADS-A).

2.6 | Caregiver ratings of patient cognition, function, and behavior

ADLs were captured with the Functional Activities Questionnaire (FAQ).[54] Dementia-related behaviors and psychological features were measured with the Neuropsychiatric Inventory (NPI).[55] Caregiver burden was captured with the 12-item Zarit Burden Inventory.[56] Caregiver depression was reported with the Personal Health Questionnaire 4 (PHQ-4).[57]

2.7 | Apolipoprotein E genotyping

Apolipoprotein E (*APOE*) genotyping was performed by True Health Diagnostics LLC (Richmond, VA). Six possible allelic combinations were obtained with individuals dichotomized as being *APOE* ε4 carriers or non-carriers.

2.8 | Volumetric MRI

A subset of individuals ($n = 76$) underwent volumetric MRI with NeuroQuant software (CorTechs Labs, San Diego, CA), a US Food and Drug Administration (FDA)–approved automated quantitative analysis of brain MRI images with normative reference data adjusted for age, sex, and intracranial volume with high correlation to FreeSurfer[58] and visual assessment.[59] Although hippocampal volume is often used as a predictor of conversion of MCI to AD, hippocampal occupancy (HOC) measures the degree of hippocampal atrophy, accounting for volume loss and compensatory inferior lateral ventricle expansion. It is calculated as a ratio of hippocampal volume to the sum of the hippocampal and inferior lateral ventricle volumes in each hemisphere separately, which are then averaged and normalized for age and sex.[60] This measure may aid in differentiation of individuals with congenitally small hippocampi from those with small hippocampi due to a degenerative disorder. The discriminative and predictive accuracy of the HOC score exceed that of the standard hippocampal volume measure,[60] so we used HOC as the primary neuroimaging outcome measure in this study.

2.9 | Statistical Analyses

Analyses were conducted with IBM SPSS Statistics v26 (Armonk, NY). Descriptive statistics were used to examine patient and caregiver demographic characteristics, informant rating scales, dementia staging, and neuropsychological testing. Analysis of variance (ANOVA) with Tukey Honestly Significant Differences post hoc tests were used for continuous and chi-square analyses for categorical data. Data completeness was assessed by calculating response rates and missing data for each CLAS item. To assess item variability, the item frequency distribution, range, and standard deviations were calculated, and data were examined for floor and ceiling effects. Kurtosis and skewness statistics were examined to characterize the shape and symmetry of the distribution. A normal distribution has a kurtosis and a skewness value of zero. In addition, a skewness value more than twice its standard error (SE) is taken to indicate a departure from symmetry. Internal consistency was examined as the proportion of the response variability that results from differences in respondents, reported as the Cronbach alpha reliability coefficient. Coefficients >0.7 are good measures of internal consistency.[48,61]

TABLE 2 Sample characteristics ($n = 318$)

Patient Characteristics			Caregiver Characteristics		
Variable	**Value**	**Range**	**Variable**	**Value**	**Range**
Age, y	75.3 (9.2)	38-98	Age, y	56.5 (14.8)	20-76
Sex, %F	46.7		Sex, %F	66.6	
Education, y	15.7 (2.7)	6-20	Education, y	15.9 (2.7)	4-20
Race, %White	97.5		Race, %White	92.7	
Ethnicity, % Hispanic	15.2		Ethnicity, %Hispanic	8.5	
Hollingshead Index	23.7 (11.7)	11-65	Relationship		
CDR-SB	4.4 (4.5)	0-18	%Spouse	66.9	
MoCA	19.2 (6.9)	1-30	%Adult Child	19.7	
Cognitive z-score	0.047 (0.996)	-2.71-1.74	%Other	13.4	
FAQ	8.9 (9.6)	0-30	Lives with Patient, %Yes	69.6	
NPI	6.6 (5.9)	0-28	Sees Patient Daily, %Yes	83.6	
HUI3	0.55 (0.32)	-0.232-1.40	Caregiver burden	12.6 (9.9)	0-48
mPPT	10.2 (3.4)	0-16	Caregiver depression	2.3 (2.7)	0-12
QPAR	20.7 (19.1)	0-132	%Adult Child	19.7	
AMPS	37.9 (11.9)	0-60	%Other	13.4	
MIND	8.7 (2.2)	2.5-14.0			
Social Engagement	2.7 (0.9)	1-4			
CLAS	24.4 (9.5)	2-64			
mCAIDE	7.6 (2.9)	0-14			
Charlson	2.4 (1.7)	0-8			
Fried Frailty Score	2.2 (1.4)	0-5			

Mean (SD) or %.
CDR-SB = Clinical Dementia Rating Sum of Boxes; MoCA = Montreal Cognitive Assessment; FAQ = Functional Activities Questionnaire; NPI = Neuropsychiatric Inventory; HUI3, Health Utilities Index Mark 3; mPPT = Mini Physical Performance Test; QPAR = Quick Physical Activity Rating; MIND = Mediterranean-DASH Intervention for Neurodegenerative Delay; CLAS = Cognitive & Leisure Activity Scale; mCAIDE = modified Cardiovascular Risk Factors, Aging, and Dementia.

Construct validity was examined based on the unified framework of construct validity,[62,63] examining six aspects: consequential (are there risks with invalid scores), content (does the test measure constructs of interest), substantive (is the theoretical foundation sound), structural (do interrelationships of test measurements correlated with construct of interest), external (does the test have convergent, discriminant, and predictive qualities), and generalizability (does the test work across different groups and settings). Strength of association was assessed comparing CLAS scores with performance on each gold standard measure of cognition (eg, CDR, neuropsychological testing), function (ie, FAQ), behavior (eg, NPI, HADS), caregiver ratings (eg, ZBI, PHQ-4), resilience (eg, physical activity, diet), vulnerability (eg, age, frailty), and hippocampal atrophy (ie, HOC) using Pearson correlation coefficients. CLAS scores were plotted with fitted regression lines against the composite cognitive z-scores and HOC scores by cognitive status (controls, MCI, dementia) to test whether higher CLAS scores were associated with better cognitive performance or greater volumes. Known-group validity was assessed by examining the CLAS scores by patient characteristics, frailty ratings, CDR and GDS staging, and dementia etiology.[48,61] Receiver-operating characteristic (ROC) curves were used to assess discrimination between patient groups (cognitively healthy controls vs cognitively impaired individuals) with the CLAS. Results are reported as area under the curve (AUC) with 95% confidence intervals (CIs). Correction for multiple comparisons was performed using Bonferroni corrections.

Finally, cross-sectional mediation analyses were employed to assess whether protective and risk factors help explain at least in part the effect of CLAS on cognitive function. To reduce the number of comparisons, we restricted these analyses to significant mediators and cognitive outcomes. Bootstrapping techniques, which involve resampling the data multiple times (1000 resamples), were used to obtain an empirical estimation of the indirect effects across the resamples with CIs around it to assess its statistical significance. Advantages of this technique include quantitative indirect effect estimates and non-stringent requirements regarding the sampling distribution of indirect effects. Effects for all paths (a = effect of predictor on mediator; b = effect of mediator on outcome; c = total effect of predictor on outcome; c' = direct effect of predictor on outcome; and ab = indirect effect of predictor on outcome) as well as the proportion of effect that is mediated were evaluated.

TABLE 3 CLAS item distributions, response frequency, item-factor, and item-total scale correlations

CLAS Item	Mean (SD)	CLAS Response Counts (%) 0	1	2	3	4	5	Missing	Item-Scale R
Chess, Checkers, Backgammon (Q1)	0.3 (0.8)	84.2	11.2	0.5	1.5	1.5	1.5	0.0	.277
Crossword, Jigsaw, Sudoku (Q2)	1.6 (2.0)	55.6	8.7	2.6	5.1	10.2	17.9	0.0	.520
Card or Board Games (Q3)	1.2 (1.5)	51.5	17.9	7.7	8.2	12.2	2.6	0.0	.429
Socializing with Friends (Q4)	3.0 (1.5)	5.6	13.3	22.4	11.7	29.6	17.3	0.0	.640
Attending a club (Q5)	1.8 (1.7)	38.8	11.2	11.7	14.3	20.4	3.6	0.0	.698
Volunteering (Q6)	0.7 (1.3)	69.9	13.3	4.1	4.6	5.1	3.1	0.0	.534
Painting or arts/crafts (Q7)	0.4 (1.1)	78.1	13.3	1.0	3.1	2.0	2.6	0.0	.378
Singing or playing instrument (Q8)	0.5 (1.2)	82.1	6.6	1.5	2.6	3.6	3.6	0.0	.231
Watching TV/listening to Music (Q9)	4.6 (1.0)	2.0	2.0	1.5	1.5	16.8	76.0	0.0	.297
Reading (Q10)	3.9 (1.6)	8.7	3.6	4.6	4.6	24.5	54.1	0.0	.461
Attending theatre, concert (Q11)	1.0 (0.8)	29.6	44.4	22.4	2.6	1.0	0.0	0.0	.424
Going to museum (Q12)	0.6 (0.6)	46.4	46.9	5.6	0.0	1.0	0.0	0.0	.505
Attending a conference or lecture (Q13)	0.7 (0.9)	49.5	37.2	7.7	3.1	2.6	0.0	0.0	.486
Attending a religious service (Q14)	1.3 (1.5)	43.9	24.0	5.6	16.8	7.1	2.6	0.0	.375
Writing a letter (Q15)	0.8 (1.5)	67.9	14.8	3.1	2.0	6.1	6.1	0.0	.526
Exercise (Q16)	2.8 (1.9)	21.9	9.2	7.1	4.1	36.7	20.9	0.0	.434

CLAS = Cognitive & Leisure Activity Scale.
CLAS Response Counts refers to frequency choice for each CLAS item: 0 = Never, 1 = Several times per year; 2 = Several times per month; 3 = Once per week; 4 = Several times per week; 5 = Daily.

3 | RESULTS

3.1 | Sample Characteristics

Patients had a mean (± standard deviation) age of 75.5 ± 9.2 years (range 38-98 years), 15.8 ± 2.9 years of education (range 6-20 years), 46.7% were female, 97.5% were White, and 15.2% reported Hispanic ethnicity. Caregivers had a mean age of 55.8 ± 14.9 years (range 20-76), 15.9 ± 2.6 years (range 4-20) of education, 66.6% were female, 92.7% were White, and 8.5% reported Hispanic ethnicity. The patients had a mean CDR-SB of 4.6 ± 4.6 (range 0-18), a mean FAQ score of 9.2 ± 9.7 (range 0-30), and a mean MoCA score of 19.0 ± 7.0 (range 1-30). Complete sample characteristics are presented in **Table** 2. The sample included a range of CDR stages: CDR 0 = 49; CDR 0.5 = 130; CDR 1 = 71; CDR 2 = 49; CDR 3 = 19. Final diagnoses included 48 cognitively normal controls, 99 MCI, 63 AD, 82 DLB, 13 VCID, and 13 FTD. Caregivers were spouses (66.9%), adult children (19.7%), or other individuals (13.4%), with 69.6% reporting living with the patient and 83.6% having daily contact.

3.2 | CLAS Data Quality

Table 3 presents the item distribution, response frequency, and item-scale correlation for the CLAS. Item-level response rates for the minimal response option (ie, Never) ranged from 2.0% (Watching TV or Listening to Music) to 84.2% (Playing Chess, Checkers, or Backgammon). Item-level response rates for the maximal response option (ie, Daily) ranged from 0% (Attending Theatre or Concerts, Going to Museum, Attending Conference or Lecture) to 76.0% (Watching TV or Listening to Music). The standard deviation (SD) was similar for all items, ranging from 0.6 to 2.0. The individual CLAS items were weakly correlated with each other, suggesting that each question covered a different form of activity (data not shown); however, each item was moderately correlated with the overall CLAS score. There were no missing data. The CLAS internal consistency was very good, with a Cronbach alpha = 0.729 (95% CI: 0.671-0.782). CLAS scale floor (0%) and ceiling (0%) effects were absent. The distribution statistics of the CLAS demonstrates a normal distribution with a mean of 24.5 ± 9.5, a median of 24.0, kurtosis of 0.38 (SE = 0.27), and skewness of 0.45 (SE = 0.14). Overall, data quality for the CLAS was very good.

3.3 | Relationship of CLAS scores to cognition, function, behavior, health, and caregiver ratings

Table 4 presents the strength of association between the CLAS and patient demographics; measures of cognition, function, behavior, and physical functionality; caregiver outcomes; and global rating scales. The CLAS had moderate correlations with all rating scales and neuropsychological tests except for the Numbers Forward task. Individuals with more medical comorbidities, worse mood, poorer cognitive performance, or worse physical functionality participated in

TABLE 4 Strength of association between CLAS and study variables

Variable	R	P	Adjusted P
Patient Characteristics			
Patient age	-.151	.006	---
Patient education	.204	**<.001**	---
FAQ	-.443	**<.001**	**<.001**
NPI	-.422	**<.001**	**<.001**
Caregiver Outcomes			
Caregiver depression	-.234	**<.001**	**<.001**
Caregiver burden	-.337	**<.001**	**<.001**
Patient Physical Status			
QPAR	.470	**<.001**	**<.001**
mPPT	.319	**<.001**	.005
Charlson	-.215	**<.001**	.016
Fried Frailty	-.347	**<.001**	.011
mCAIDE	-.261	**<.001**	.007
Global Rating Scales			
CDR-SB	-.378	**<.001**	**<.001**
GDS	-.444	**<.001**	**<.001**
Mood and Subjective Complaints			
HADS-A	-.189	**.001**	.008
HADS-D	-.318	**<.001**	**<.001**
AD8, patient-reported	-.279	**<.001**	.005
QDRS, patient-reported	-.396	**<.001**	**<.001**
Resilience Factors			
MIND Diet	.201	**.002**	.021
AMPS	.269	**<.001**	.008
Social Engagement	.446	**<.001**	**<.001**
Neuropsychological Testing			
MoCA	.342	**<.001**	**.001**
Numbers Forward	.095	.09	**<.001**
Numbers Backward	.331	**<.001**	**<.001**
HVLT-immediate	.398	**<.001**	**<.001**
HVLT-delayed	.382	**<.001**	**<.001**
Trailmaking A	-.301	**<.001**	.004
Trailmaking B	-.373	**<.001**	**<.001**
Number Symbol	.302	**<.001**	**<.001**
Animal Naming	.386	**<.001**	**<.001**
MINT	.149	.008	.164
Cognitive Z-Score	.395	**<.001**	**<.001**

Adjusted *P* value for age and education.
FAQ = Functional Activities Questionnaire; HUI3 = Health Utilities Index-Mark 3; NPI = Neuropsychiatric Inventory; QPAR = Quick Physical Activity Rating; mPPT = Mini Physical Performance Test; mCAIDE = modified Cardiovascular Risk Factors, Aging, and Dementia; CDR-SB = Clinical Dementia Rating Sum of Boxes; GDS = Global Deterioration Scale; HADS-A = Hospital Anxiety and Depression Scale-Anxiety Subscale; HADS-D = Hospital Anxiety and Depression Scale-Depression Subscale; QDRS = Quick Dementia Rating System; MIND = Mediterranean-DASH Intervention for Neurodegenerative Delay; MoCA = Montreal Cognitive Assessment; HVLT = Hopkins Verbal Learning Test; MINT = Multilingual Naming Test.
Bold signifies significance after controlling for multiple comparisons.

few cognitive leisure activities. Individuals with higher CLAS scores also participated in more physical activities, ate healthier diets, had higher levels of mindfulness, and were more socially engaged. The CLAS was also negatively associated with caregiver burden (R = –.337, $P < .001$) and caregiver depression (R = –.234, $P < .001$), suggesting that patients who participate in more cognitive and leisure activities experience better caregiver outcomes. We repeated these analyses controlling for age and education (**Table 4**). Correlations remained significant for most variables.

3.4 | Known Group Validity of the CLAS

Performance of CLAS was compared between patient age, education, sex, race, ethnicity, SES, apoE status, CDR and GDS stages, and dementia etiologies in **Table 5**. Females participated in more cognitive and leisure activities than males (F = 22.7; $P < .001$). African Americans reported higher CLAS scores than Non-Hispanic Whites or Hispanics (F = 9.9; $P < .001$); however, this difference should be interpreted with caution as the absolute numbers of African Americans and Hispanics in the sample were small, so this needs to be investigated further. CLAS scores differed by age strata (F = 3.7; $P = .01$), with individuals older than age 80 reporting the lowest CLAS scores. CLAS scores differed by education strata (F = 4.7; $P = .001$) and SES class (F = 3.2; $P = .04$), with the lowest education and the lowest SES class reporting the lowest CLAS scores. There was no difference in CLAS scores by *APOE* carrier status. Physical frailty had a significant effect on CLAS scores (F = 8.5; $P < .001$), with individuals with no frailty (Fried Score 0) or pre-frailty (Fried Score 1-2) reporting higher CLAS scores than individuals with frailty (Fried Scores 3-5). There were significant differences in mean CLAS scores with worsening global cognitive ratings by CDR (F = 20.5; $P < .001$) and GDS (F = 13.7; $P < .001$). Post hoc analyses revealed that CDR 0 patients were different from all other CDR stages. Individuals at CDR 0.5 were different from CDR 1-3. In individuals who were rated CDR ≥1, CLAS scores did not differ between adjacent CDR stages. Similarly, when considering the GDS, post hoc analyses revealed that GDS 1 and GDS 2) were not different from each other but were different from all other GDS stages. Individuals with GDS 3 and 4 were not different from each other. Examining consensus clinical diagnoses, CLAS scores in cognitively normal controls were significantly different than MCI and all dementia etiologies, whereas MCI individuals were different from individuals with any form of dementia. CLAS scores were not different between dementia etiologies. ROC analyses demonstrated that the CLAS ability to discriminate between controls and cognitively impaired individuals (MCI + Dementia) was good, with an AUC 0.767 (95% CI: 0.692-0.841, $P < .001$).

3.5 | Association of CLAS Scores with Cognitive Performance and Hippocampal Occupancy Scores

We next examined the relationship between CLAS scores with overall cognitive performance (composite z-score) and hippocampal volumes

TABLE 5 CLAS scores by sociodemographic characteristics, frailty phenotype, staging, and dementia etiology

	Sex			Race/Ethnicity			
Variable	Male	Female	F-statistic (*P*)	White	Black	Hispanic	F-statistic (*P*)
CLAS	22.0±7.8 20.9-23.2	26.9±10.5 25.3-28.6	22.69 (< .001)	24.2±9.1 23.2-25.3	38.0±13.9 26.3-49.7	20.8±9.0 16.0-25.6	9.95 (< .001)[a]

	Age strata					*APOE* status		
	<60 y	60-69 y	70-79 y	80+ y	F (*P*)	Carrier	Noncarrier	F-statistic (*P*)
CLAS	25.8±10.2 21.3-30.4	26.8±7.5 24.7-28.9	25.1±10.2 23.4-26.9	22.1±8.9 20.5-23.8	3.70 (.012)[b]	27.3±10.5 24.7-29.8	25.6±8.9 23.9-27.2	1.32 (.252)

	Education Strata				SES Strata			
	≤12 y	13-16 y	>16 y	F-statistic (*P*)	Class I	Class II-II	Class IV-V	F-statistic (*P*)
CLAS)	21.7± 10.3 19.2-24.3	24.2±9.8 22.6-25.8	26.2±8.1 24.7-27.7	4.69 (.010)[c]	27.6±8.5 25.3-29.9	24.2±9.5 22.5-25.9	29.2±14.9 20.2-38.3	3.25 (.041)[d]

	Physical Frailty Status						
	Fried 0	Fried 1	Fried 2	Fried 3	Fried 4	Fried 5	F-statistic (*P*)
CLAS	29.5±7.9 27.2-31.7	27.4±8.8 24.8-29.9	25.3±9.9 23.0-27.6	22.1±8.6 20.2-23.9	20.9±9.3 18.0-23.9	18.2±6.1 15.1-21.2	8.53 (< .001)[e]

	Clinical Dementia Rating					
	CDR 0	CDR 0.5	CDR 1	CDR 2	CDR 3	F-statistic (*P*)
CLAS	32.5±9.9 29.7-35.4	25.8±8.7 24.2-27.3	20.3±6.0 18.9-21.8	20.3±9.1 17.7-22.9	19.6±8.9 15.3-23.9	20.49 (< .001)[f]

	Global Deterioration Scale						
	GDS 1	GDS 2	GDS 3	GDS 4	GDS 5	GDS 6	F-statistic (*P*)
CLAS	33.5±11.3 28.9-38.0	31.7±8.4 28.1-35.4	26.0±9.0 24.2-27.8	22.6±6.9 21.1-24.2	20.5±8.1 18.2-22.8	15.7±4.4 16.4-22.1	13.68 (< .001)[g]

	Consensus Clinical Diagnosis						
	Control	MCI	AD	DLB	VCID	FTD	F-statistic (*P*)
CLAS	32.5±10.3 29.6-35.4	26.1±9.0 24.3-27.9	23.0±8.9 20.7-25.3	19.4±6.2 18.0-20.7	20.8±10.5 14.5-27.2	23.8±7.4 19.3-28.3	13.46 (< .001)[h]

Means ± SD, (95% confidence intervals); F-statistic, (*P*).

CLAS = Cognitive & Leisure Activity Scale; SES = Socioeconomic Status measured with the Hollingshead Index; CDR = Clinical Dementia Rating; GDS = Global Deterioration Scale; MCI = mild cognitive impairment; AD = Alzheimer's disease; DLB = Dementia with Lewy bodies; VCID = vascular contributions to cognitive impairment and dementia; FTD = frontotemporal degeneration.

[a]Post hoc analyses: African Americans are different from White and Hispanic patients (Note: interpret with caution due to low numbers).

[b]Post hoc analyses: Age 80+ are different from other age strata.

[c]Post hoc analyses: Education < 12 y different Education > 16 y.

[d]Post hoc analyses: Middle socioeconomic status (SES) marginally different from other SES.

[e]Post hoc analyses: Fried Score 0-2 not different from each other; Fried 2 is not different from Fried 3-4; Fried Scores 3-5 are not different from each other.

[f]Post hoc analyses: CDR 0 different from all other CDR stages; CDR 0.5 different from all other CDR stages; CDR 1, CDR 2 and CDR 3 not different from each other.

[g]Post hoc analyses: GDS 1 and GDS 2 not different from each other; GDS 3 not different from GDS 4; GDS 4, GDS 5 and GDS 6 not different from each other.

[h]Post hoc analyses: Cognitively normal controls different from MCI and all dementia etiologies; MCI different from all dementia etiologies; Dementia etiologies not different from each other.

of MRI (measured with HOC scores) in **Figure 1**. Because CLAS scores were different between cognitively normal controls, MCI, and all dementia diagnoses but dementia etiologies were not different from each other, cases were divided into three groups: cognitively normal controls (blue circles), MCI (red circles), and dementia (green circles) with subgroup regression lines. **Panel 1A** demonstrates the association between CLAS scores and the composite cognitive battery z-score. Higher CLAS scores are moderately associated with better cognitive performance in controls (R = 0.221, *P* < .001) and MCI cases (R = .336, *P* < .001) but not in dementia cases (R = .063). **Panel 1B** shows the association between CLAS scores and HOC scores. Higher CLAS scores are strongly correlated, with higher HOC scores in controls representing less hippocampal atrophy (R = 0.737, *P* < .001) but not in MCI (R = .063) or dementia cases (R = .017).

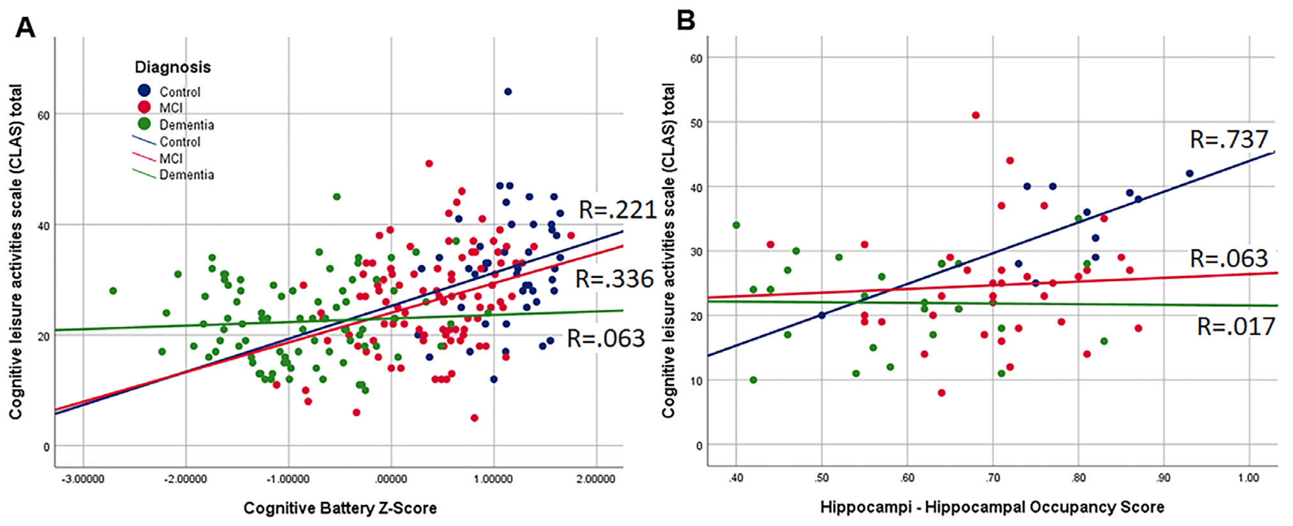

FIGURE 1 Association of CLAS scores with cognitive performance and hippocampal occupancy scores. Scatterplots are shown for cognitively normal controls (blue circles), mild cognitive impairment (MCI; red circles), and dementia (green circles) with fitted regression lines for the three subgroups. A demonstrates the association between CLAS scores (y-axis) and the cognitive battery z-scores (x-axis). Higher CLAS scores are moderately associated with better cognitive performance in cognitively normal controls (R = 0.221, *P* < .001) and MCI cases (R = .336, *P* < .001) but not with dementia cases (R = .063). **B** the association between CLAS scores (y-axis) and hippocampal occupancy scores (x-axis). Higher CLAS scores are strongly correlated with higher hippocampal occupancy scores in cognitively normal controls representing less hippocampal atrophy (R = 0.737, *P* < .001) but not in MCI (R = .063) or dementia cases (R = .017). KEY: MCI=Mild Cognitive Impairment.

3.6 | Comparison of CLAS with Other Modifiable Resilience and Vulnerability Factors

We hypothesized that individuals who participated in more cognitive and leisure activities would likely also have higher ratings in other activities that may offer ADRD protective benefits. We examined six resilience factors: education, social engagement, physical activity (QPAR), mindfulness (AMPS), diet (MIND), and cognitive and leisure activities (CLAS) by diagnostic group (**Table 6**). Controls and MCI were similar but different from dementia on education, social engagement, and diet resilience factors. Controls were different from MCI, and MCI different from dementia on physical activity, mindfulness, and cognitive and leisure activities (all *P* values except for educational attainment < .001). We then evaluated the relationships between CLAS tertiles with distribution of diagnosis and disease severity, performance on neuropsychological test adjusted for age and sex, and with scores for resilience and vulnerability factors adjusted for age and sex (**Table 7**). Relationships between cognitive and HOC scores were examined by CLAS tertile. For each CLAS tertile, better neuropsychological test performance was associated with better HOC scores, with the highest CLAS tertile (R = 0.776) showing a greater effect than the middle (R = 0.535) or lowest (R = 0.489) tertiles.

TABLE 6 Comparison of participation in modifiable resilience factors by diagnostic group

Resilience Factor	Control	MCI	Dementia	F-statistic (*P*)
Education	16.1±2.2 (15.5-16.8)	16.0±2.5 (15.6-16.5)	15.3±2.8 (14.9-15.6)	4.35 (.014)[a]
Social Engagement	3.3±0.6 (3.2-3.5)	3.0±0.8 (2.9-3.2)	2.4±0.9 (2.3-2.5)	**31.77 (<.001)**[a]
QPAR	39.0±24.5 (32.1-45.9)	23.5±18.8 (20.1-26.9)	14.0±13.4 (12.2-15.8)	**48.38 (<.001)**[b]
AMPS	44.8±10.7 (41.7-47.9)	39.4±10.8 (37.2-41.6)	34.9±11.8 (32.9-36.8)	**14.92 (<.001)**[b]
MIND	9.6±2.2 (8.9-10.3)	9.1±2.0 (8.7-9.5)	8.3±2.1 (7.9-8.6)	**9.29 (<.001)**[a]
CLAS	32.5±10.3 (29.6-35.4)	26.1±9.0 (24.3-27.9)	21.2±7.9 (19.9-22.3)	**35.13 (<.001)**[b]

Means ± SD, (95% confidence intervals); F-statistic, (*P*).
KEY: MCI = mild cognitive impairment; QPAR = Quick Physical Activity Rating; AMPS = Applied Mindfulness Process Scale; MIND = Mediterranean-DASH Intervention for Neurodegenerative Delay; CLAS = Cognitive & Leisure Activity Scale.
[a]Post hoc analyses: Controls and MCI not different from each other; Dementia different from Controls and MCI.
[b]Post hoc analyses: Controls, MCI, and Dementia all different from each other.
Bold indicates significance after adjustment for multiple comparison.

3.7 | Association Between CLAS and Global Cognition

Finally, we used mediation analysis to test whether resilience and vulnerability factors explain the effect of CLAS on cognitive function, using the MoCA (**Figure 2**). Five of the six protective and risk factors assessed were found to mediate the CLAS-MoCA association. Most path effects were significant at *P* < 0.001, indicating highly significant relationships between CLAS score, individual mediators, and MoCA. Mediators varied, however, in terms of their impact. Using the pro-

TABLE 7 Relationship between CLAS tertiles and diagnosis, cognitive testing, resilience, and vulnerability factors

	Bottom Tertile	Middle Tertile	Top Tertile	*P*
Diagnosis	%	%	%	<.001
Controls	12.5	18.8	68.8	
MCI	25.0	36.0	39.0	
Dementia	48.2	32.9	18.8	
Neuropsychologic Tests	**Mean±SD(95% CI)**	**Mean±SD(95% CI)**	**Mean±SD(95% CI)**	**F-statistic (*P*)**
MoCA	16.9±0.6 (15.8-18.1)	19.1±0.6 (17.9-20.3)	21.6±0.6 (20.4-22.8)	**26.72 (<.001)**
Numbers forward	6.6±0.1 (6.3-6.9)	6.6±0.1 (6.3-6.9)	6.9±0.1 (6.7-7.3)	3.72 (.116)
Numbers backward	3.9±0.1 (3.6-4.2)	4.2±0.2 (3.9-4.5)	5.0±0.2 (4.7-5.3)	**10.29 (<.001)**
HVLT recall	12.3±0.6 (11.1-13.4)	15.2±0.6 (14.1-16.4)	17.0±0.6 (15.8-18.2)	**28.16 (<.001)**
HVLT delay	2.9±0.3 (2.2-3.4)	4.1±0.3 (3.4-4.7)	5.2±0.3 (4.6-5.8)	**37.22 (<.001)**
Trail Making A	77.1±3.9 (69.3-84.9)	54.0±4.0 (46.1-61.9)	49.9±4.0 (41.9-57.9)	**18.64 (<.001)**
Trail Making B	137.7±5.2 (127.5-147.9)	112.8±4.7 (103.5-122.2)	101.2±4.6 (92.2-110.3)	**27.78 (<.001)**
Number Symbol Coding	25.9±1.2 (23.4-28.3)	31.7±1.2 (29.3-34.1)	33.8±1.1 (31.5-36.0)	**35.50 (<.001)**
Animal Naming	11.4±0.5 (10.3-12.5)	13.7±0.5 (12.6-14.8)	16.2±0.6 (15.1-17.3)	**29.74 (<.001)**
MINT	13.1±0.3 (12.5-13.7)	13.6±0.3 (12.9-14.1)	13.4±0.3 (12.9-14.0)	7.00 (0.509)
Resilience factors				
Education	14.9±0.2 (14.5-15.4)	15.9±0.2 (15.4-16.4)	16.7±0.3 (16.1-17.2)	**16.47 (<.001)**
Physical activity	12.5±1.6 (9.3-15.7)	21.1±1.7 (17.8-24.5)	29.4±1.7 (26.0-32.8)	**23.57 (<.001)**
Mindfulness, patient	35.2±1.2 (32.8-37.5)	36.9±1.2 (34.5-39.4)	41.5±1.2 (39.1-43.9)	**4.46 (.001)**
MIND diet	8.0±0.2 (7.6-8.4)	9.0±0.2 (8.6-9.4)	9.3±0.2 (8.8-9.8)	**8.20 (<.001)**
Socialization	2.2±0.1 (2.0-2.4)	2.9±0.1 (2.8-3.2)	3.3±0.1 (3.1-3.5)	**17.50 (<.001)**
Vulnerability factors				
Age	76.2±0.9 (74.4-77.9)	76.4±0.9 (74.6-78.2)	73.2±0.9 (71.4-75.0)	3.47 (.025)
Mini PPT	9.0±0.3 (8.5-9.5)	10.7±0.3 (10.6-11.7)	11.1±0.3 (10.6-11.7)	**39.88 (<.001)**
Frailty, Fried	2.8±0.1 (2.6-3.0)	2.2±0.1 (1.9-2.4)	1.7±0.1 (1.4-1.9)	**31.48 (<.001)**
mCAIDE	8.1±0.2 (7.6-8.5)	7.7±0.2 (7.2-8.1)	6.9±0.2 (6.5-7.4)	**60.61 (.001)**
Charlson	2.6±0.1 (2.3-2.9)	2.5±0.1 (2.2-2.8)	2.0±0.1 (1.7-2.3)	20.05 (.024)

Means ± SD, (95% confidence intervals); F-statistic, (*P*).
MCI = mild cognitive impairment; CDR = Clinical Dementia Rating; MoCA = Montreal Cognitive Assessment; HVLT = Hopkins Verbal Learning Test; MINT = Multilingual Naming Test; MIND = Mediterranean-DASH Intervention for Neurodegenerative Delay; mCAIDE = modified Cardiovascular Risk Factors, Aging, and Dementia.
Note : Models adjusted for age and sex, except for when modeling age.
Bold indicates significance after adjustment for multiple comparison.

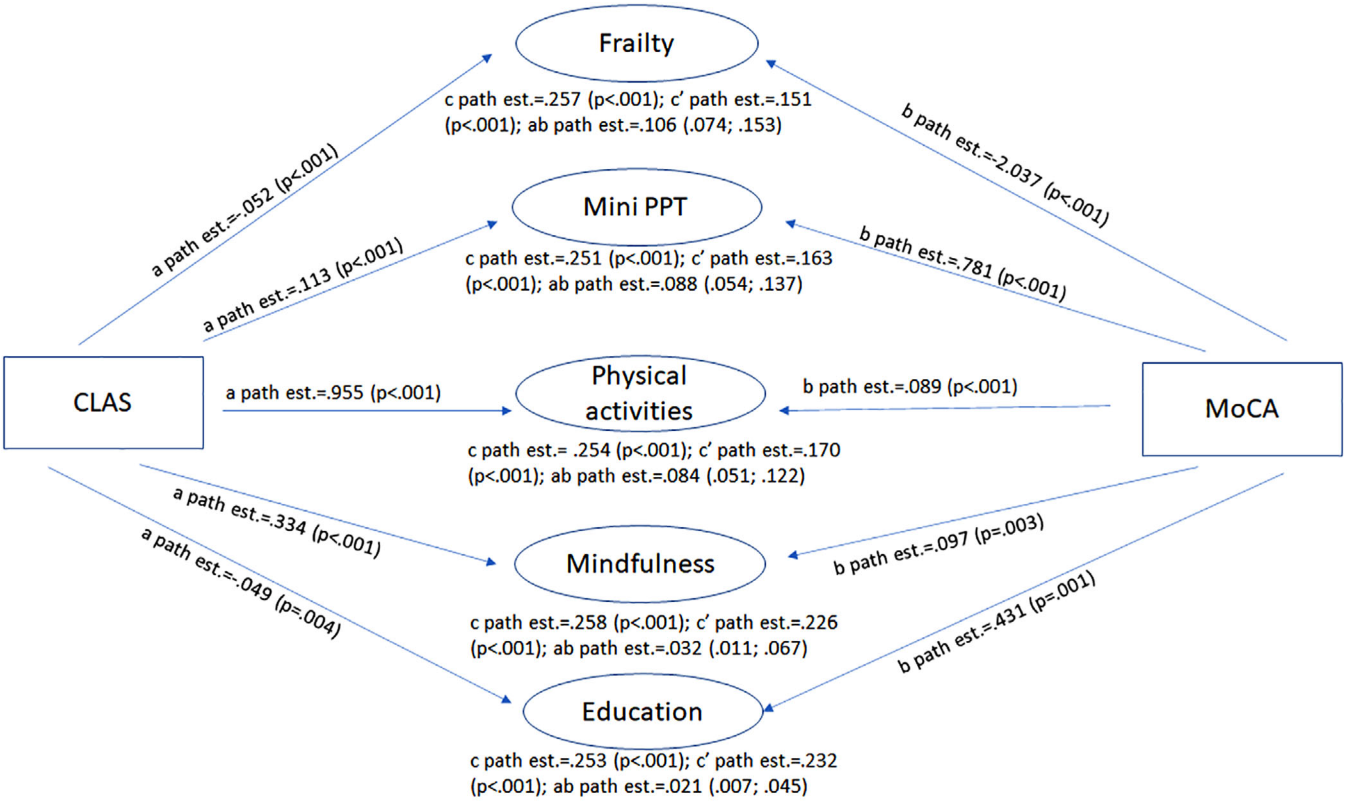

FIGURE 2 Mediation Analyses of Effect of CLAS on Global Cognition. Cross-sectional mediation analyses were employed to assess whether protective and risk factors help explain, at least in part, the effect of CLAS on cognitive function. Five of the six protective and risk factors assessed were found to mediate the CLAS-MoCA association. Most path effects were significant at $P < 0.001$, indicating highly significant relationships between CLAS score, individual mediators, and MoCA. Education (8%) and mindfulness (12%) have the weakest impact of the CLAS effect on MoCA, respectively. In contrast, about a third of the effect of CLAS was mediated by physical activity (33%) and physical functionality (35%). with frailty having the highest impact at 41% mediation. (See text for further details.)

portion of effect that is mediated, we found years of education and mindfulness (AMPS) to have the weakest impact, explaining 8% and 12% of the CLAS effect on MoCA, respectively. In contrast, about a third of the effect of CLAS was mediated by physical activity measured by the QPAR (33%) and physical functionality measured by the mPPT (35%), whereas frailty had the highest impact at 41% mediation. Similar patterns were observed when mediation analyses were reported for memory (HVLT), processing speed (Trailmaking A), and executive function (Number Symbol Coding, Trailmaking B), with physical activity explaining between 38% and 48% of the effect of CLAS, physical functionality between 26% and 41%, and frailty between 30% and 44%. The impact of mindfulness was consistent across cognitive domains (at ≈12%), with a stronger impact for Trailmaking B (34%). In addition, the effect of CLAS was mediated through patient socialization level at 23% for Trailmaking A and 28% for Trailmaking B.

4 | DISCUSSION

The CLAS is a brief inventory that allows clinicians and researchers to estimate the types of cognitive and leisure activities an individual is participating in, and how frequently they do so. The CLAS showed strong psychometric properties and has very good data quality. CLAS scores correlated with gold standard measures of cognition, function, physical functionality, and behavior in individuals with and without cognitive impairment. Individuals with higher CLAS scores had better cognitive performance and larger HOC scores in both the sample as a whole and in subgroup analyses. CLAS scores were lower in individuals with greater cognitive or physical impairment, and in individuals with more medical comorbidities. Higher CLAS scores were associated with less caregiver burden and depression. CLAS scores were positively associated with other ADRD resilience factors (eg, physical activity, diet) and inversely associated with ADRD vulnerability factors (frailty, medical comorbidities). CLAS score effects on cognitive performance were mediated by these same resilience and vulnerability factors, with physical activity, physical performance, and frailty having the greatest effect. The CLAS scores were different between cognitively normal controls, MCI, and ADRD; however, the CLAS was not developed to differentiate between different dementia etiologies. The CLAS instead was developed to provide the dose of cognitive activities in which a patient is participating so a researcher could have a baseline for an intervention study, or a clinician could have a baseline of extent and type of activities a patient is doing in order to make tailored therapeutic recommendations and determine if interventions increase the frequency and extent of activities.

Cognitive activities are a potentially modifiable risk factors for ADRD.[6] In clinical practice, however, it can be difficult to gauge accurate accounting of how many activities in which a person participates because direct observation is not practical, and in the case of older adults with a risk of cognitive impairment, histories may be unreliable. There are few instruments available to capture and quantify cognitive activities in older adults. The Patient-Reported Outcome Measurement Information System (PROMIS) has several scales that capture satisfaction with social roles and activities, and questions about social isolation.[64] However, these instruments do not capture individual cognitive activities and have not been tested in individuals with cognitive impairment. The Florida Cognitive Activities Scale (FCAS)[28] is a 25-item scale with two empirically derived subscales (higher cognition and functional activity) and a moderate internal consistency (Cronbach alpha = 0.65). Items include playing various games (eg, chess, board games, crossword puzzles), reading, watching TV, and listening to music, but also include physical activities (ie, home repairs), ADLs (ie, cooking, finances), and driving. The FCAS was validated against cognitive testing but did not consider association with other resilience or vulnerability factors. The Meaningful and Enjoyable Activities Scale (MEAS)[65] has been described recently as a measure of activities in older adults with mild dementia. The MEAS is a nine-item questionnaire with three dimensions (leisure-time physical activity, social engagement, and mentally stimulating activities) that correlates with functional independence and quality of life measurements. The items include going for a walk, light housekeeping and exercising, reading, keeping up with current events, gardening, volunteering, visiting with friends, and shopping.[65] To date, the MEAS does not appear to have been tested in cognitively normal individuals, and individuals with dementia included in the MEAS study were reported to be generally active without mobility issues or multiple comorbidities. The addition of the CLAS to the existing battery of tools could benefit researchers and clinicians looking for a validated measure of cognitive and leisure activities. The CLAS adds new information to the field of dementia prevention by examining older adults across a range of sociodemographic variables and cognitive status, and cross-validating with neuropsychological test performance, resilience and vulnerability factors, and imaging biomarkers.

The potential advantages of quantifying cognitive leisure activities are multifold. An abundance of research suggests that cognitive activity is essential to healthy aging[13,22] and that interventions to promote cognitive activity in older adults can have positive effects on health outcomes.[15] Multiple ADRD interventions are already underway[23–25] and many more are planned, nearly all of which are multimodal in nature[66] and contain some aspect of cognitive stimulation activities.[67] Designing cognitive interventions and quantifying their potential effect on outcomes requires that measurements of cognitive activity are valid and reliable, that the domains captured reflect the multidimensionality of the construct, and that sufficient responsiveness of items is necessary to accurately measure changes of cognitive activity. Questionnaires are commonly used in intervention studies in older adults, for example, in interventions of physical activity.[68–70] Recommendations for choosing a questionnaire to measure physical activity have been established and include[68]: sufficient content and construct validity, sufficient reliability, containing all relevant domains, capturing "dosage" of activity, and having a recall period of at least 1 week. The CLAS meets many of these requisite criteria for capturing cognitive and leisure activities. Although is it difficult to directly establish validity of a new instrument,[62,63] particularly when there is no gold standard way to measure the construct, the evidence presented here supports that the interpretation of the CLAS is sound. The content validity was based on a review of the literature, the items had strong associations with hypothesized constructs of resilience and vulnerability, known groups performed differently on the CLAS where expected, and the CLAS provided discrimination between individuals with and without cognitive impairment—hypothesized outcome consequences of low cognitive activity.

There are limitations to this study. The CLAS as captured in this study is reported by an informant covering a 1-year period and recall bias is possible. It is also possible the activities initiated and stopped during the 1-year period might fail to be calculated, although the goal of the CLAS was to capture cognitive and leisure activities in which the individuals were participating currently. The CLAS was validated in the context of an academic research setting where the prevalence of MCI and dementia is high, and the patients tend to be highly educated and predominantly White. Validation of the CLAS in other settings where dementia prevalence is lower (ie, community samples) and the sample is more diverse is needed. Different cultures may have different preferences for activities that they consider hobbies, leisure, or are available to them. Future studies of the CLAS will need to study different cultures to determine if the list needs to be locally modified. Because this is a cross-sectional study, the longitudinal properties of the CLAS still need to be elucidated; however, the current study supports that the CLAS could provide a valid baseline of cognitive and leisure activities in older adults in order to study effect of interventions and design personalized plans. In this study, the CLAS used information reported by an informant to capture cognitive and leisure activities in individuals with and without cognitive impairment but would likely be able to be completed by healthy controls and MCI individuals with little difficulty.

Strengths of this study include the use of a comprehensive evaluation that is part of standard of care with measurement of multiple gold standard instruments of cognitive, function, physical functionality, behavior, mood, and medical co-morbidities to understand the relationship of the CLAS to these constructs and with other hypothesized constructs of resilience and vulnerability. Another advantage of the CLAS is its brevity; the measure consists of 16 questions that can be printed on a single sheet of paper or viewed in a single screenshot to maximize its clinical and research utility. Unlike the PROMIS tools,[64] the CLAS captures specific activities over a 1-year period and captures the frequency to permit estimation of a "dose" of cognitive leisure activities that can be compared across individuals. Unlike the MEAS,[65] the CLAS captures both complex and simple activities carried out by older adults with and without cognitive impairment permitting its use in ADRD prevention studies. Unlike the FCAS,[28] the CLAS is focused on mental activities rather than overlapping with ADLs and physical activity, and is cross-validated against resilience and vulnerability factors and HOC scores.

The CLAS may serve as an effective clinical tool to determine the types and extent of cognitive leisure activities among older adults and provide a baseline dosage. The CLAS may be useful in community studies and in busy primary care settings to quantify the extent and type of activities a patient with which a patients is engaged in order to make tailored therapeutic recommendations and promote physician-patient dialogue. Similarly, the CLAS could provide researchers with a baseline assessment of cognitive and leisure activity for an intervention[67,71] or assist in determination of inclusion/exclusion criteria. Because of the wide range of activities and possible scores, the CLAS could assist in the assessment of improvements and serve as outcome measure following cognitive interventions or cognitive rehabilitation. Our study supports our hypotheses that participation in cognitive and leisure activities is associated with better cognitive performance and may offer protective benefits for older adults. The CLAS has strong psychometric properties, capturing 16 common activities in older adults to give a standardized dosage of cognitive and leisure activities, but in a brief fashion that could facilitate its use in clinical care and research.

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AUTHOR CONTRIBUTIONS

Dr Galvin was involved in the conceptualization, data curation, formal analysis, funding acquisition, methodology, supervision, and writing of original draft, review, and editing; he approves of the final version and ensures the accuracy and integrity of the work. **Dr Tolea** was involved in the data curation, formal analysis, and writing, review, and editing; she approves of the final version and ensures the accuracy and integrity of the work. **Dr Chrisphonte** was involved in the data curation, project administration, and writing, review, and editing; she approves of the final version and ensures the accuracy and integrity of the work.

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