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Associations between AQT Processing Speed and Neuropsychological Tests in Neuropsychiatric Patients

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Associations between A Quick Test of Cognitive Speed (AQT) perceptual and cognitive speed and neuropsychological tests, including the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III), Mini Mental State Examination (MMSE), and the Trail Making Test (TMT), were evaluated in 41 neuropsychiatric patients. Neuropsychological and neurological tests, including CT scan, were administered to all of the patients. AQT was also administered to 75 controls. All AQT means differed significantly for patients and controls. Dual-dimension naming time means in the patient group were in the atypical range and indicated generally reduced cognitive speed, whereas controls performed in the normal range. In the patient group, WAIS-III verbal, performance, and full-scale IQ means were in the normal range. AQT perceptual and cognitive speed correlated negatively with WAIS-III P IQ and MMSE scores, and the relationships were nonlinear. The findings support that AQT dual-dimension naming evaluates cognitive speed (i.e., attention, set shifting, working memory) and can be used for first-line or complementary screening for mild or progressive cognitive impairments.

Keywords: AQT; WAIS-III; MMSE; AD; cognitive impairment; cognitive tests; processing speed

In neuropsychological practice, cognitive impairments are traditionally assessed with neuropsychological tests that probe verbal learning (paired-associate or word-list), memory, retention, and recall. Tests of broad cognitive abilities and visual-spatial construction are also commonly used, as are screening tests for cognitive impairments and decline associated with neurological disorders. An alternative approach to assessing cognitive function is to use processing speed tests, such as A Quick Test of Cognitive Speed (AQT),[1,2] the Trail Making Test (TMT),[3] or the Stroop Color-Word Test.[4] These measures include reaction and response time; they use single tasks to measure perceptual speed and dual tasks to measure cognitive speed, including attention, set shifting, and working memory; and performance times are outcome measures.[1-5] Processing speed tests have been used to examine cognition in normal aging, executive function disorders, frontal- and temporal-parietal lobe involvement, dementia, and other neurological conditions.[6-10]

AQT, the experimental measure, evaluates perceptual (i.e., reaction + response time), and cognitive speed (i.e., perceptual speed + cognitive overhead resulting from increased demands for attention, set shifting, and working memory). It has been subjected to clinical research and validation with functional neuroimaging.[8,9,11] It provides objective, timed measures (seconds) of naming speed

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for familiar single- (e.g., colors, forms) or dual-dimension (e.g., color-form combinations) visual stimuli. AQT color-form (C-F) naming, a dual task, shows high specificity (97%), sensitivity (99.9%), and positive and negative predictive values (100% and 97.9%) in differentiating patients with diagnosed probable Alzheimer's disease (AD) from normal controls across cultures.[9,11] A comparative study of the clinical utility of Mini Mental State Examination (MMSE) and AQT resulted in 100% specificity and 84% sensitivity (i.e., 16% false negatives) for MMSE.[9]

AQT C-F has been the focus of extensive neuroimaging. Among cognitively normal adults, 2-dimensional, regional, cerebral blood flow (rCBF) measures during AQT C-F show significantly increased flow bilaterally in the temporal-parietal-occipital regions. Concurrently, there is significant suppression in frontal regions when compared to rest.[1,12] This pattern signifies involvement of attention and working memory for visual input.[13-15] In contrast, adults with mild to moderate AD show significantly suppressed blood flow in the temporal-parietal regions bilaterally and increased blood flow in frontal regions compared to rest and normal controls.[12]

Relatively few studies have explored associations between neuropsychological test results and single- and dual-task performance.[7,16-18] In one study, dual-task reaction times correlated with Wisconsin Card Sorting Test scores in patients with Parkinson's disease and normal controls, whereas single-task performances did not.[16] In a second study, timed measures of speed on TMT Tests A and B-A correlated with verbal recall accuracy when meaningful distracters were introduced, but not during quiet.[18] A more recent study used delayed visual recognition in 2 paradigms, and factor analyses delineated associations between neuropsychological tests and performances on single and dual tasks.[7] TMT and Rey Complex Figure Test (RCFT) were included among the neuropsychological tests used, and factor analyses revealed attention/executive, memory, motor speed, and cognitive status factors. Single-task delayed recognition was most strongly predicted by memory and motor speed factors, whereas dual-task delayed recognition was most strongly predicted by the attention/executive factors. Based on shared characteristics with the timed tests used by Holtzer and associates, performances on the AQT dual-dimension naming tests and TMT and RCFT were expected to be associated in the neuropsychiatric patient group studied.

This study was clinical and naturalistic, the data were collected as part of in-depth neuropsychiatric intake evaluations, and patients were admitted consecutively. The objective was to test hypotheses for relationships between performances on AQT single- and dual-dimension processing speed tests and standard neuropsychological tests used to assess cognition in neuropsychiatric patients. The primary hypothesis was that AQT dual-dimension naming times, as indicators of cognitive speed (i.e., attention, working memory for visual input, and set-shifting), would correlate significantly with clinical measures of (a) memory for cognitive content, (b) verbal learning, and (c) attention/executive functions, including set shifting, but not with verbal fluency. A null hypothesis stated that the AQT single-dimension naming times, as indicators of perceptual speed (i.e., reaction and response time) would not correlate significantly with any of the clinical measures of cognition.

The rationale for the study was that AQT, which appears deceptively simple at first glance and is a newcomer to the complement of cognitive screening tests, warranted validation as a neuropsychological test and as a complementary cognitive screening test. The validation was considered of clinical value, because AQT outcomes are objective, not significantly affected by gender or years of education beyond completion of grade 9, and minimally affected by age (about 1 second per decade).[1,6,19] Moreover, AQT can be administered in minutes by trained paraprofessionals, and responses do not require professional judgments for interpretation and referral. In addition, AQT can be used with culturally and linguistically diverse populations,[19] a feature of importance in countries with cultural and linguistic diversity.

Methods

Subjects

The patient group consisted of 41 Swedish neuropsychiatric patients, 15 females and 26 males, who were admitted consecutively for neuropsychiatric evaluation and diagnosis after completing a 3-step admission process. They were first referred by a primary physician to a regional care center, where the MMSE; AQT color,

form, and color-form naming; and Clock test were administered, and a family interview was conducted. Subsequently, they were referred to a regional neuropsychiatric center (memory clinic) for diagnosis. All underwent a thorough clinical investigation, including medical history, physical and neurological examination, laboratory tests, and brain imagining (CT scan). Patients ranged in age from 35 to 84 years (mean 65 years, 7 months; standard deviation [SD] 10 years, 8 months) and had completed 10 or more years of formal education in Sweden, which is considered equivalent to completing high school in the United States. Patients with diagnoses of dementia of the AD type were identified as defined by Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV)[20] and National Institute of Neurological and Communicative Diseases and Stroke/ Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA) criteria. Neuropsychiatric diagnoses were established with the World Health Organization (WHO) International Classification of Diseases, Tenth Edition (ICD-10) classification system.[21] This process identified (a) 16 patients with mild to moderate AD (F00-00.1/G30.0, 30.1), (b) 11 patients with affective disorders (depression/bipolar) (F30-34), and (c) 14 patients with mild cognitive impairments (Z03.3), with clinical and behavioral profiles characteristic of mild cognitive impairment (MCI).[22] The study used the neuropsychological test norms for evaluating levels of performance by the patient group. A group of 75 cognitively intact adults, proportionally matched for gender, served as controls for the AQT measures. The controls ranged in age from 34 to 94 years (mean 65 years, 3 months; SD 11 years, 9 months), and there was no significant mean difference in age between groups ($p > .05$).

Materials and Administration

A fixed neuropsychological test battery was administered in Swedish. The protocol contained tests of broad cognitive ability, processing speed, verbal fluency, memory for content, verbal learning, and visual-spatial construction. The same neuropsychologist tested all patients in the same clinical setting. The experimental tasks were: AQT color-form (C-F), color-number (C-N), and color-letter naming (C-L), each consisting of 3 rapid-naming tests.[2] Test 1, a single-dimension task, required naming the color of 40 repeated colored squares (black, blue, yellow, or red). Test 2, also a single-dimension task, required naming of 40 forms (circle, square, line, or triangle), numbers (2, 4, 5, 7), or letters (a, b, e, o, k, m, p, t), rendered in black. Test 3, a dual-dimension task, required patients to name first the color and then the form, number, or letter in stimulus combinations (e.g., red circle). Tests 1 and 2 probed perceptual speed, defined as reaction + response time. Test 3 assessed cognitive speed, defined as perceptual speed + cognitive overhead, resulting from the need for rapid set shifting and increased demands on attention and working memory. AQT C-F, C-N, and C-L were also administered to all controls.

The WAIS-III[23] assessed broad cognitive ability. Verbal (V), performance (P) and full-scale (F-S) standard scores (IQ) were used in the statistical analyses. MMSE[24] assessed memory for cognitive content. The FAS Verbal Associative Fluency (FAS)[25] test probed the ability to rapidly and effectively produce Swedish words beginning with the letters F, A, and S. The TMT[3] evaluated visual scanning, visual-motor tracking, divided attention, and set shifting in 2 tests. Of these tests, Test A required single-task numerical and Test B, dual-task alphanumerical tracking. Subtracting Test A from Test B time (B-A) minimized the motor speed component of TMT. The Swedish Cronholm-Molander test (C-M)[26] assessed paired-associate word learning with 3 lists, each with 10 word pairs, presented for immediate and delayed recall after 3 hours. RCFT[27] assessed perceptual organization and visual memory in 4 tasks: copy, immediate recall after 3 minutes, delayed recall after 30 minutes, and recognition of parts. Raw scores were used for statistical analyses.

Data Analyses

Test scores were expressed as raw scores, except for WAIS-III, for which standard scores (IQ) were used. The results from each test were analyzed for central tendency and dispersion of measures. The effects of age on AQT naming times were evaluated in the patient group and the control group with linear regression analyses. AQT naming-time means for the patient group and the control group were compared for statistical significance by independent samples *t* tests. In the patient group, correlation coefficients (Pearson *r*) evaluated relationships between AQT naming times (seconds), WAIS-III IQ,

and neuropsychological test scores. Linear and polynomial regression analyses described significant relationships between the AQT and neuropsychological test results. The level of significance for rejecting a null hypothesis was set at $p < .01$.

Results

Means and SDs for the patient group are shown in Table 1, as are the AQT means and SDs for the control group and the average normal performance ranges for each test, expressed in either standard scores or percentile ranks. The significance of mean differences in AQT naming times between the patient group and the control group was tested with independent samples *t* tests. Levene's test for equality of variances indicated significant differences between groups ($p < .01$), and equal variances were therefore not assumed. All AQT naming-time means proved significantly different in the groups (t = 5.32 – 6.90; $p < .01$), and patients required significantly more time to name the single- as well as the dual-dimension stimuli than their controls. In the control group, all AQT naming-time means are in the normal range (< +1 SD). In the patient group, the means for single color, number, and letter naming were in the normal range (< +1 SD). The means for form, color-number, and color-letter naming were in the slower-than-normal range (> +1 SD and < +2 SD) and for color-form naming in the atypical (pathological) range (> 70 seconds/+2 SD) compared to reported AQT criterion-referenced norms.[2]

In the patient group, WAIS-III V, P, and F-S IQ means were within the average normal range, and standard deviations were similar to the norm (SD = 15). The group means for MMSE; C-M paired-associate word learning; immediate and delayed recall; TMT Tests A, B, and B-A; and RCFT were within the average normal range (25th-75th percentile). In contrast, the mean for FAS verbal fluency approximates the 10th percentile for a normative sample, and the means for C-M immediate and delayed recall fall below −1 SD of the normative means.[25,28] Standard deviations for most neuropsychological tests are large compared to the means, indicating heterogeneity in performance in the patient group.

The effects of age on the neuropsychological measures were tested with linear regression analyses. Linear regression coefficients (beta) with age as independent variable were nonsignificant ($p > .05$) for all AQT measures. In the control group, linear regression coefficients with age as independent variable were nonsignificant ($p > .05$) for AQT number, color-number, letter, and color-letter naming ($r = 0.01$ to 0.11). The linear regression coefficients proved significant ($p < .01$) for color, form, and color-form naming ($r = 0.30$, 0.35, and 0.32, respectively), and naming times increased by about 1 second per decade of age. In the patient group, the linear regression coefficients (beta) were nonsignificant for WAIS-III V, P, and F-S IQ, FAS, C-M paired-associate word learning, and RCFT delayed recall ($r = 0.07$ to 0.25; $p > .05$). In contrast, the regression coefficients (beta) for MMSE ($r = 0.34$; $p < .05$); TMT A, B, and B-A ($r = 0.34$, 0.39, and 0.41; $p < .05$); and RCFT copy ($r = 0.32$; $p < .05$) were significant, and age accounted for from 10% to 33% of the variances. Linear regression analyses were not performed for effects of education, because prior research indicated nonsignificant relationships (*r*) between AQT naming times and years of education past grade 9.[6,19]

The strengths of associations (Pearson *r*) between AQT naming times and neuropsychological test scores were evaluated next (Table 2). All correlations between the AQT naming-time measures and WAIS-III P IQ proved significant ($r = -0.50$ to -0.61), whereas V IQ correlated significantly only with AQT number and letter naming ($r = -0.48$ and -0.43; $p < .01$). WAIS-III F-S IQ correlated significantly with all AQT measures ($r = -0.46$ to -0.58; $p < .01$), except number and color-letter naming. MMSE and AQT form, color-form, color-number, and color-letter naming also correlated significantly ($r = -0.60$ to -0.72; $p < .01$), whereas none of the correlations between the AQT naming and FAS verbal fluency measures proved significant ($p > .05$). AQT form naming correlated significantly ($p < .01$), but moderately, with TMT tests A, B, and B-A ($r = 0.43$ to 0.56), C-M immediate and delayed recall ($r = -0.59$ and -0.53), and RCFT copy, immediate and delayed recall, and recognition ($r = -0.43$ to -0.60).

The significant associations ($p < .01$) between AQT C-F naming (dual-dimension) and WAIS-III P IQ ($r = -0.61$) and MMSE ($r = -0.72$) were explored further with linear and polynomial regression analyses. The resulting plots are shown in Figures 1 and 2. The linear equation for the relationship between AQT C-F and WAIS-III P IQ is $y = -0.80x + 148.95$

Table 1. Means and Standard Deviations for Patients with Neuropsychiatric Disorders (n = 41) and Cognitively Normal Controls (n = 75) and Average Normal Performance Ranges

		Patients (n = 41)		Controls (n = 75)		
Test	Measure	Mean	SD	Mean	SD	Average Normal Range
AQT Naming(s)	Color	30.00	6.86	22.16	3.61	< 30 s*
	Form	38.78	10.94	25.91	4.76	< 30 s*
	Color-form	75.87	21.63	51.08	8.46	< 60 s*
	Number	19.29	5.18	14.74	3.03	< 20 s*
	Color-number	57.57	12.87	43.16	6.25	< 50 s*
	Letter	18.74	5.04	14.50	2.78	< 20 s*
	Color-letter	59.26	16.14	43.16	5.77	< 50 s*
WAIS-III IQ	Verbal	97.42	14.66	NA	NA	85-115†
	Performance	95.24	14.83	NA	NA	85-115†
	Full-scale	96.02	14.70	NA	NA	85-115†
MMSE	Total score	28.30	2.12	NA	NA	28-30†
FAS Verbal Fluency	Number of words	21.12	11.02	NA	NA	31- 44‡
Trail-Making Test(s)	Test A	57.75	46.06	NA	NA	36-67‡
	Test B	134.23	92.70	NA	NA	88-172‡
	Test B-A	83.03	58.92	NA	NA	54-105‡
Cronholm-Molander	Immediate recall	12.97	6.36	NA	NA	Mean 21.31 (SD 5.99)
	Delayed recall	7.74	6.27	NA	NA	Mean 18.38 (SD 6.84)
RCFT	Copy	33.88	3.29	NA	NA	34-35‡
	Immediate	18.57	6.63	NA	NA	-
	Delayed	18.63	6.64	NA	NA	-
	Recognition	19.58	2.84	NA	NA	-

Note: SD indicates standard deviation; WAIS-III, Wechsler Adult Intelligence Scale; MMSE, Mini Mental State Examination; FAS, FAS Verbal Associative Fluency; RCFT, Rey Complex Figure Test.

* Criterion cutoff for normal range at +1 SD.

† Normal range.

‡ 25th-75th percentile range.

($R^2 = 0.44$) and the polynomial equation $y = 0.01x^2 - 3.43x + 271.59$ ($R^2 = 0.49$). The linear equation for the relationship between AQT C-F and MMSE is $y = -6.90x + 268.05$ ($R^2 = 0.49$) and the polynomial equation $y = -0.64x^3 + 56.75x^2 - 1670.7x + 16\,453$ ($R^2 = 0.74$). The polynomial regression lines provide the best fit for both sets of data (AQT C-F vs. WAIS-III P IQ and MMSE).

Discussion

At first glance, the AQT test design appears simple and may, therefore, be interpreted to measure primarily perceptual and motor skills. However, prior clinical research supported that AQT measures not only perceptual speed, but also cognitive speed associated with bilateral temporal-parietal lobe activation.[1,2] It has also been argued that AQT cannot test memory functions, generally assessed by memory for content and verbal learning and recall, which are currently the primary approaches to screening for mild cognitive impairments and probable Alzheimer's disease. Neuroimaging studies during AQT color-form combination suggest, however, that this task probes executive functions. Our primary objective was, therefore, to explore relationships between AQT cognitive speed measures and standard neuropsychological test results. If significant associations could be demonstrated between performances

Table 2. Correlation Coefficients (*r*) between AQT Naming Speed (s) and Neuropsychological Test Scores among Patients with Neuropsychiatric Disorders (n = 41)

Test	Measure	AQT Color	AQT Form	AQT C-F	AQT Number	AQT C-N	AQT Letter	AQT C-L
WAIS	V IQ	–0.23	–0.34	–0.30	–0.48*	0.34	–0.43*	–0.24
-III	PIQ	–0.60*	–0.52*	–0.61*	–0.57*	–0.54*	–0.63*	–0.50*
	F-S IQ	–0.42	–0.46*	–0.46*	–0.58*	–0.47*	–0.56*	–0.38
MMSE		–0.38	–0.70*	–0.72*	–0.07	–0.66*	–0.34	–0.60*
FAS		–0.09	–0.35	–0.13	–0.12	–0.11	–0.23	–0.13
TMT	Test A	0.39	0.56*	0.29	0.29	0.33	0.48*	0.28
	Test B	0.35	0.52*	0.10	0.15	0.22	0.35	0.13
	B-A	0.27	0.43*	0.11	0.07	0.14	0.21	0.06
Cronholm-	Immed.	–0.26	–0.59*	–0.29	–0.12	–0.28	–0.27	–0.16
Molander	Delayed	–0.13	–0.53*	–0.17	–0.07	–0.12	–0.16	0.00
RCFT	Copy	–0.19	–0.51*	–0.05	–0.12	–0.21	–0.17	–0.13
	Immed.	0.08	–0.46*	–0.04	0.22	–0.03	0.39	0.05
	Delayed	0.04	–0.43*	–0.14	0.23	–0.07	0.38	0.01
	Recog.	–0.28	–0.60*	–0.32	–0.15	–0.26	–0.24	–0.24

Note: AQT indicates A Quick Test of Cognitive Speed; WAIS-III, Wechsler Adult Intelligence Scale; MMSE, Mini Mental State Examination; FAS, FAS Verbal Associative Fluency; TMT, trail-making test; RCFT, Rey Complex Figure Test.
*$p < .01$.

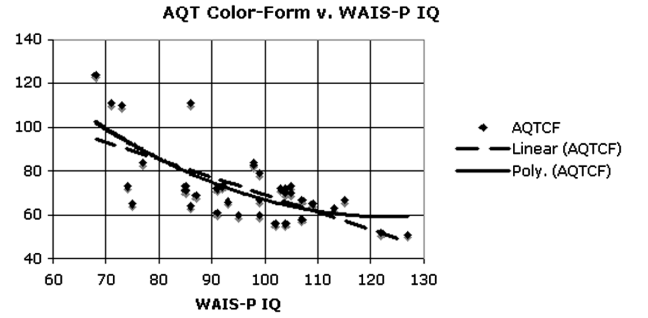

Figure 1. Plot of AQT Color-Form Times (seconds) versus WAIS-III Performance IQ for Patients with Neuropsychiatric Disorders (n = 41)

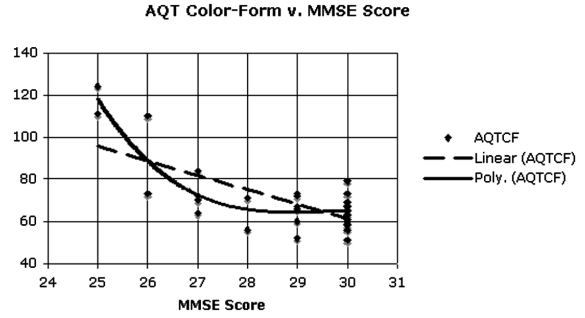

Figure 2. Plot of AQT Color-Form Naming Times (seconds) versus MMSE Point Scores for Patients with Neuropsychiatric Disorders (n = 41)

on tests of cognitive content (e.g., WAIS-III, MMSE, paired-associate, and word list learning) and AQT cognitive speed, such associations would appear to validate AQT as an alternative or complementary measure of cognition. Based on previous, unrelated research,[7] we expected significant associations between AQT dual-dimension naming times; WAIS-III P IQ, which reflects perceptual organization and processing speed; and scores on neuropsychological tests of executive functions, including attention, set shifting, and working memory.

One of the issues associated with tests of geriatric cognition is the expected normal cognitive decline with age. Advancing age is also recognized as a critical risk factor for AD, with prevalence increasing exponentially between ages 65 and 85.[29] In this study, age had no significant effect on the single- or dual-dimension naming times in the patient group. In contrast, age significantly affected AQT color, form, and color-form naming in the control group and accounted for about 10% of the variances. This result suggests that in the patient group, cognitive

impairments and AD pathology were the primary factors that affected perceptual and cognitive speed among patients. In combination, the differences in age effects validate the use of AQT as an age-independent measure of progressive cognitive impairments. Age had no significant effect on verbal or performance IQ, verbal fluency, or paired-associate learning.[23,25,26] However, age affected performance on MMSE, visual tracking speed, and copying a complex figure.[3,24,27]

The patients in this study exhibited mild to moderate cognitive impairments on most standard neuropsychological measures. They also exhibited significantly reduced perceptual and cognitive speed, as measured by AQT and compared to normal controls and reported norms.[1,2] This outcome was in spite of the fact that the WAIS-III verbal, performance, and full-scale IQ, and MMSE means were within the normal range. The considerable variation in patient performances on most of the neuropsychological tests agrees with the heterogeneity within the group, as indicated by the neuropsychiatric diagnoses. On the AQT dual-dimension naming tests, the majority of patients performed within the atypical time range (> +2 SD), indicating significant deficits in cognitive speed. The patients also required significantly longer than average to complete the TMT single (numerical) and dual (alphanumerical) visual-tracking tasks. The combined findings suggest related difficulties with divided attention, working memory, and set shifting (attention/executive factors). They concur with unrelated observations of impairments of set shifting in patients with focal parietal lesions and AD and with suggestions that set-shifting deficits are not conclusively tied to frontal-lobe damage.[30-32]

WAIS-III P IQ correlated moderately, but significantly, with all AQT processing speed measures, and both perceptual (single-task) and cognitive (dual-task) speed decreased (i.e., naming times increased) with increasing reductions in nonverbal cognitive abilities. The associations between nonverbal cognitive abilities and perceptual and cognitive speed may reflect similarities in demands on executive functions, including attention, working memory, and set shifting.[1,2,12] We did not anticipate that AQT single-dimension naming, which measures primarily perceptual speed, would be significantly associated with WAIS-III P IQ. The associations therefore suggest that AQT identifies perceptual and cognitive processing deficits that reflect broader cognitive impairment.

Among the single-dimension AQT tests, form naming was moderately associated with paired-associate word learning and recall, single- (numerical) and dual-task (alphanumerical) visual tracking, and complex figure copying, recall, and recognition. The associations between visual tracking (TMT) and AQT processing times were not as strong as hypothesized, and significant relationships occurred only between visual tracking and perceptual speed for form naming. Visual tracking has been linked to frontal-lobe damage and frontostriatal dysfunction, and functional neuroimaging indicates increased prefrontal activation, especially in the left prefrontal region, during the TMT set-shifting condition (Test B).[33,34] Cognitive speed during AQT dual-dimension naming has been linked to increased temporal-parietal activation, and the combination of demands on executive functions therefore appears to differ in the 2 tests.[12] Complex figure copy errors, specifically repetitions, and problems in programming an approach for copying have been associated with localized frontal lobe lesions.[35] In contrast, difficulties with spatial orientation appear associated with parietal-occipital lesions.[36] Unfortunately, this study did not differentiate qualitative aspects of complex figure copying by the patients. However, the fact that all complex figure and visual tracking measures correlated only with AQT form naming suggests that similarities in content and perceptual demands may have supported the associations between the tests.

Verbal fluency was not related to any AQT naming measures. This outcome was anticipated, because depressed verbal fluency has been related to brain dysfunction associated with frontal lobe lesions.[37] In contrast, reductions in cognitive speed, as measured by AQT, are consistently associated with suppressed temporal-parietal lobe activation in patients with mild to moderate AD.[1,2] These findings therefore strengthen evidence of independence between verbal fluency and cognitive speed, as measured by AQT, among patients with mild cognitive impairments and probable AD.

Linear and polynomial regression analyses described the associations between cognitive speed, as measured by C-F naming, nonverbal cognitive abilities, and MMSE. The relationship between cognitive speed and performance IQ was nonlinear. As shown in Figure 1, 2 patients with WAIS-III P IQ above the normal range (between 120 and 130) named the C-F combinations at speeds in the normal performance range (< 60 seconds). As nonverbal cognitive abilities

regressed among the patients, cognitive speed slowed and registered increasingly within the slower-than-typical (between 61 and 69 seconds) and atypical performance ranges (> 70 seconds).

The relationship between AQT C-F naming and MMSE was also nonlinear (Figure 2). The relationship illustrates that patients considered "normal," based on their MMSE scores, showed considerable variation in the AQT C-F measures of cognitive speed. Thus, several patients with MMSE scores of 30 obtained cognitive speed measures that ranged between 50 and 80 seconds (< +1 SD to > +2 SD). Although the variability in cognitive speed measures and MMSE scores decreased concurrently, AQT C-F naming may provide finer tuned measures (seconds) of cognitive decline in the "preclinical" stages of the AD process.

From a clinical perspective, the use of comprehensive batteries of neuropsychological tests for identifying cognitive impairments results in significant costs to patients and society. This study validates AQT as a neuropsychological test of cognitive speed and indicates that it is sensitive to cognitive impairments associated with neuropsychiatric disorders. The findings support recommendations that AQT C-F may serve as an objective, staff-efficient, and time-efficient (3 minutes) complement to MMSE, TMT, and paired-associate word learning tests in early screening and assessing progressive cognitive impairments. By using functional magnetic resonance imaging (fMRI) during AQT single- and dual-dimension naming, future studies should be able to clarify whether or not activation of the hippocampus occurs concurrently with the characteristic, normal pattern of cortical activation observed with rCBF.

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