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Correlations and Contingency Between A Quick Test of Cognitive Speed (AQT) and Connors Continuous Performance Test 3rd Edition (CCPT-3)

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Abstract

This register study compared processing-speed measures obtained with A Quick Test of Cognitive Speed (AQT) and Connors Continuous Performance Test 3rd Edition (CCPT-3). It was conducted in regional psychiatric centers in Sweden with 111 participants referred for in-depth psychiatric evaluation. Data were collected in two phases with concurrent administrations of the AQT and CCPT-3. Phase 1 (n = 42) used the original AQT color form and color-form combination tasks. Phase 2 (n = 69) used AQT and an added alternating color-then-form naming task and an associated shift-cost quotient. Mann-Whitney U compared samples for the shared AQT and CCPT-3 measures and found no significant differences ($p > .05$). Spearman Rank correlations (R) tested associations between CCPT-3 T-scores and AQT time measures. In both phases, associations between color-form naming (s) and shift costs and CCPT-3 error types proved nonsignificant ($p > .05$). In contrast, in Phase 1 color-form naming correlated significantly with CCPT-3 reaction-time components Hit RT SD ($R = 0.45$; $p = .003$) and Variability ($R = 34$; $p = 0.29$). In Phase 2, CCPT-3 Hit RT SD correlated with color-form ($R = 0.33$; $p = .006$), alternating color-then-form ($R = 0.38$; $p = .001$), and the shift-cost quotient ($R = 0.37$; $p = .001$). Variability correlated significantly with alternating color-then-form ($R = 0.35$; $p = .003$) and the shift-cost quotient ($R = 0.36$; $p = .003$). According to CCPT-3 criteria, Hit RT SD and Variability are both categorized indicators of Inattentiveness as well as Impulsivity. This suggests that adding color-then-form and the shift-cost quotient to AQT provides a broader scope for interpretation.

The contingency between informed judgments of probable ADHD by the AQT and AQT-Advanced time measures and CCPT-3 was established. The statistics for Phase 1 and for the combined AQT sample (n = 111) reached substantive levels of significance with large effect sizes compared to the statistics for Phase 2. This outcome was not anticipated. The similarity of results obtained with the original AQT in Phase 1 and in the combined AQT sample validated that AQT in its original form can be used for initial screening for probable ADHD. The original version has been proven to provide significant measures for monitoring dose effects during pharmacological treatment. Both the AQT and expanded AQT-A can be given by trained allied professionals and require less than 10 minutes for administration.

Keywords: Register study, AQT, CCPT-3, Associations, Contingency

Background

In psychiatric practice, A Quick Test of Cognitive Speed (AQT) is a relative newcomer to the field of short cognitive tests.[1-4] In contrast, Conners Continuous Performance Test 3rd Edition (CCPT-3) is an established neuropsychological test in clinical practice.[5] In the past decade, the AQT test has been featured in several clinical research projects involving elderly adults with dementia.[3,4,6,7] It has also been featured in research of screening and monitoring dose titration and treatment effects, in adults with ADHD and ADHD and substance disorder, psychiatric referrals with, and without ADHD, and ADHD and treatment resistant depression.[8-13] As research of ADHD has shifted focus from children to adults, it has become obvious that existing ADHD symptomatology has often been overlooked, especially when it manifested as a comorbidity to common psychiatric disorders such as autism or depression.[14-16]

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AQT, in its original version[1,2] is a processing-speed test with three components that require rapid naming of basic colors (e.g., *blue*), geometric forms (e.g., *square*), and color-form combinations (e.g., *blue square*), presented on a test plate with 40 randomized stimuli. Test takers are asked to name the randomized colors, forms, and color-form combinations as rapidly and accurately as possible in continuous performance tasks. Based on a test taker's performance on each processing-speed test, the examiner can calculate shift costs (overhead) that account for the added demands on co-articulation and active attention and working memory, central executive functions. The execution of each task is timed, and the naming time measures (s) serve as the basis for clinical judgments. The underlying processing-speed construct of AQT is like that of the Stroop Color-Word Test 17 but the design avoids the necessity for test takers to read.

Neuroimaging (rCBF) during the execution of the AQT color-form combination task established that the posterior temporal-parietal, and occipital lobes bilaterally showed increased cortical activation.[1,2,18] Subsequently, sagittal and coronal functional fMRI images, contributed by Jonas Svensson Ph.D. (Malmö University Hospital Brain Center, Sweden) supported that the cortical areas identified and the associated subcortical regions were activated in healthy adults during performance of the color-form naming task. These areas are recognized to play a role in attention and working memory, central executive functions, and cognitive control.[19-23] Functional MRI of adults with ADHD also point to the pivotal role of the parietal lobes in the psychopathology associated with the disorder.[23-26] In children, the role of the superior parietal lobes is reflected in relatively weaker cortical activation than among neurotypical children, while performing selective attention tasks. Weakening of the frontal-parietal functional connectivity has also been observed among children and adults with ADHD.[25-26]

Functional neuroimaging (rCBF) with AQT was also performed with patients with diagnosed dementia of the Alzheimer's and Lewy Body types.[1,3,4,27] The images indicated that with advancing cognitive decline the activation of the posterior cortical regions decreased and was substituted by compensatory activation of the frontal lobes.[1,3,4] Based on this evidence, it was concluded that the original AQT was a test of cognitive functioning primarily associated with bilateral activation of the posterior temporal-parietal and respective subcortical regions.[1,3,4] We hypothesized that the AQT processing and naming tasks might complement the established clinical use of short tests such as the Stroop Color and Word Test (SCWT), Mini Mental Status Examination (MMSE), and behavioral rating scales in the preliminary/basic assessment of cognitive decline.[3,4,28,29] Subsequent research explored the ability and stability of AQT in tracing cognitive decline over time and estimating the effects of ameliorating medications for dementia.[7] Over time, normative data were collected for randomly selected healthy adult speakers of American English, Danish, Norwegian, and Swedish in the age range from 18 to 85 yrs., and similar data were collected in Italy and Spain.[1,2,30-33]

AQT was later used in controlled, multicenter studies to evaluate cognitive status and monitor the effects and optimal dosage of ADHD specific medications in adult referrals for psychiatric assessment and treatment.[7-11, 34-36] It was administered in Scandinavian psychiatric centers to evaluate the test's ability to differentiate between processing-speed measures in adults with (a) established ADHD and healthy age peers, (b) ADHD and ADHD and substance use disorder, (c) psychiatric disorders with and without ADHD, and (d) ADHD and treatment resistant depression.[11-13] Recently, we added an alternating color and form naming task that uses the color-form combinations as stimuli and requires naming the color of the first stimulus and the shape of the second stimulus and so on. The purpose was to expand the range of AQT processing-speed measures to include a task that might challenge the test taker's ability to inhibit impulsivity and provide a screening test, AQT-A, with a broader scope.

CCPT-3 is a computer-administered test that uses letters as the visual stimuli to evaluate aspects of attention, inhibition, and impulsivity.[5] The stimuli are arranged into 18 sub-blocks with 20 letters each. The intervals within and between the presentation of letters in a block can be varied from 1s, 2s, and 4s. Test takers are directed to press the space bar except when the letter X is shown on the screen. This design requires the test taker to inhibit impulsive, anticipatory responses when the letter X is shown. The underlying constructs of AQT-A and the CCPT-3 are similar in that processing speed (s) and ability to control response rate and sustain attention during the task are the performance measures. CCPT-3 categorizes response time and accuracy measures within three variable types, (a) Detectability (*d*'), indicating accuracy in differentiating between targets and non-targets, (b) error types, including Omissions, Commissions, and Perseverations (i.e., responses within 100 microseconds) and (c) reaction-time statistics, including average time for all non-perseverative responses, variations from the average reaction time, and variations within and between blocks. The CCPT-3 components are not orthogonal as the same component score may be assigned to different behavioral manifestations of the ADHD symptomatology. As examples, Omissions, where non-targets are wrongly identified, and Perseverations, indicating random/anticipatory responses, have been associated with the CCPT-3 behavioral criteria for Inattention as well as for Impulsivity.[5]

Models and cognitive theories generally consider ADHD to be an executive function disorder, characterized by inattentiveness and hyperactivity-impulsivity associated with frontal lobe dysfunction.[39] Barkley formulated an integrated executive-function model of ADHD that accounts for how specific aspects of the disorder can be identified during the developmental progression over the lifetime.[40] The model also describes how specific strengths and weaknesses associated with ADHD can be linked to everyday

activities and demands. Other theories and models of ADHD have emerged, among them the motivational theory and the dual pathway model.[41,42] Behavioral symptoms of ADHD have been attributed to, among others, impairments of inhibitory control, sustained attention and working memory, emotional processing, social cognition, and visuo-spatial and time perception.

There has been a shift in the focus of neuroimaging in recent research of ADHD symptomatology to consider the functional connectivity of the frontal-parietal network and of the posterior parietal and occipital cortical regions. This shift can be seen in evidence from adults with ADHD that functional differences in the superior parietal lobes and the frontal-parietal network appear associated with ADHD symptomatology and diagnoses.[24,25] In addition, pharmacological treatment of children with methylphenidate has been reported to normalize the functional connectivity between frontal and posterior temporal-parietal cortical regions of the brain.[22] Research also points to specific perceptual deficits that are of a visuo-spatial nature among medication-naïve children with ADHD.[43,44] The deficits appear associated with lower perceptual processing levels that might affect higher level cognitive functions negatively.

The objective of this register study was to compare performances on the processing-speed tests in AQT and AQT-Advanced (AQT-A), and the CCPT-3 variables and test components. We anticipated that among psychiatric referrals there would be adults, who showed evidence of moderate-to-severe ADHD symptomatology, as well as adults, who would not meet the informed criteria for ADHD set for CCPT-3, AQT, or AQT-A. We formulated several hypotheses based on results from previous research and clinical observations of performances by adults with ADHD.[12,13,34,37,38] The first hypothesis was that there would be no significant associations ($p > .05$) between the AQT or AQT-A processing-speed variables and the CCPT-3 T-scores for Detectability (*d'*) and error types. The second was that the AQT-A processing-speed measures (s) color, form, color-form, and AQT-A alternating color-then-form naming, would correlate at significant levels ($p < .05$) with one or more of the CCPT-3 reaction-time statistics. Thirdly, we hypothesized that contingency tests, using informed judgments of AQT/AQT-A and CCPT-3 responses, would result in significant agreement between measures. In other words, we expected similar informed judgments of the presence (Yes/Yes) or absence (No/No) of probable ADHD symptomatology based on the two tests. The statistical significance level set for accepting or rejecting a null hypothesis was set a priori at $p < .05$. This level was adopted because it was a register study that included a previously unexplored alternating naming test of first colors-then-forms, AQT-A, presented in randomized visual stimuli that combined both.

Methods

The total sample of participants in Phase 1, which compared AQT and CCPT-3, and Phase 2, which compared AQT-A and CCPT-3, included 111 adults ages 18 to 58 yr. Participants were referred for in-depth neuropsychiatric assessment of probable ADHD symptomatology to regional psychiatric centers in the Kalmar Region over a three-year period. The study was divided into two data-gathering and analysis phases. In Phase 1 (n = 42), the original AQT color, form, and color-form processing and naming tasks were administered concurrently with the administration of the CCPT-3 test. In Phase 2 (n = 69), the advanced AQT-A test version with a new alternating naming task and CCPT-3 were administered to all participants. During all phases, the computer-based CCCPT-3 test was administered to all participants, and they gave signed informed consent in accordance with the WMA Declaration of Helsinki.[44] The procedures followed the EMEA guidelines for best practice.[45] The inclusion criteria for both phases were identical and included that participants must have (a) Swedish as their primary native language, (b) no evidence of substance abuse at the time of study, (c) no evidence of psychosis, (e) well-regulated diabetes and thyroid function, and (f) intellectual functioning slightly below (IQ>80), within, or above the average range. Patients in both samples, who received ongoing pharmacological treatment for depression or other non-ADHD disorders, continued medication during the assessment. This meant that any positive or negative influences on the ADHD symptomatology were not controlled. In the total sample (n = 111), there were 22 participants (19.8%), who received ongoing non-ADHD medication for depression and/or anxiety disorders.

The patient sample in Phase 1 included 29 males and 13 females, between ages 18 and 56 yrs. (Mean = 33.02 yr.; SD = 12.06 yr.). Participants in the first phase were administered the original AQT tests, color, form, and color-form combination naming. A measure of shift costs (overhead) (s) was calculated by using the formula [color-form– (color + form)] = shift cost/overhead. This measure reflects the time imposed by articulatory transitions and added cognitive demands for rapid processing and naming of the color-form combination stimuli.

The sample for Phase 2 featured 26 males and 43 females, ranging in age from 18 to 58 yr. (Mean = 35.54 yr.; SD =11.09 yr.). They were administered AQT-A, which included the original color, form, and color-form naming tasks, and shift costs/overhead, as well as the newly developed alternating naming of color-then-form task. The alternating naming task allowed for the calculation of a quantitative time-cost quotient, tentatively considered to represent aspects of efficiency of inhibiting impulsive responses during alternating color-then-form naming. The quotient was calculated by dividing the sum of color plus form (s) by two to obtain an average naming time for the 40 single-color visual stimuli and subtracting this number from the total alternating naming time (s). The alternating cost quotient was proposed to reflect that alternating naming of color-then-form would place fewer demands

on coarticulation, while requiring cognitive control to facilitate inhibition of impulsive-responding tendencies. It should be noted that the alternating naming of color-then-form measure has not yet been subjected to rCBF or fMRI neuroimaging for validation. In Phase 3, the individual AQT measures for color, form, and color form naming, and shift-costs from the two samples were combined (n = 111). The analyses were performed to provide validation of the statistical outcomes reported for the smaller sample in Phase 1 (n = 42).

Materials

In Phase 1 (n = 42), participants were administered the original AQT processing and naming tasks with randomized colors, forms, and color-form combinations and the CCPT-3.[1,2,5] The AQT visual stimuli were presented on three test plates, each with 40 highly familiar, basic colors (*black, blue, red, yellow*), forms (*circle, line, triangle, square*), or color-form combinations (e.g., *black circle*). The total naming time (s) for each task was measured digitally, beginning at voice onset, and ending after articulation of the last item. The single color and form naming tasks are considered to probe reactive attention, rely on established automaticity in perception and articulation, and reflect a combination of reaction, retrieval, and response time. The color-form combination naming task probes active attention, which reflects sustained attention, working memory, and cognitive control. The statistic characteristics of AQT indicate a high degree of test-retest reliability (r) among healthy adults with correlations .91 for color, .92 for form, and .95 for color-form combination naming.[1,2] In normative groups, AQT showed no gender or educational bias after early literacy had been achieved.[30,31] Test-retest reliability of color-form naming was also evaluated for adults with ADHD before and after extended methylphenidate IR use.[10] Before receiving ADHD specific medication, the correlation was r = .89, and after stabilization with methylphenidate IR it was r = .94, and resembled that for healthy adults.[1,2]

In Phase 2 (n = 69), participants were administered the AQT-A test, which consists of the original AQT tasks, and the new alternating color-then-form naming task and CCPT-3.[5] The stimulus plate used for color-form combination naming was also used for the AQT-A alternating color-then-for naming task. Participants in both phases of the study were administered the complete CCTP-3.[5] The computer administered and scored test provides T-scores, ranging between 20 and 80 with a mean of 50 to determine the probable presence and relative severity of ADHD symptomatology. A high T-score between 60-69 indicates a moderate level of difficulty (e.g., slow reaction time), and a score of 70 or above indicates severe difficulties in responding (e.g., atypically slow). Separate tasks, designed in blocks with visual stimuli and requiring non-verbal responses, place demands on potential behavioral differences accepted as common among persons with ADHD.[12,13,40] The tasks emphasize the ability to identify targets from non-targets, and adapt to variable rates of presentation to evaluate different aspects of error responses and reaction time. The tasks are grouped into three behavioral variables that include (a) Detectability (*d'*) that probes perception and discrimination and differentiating between targets and non-targets, (b) error types, Omissions, Commissions, Perseverations, that probe inattention and difficulty in focusing, and (c) reaction-time statistics that probe aspects of controlling response speed across tasks, blocks, and at variable presentation rates.

Procedures

During the intake evaluation, participants were administered basic norm-referenced tests and rating scales to determine intellect, visual-spatial abilities, personality traits, and evidence of possible bipolarity or autism. The ASRS-1.1[45] self-evaluation and Brown Attention Deficit Disorders Scale[46] rating scales were routinely administered. The intake results and observations were evaluated by professional teams consisting of psychiatrists, neuropsychologists, nurses, and social workers. If the results indicated clear evidence of ADHD or other psychiatric disorders, the case was referred directly for follow-up and psychiatric treatment. In cases where the basic intake evaluation did not produce clear evidence of a psychiatric condition, the adults were referred for additional testing, which routinely included a broader range of tests of cognition, executive functions, and behavioral rating scales. The CCPT-3, AQT, or AQT-A were routinely administered as part of in-depth evaluations. The neuropsychological test results, and evidence from psychiatric interviews, were reviewed by a professional staff team to arrive at informed judgments of the probable presence or absence of ADHD symptomology. A final diagnosis followed, with recommendations for pharmacological or other forms of treatment. Adults, who met the inclusion criteria for the register study, were asked to volunteer to contribute the AQT or AQT-A test results to the register study and signed informed consents according to the Declaration of Helsinki.

Results

During the three-year study, forty-two participants entered Phase 1 of the study and were administered the original AQT with three primary tasks, Color, Form, and Color-Form naming, and CCPT-3. While Phase 1 of the study was ongoing, the alternating color-then-form naming task was developed, and pilot tested in clinical practice. During pilot testing, examiners obtained quantitative measures as well as qualitative behavioral observations. Several adults in the pilot study were unable to perform the alternating naming task prior to receiving ADHD-specific medication. After stabilization with ADHD-specific medication, periodic follow-up assessment indicated increasing ability to perform the alternating naming task. This led to adding alternating color-then-form naming to the original AQT protocol, and the advanced AQT-A version was administered to all participants (n = 69), who entered the study

after completion of Phase 1. Participants in Phase 2 of the study were administered the three primary AQT tasks (color, form, and color-form naming), the alternating color-then-form naming task (AQT-A), and CCPT-3.

Descriptive statistics

Statistical analyses were performed to evaluate the normality of distributions of test scores and obtain descriptive statistics of performances by the participants in Phase 1 (n = 42) and Phase 2 (n = 69). Judgments of normality were based on Shapiro-Wilk W and Kolmogorov-Smirnov (Lilliefors) statistics and measures of skewness see Table 1 and 2. The results indicated that the majority did not meet criteria for normality or use of parametric statistics. All further analyses for associations between the AQT/AQT-A time measures and CCPT-3 T-scores were performed with non-parametric statistics. Comparison of the group means for participants in Phase 1 (n = 42) indicated that the group means for AQT color, form, color-form combinations, and shift costs/overhead were greater than for a normative sample of healthy adults between ages 18 and 54.[30,31] In a normative healthy sample (n = 234), the upper limits of the time measures (+1 SD of the mean) were 25 s for color, 30 s for form, and 55 s for color-form naming. Shift costs (overhead), calculated as [color-form combinations - (color + form)], were also substantially larger than among healthy adults, for whom 5 s at +1 SD of the mean was the upper limit for typical performance. The means for the CCPT-3 T-scores ranged from average to above average and standard deviations tended to be slightly larger than those for the normative population.[5] Table 1 provides descriptive statistics for the 42 participants in Phase 1 Table 1.

Table 1: Descriptive statistics for AQT naming times (s) and CCPT-3 T-scores (n = 42).

AQT	Mean (s)	SD (s)	Skewness
Color	30.12	16.18	3.47
Form	37.86	22.50	2.84
Color-Form	76.55	32.64	1.05
Shift cost	16.59	21.19	1.13
CCPT-3			
Detectability (*d'*)	57.38	9.01	0.19
Omissions	53.81	11.38	1.68
Commissions	57.64	10.63	0.02
Perseveration	55.10	13.24	1.37
Hit RT	42.31	11.73	1.27
HRT SD	57.40	11.56	1.10
Variability	55.62	12.09	1.09
HRT Block	47.95	9.54	0.27
HRT ISI	48.44	8.78	-0.29

Comparison of the means for participants in Phase 2 (n = 69) also indicated that all values for AQT-A color, form, color-form combination naming, and shift costs/overhead, were larger than for healthy adults ages 18 and 54 yr.[30,31] Standard deviations (SD) and shift costs/overhead proved substantially larger than for healthy adults.[1,2,31] It should be noted that normative means and SDs for alternating color-then-form naming and the cost quotient have not yet been established for healthy adults ages 18 to 54 yr. There are, however, normative data for healthy adolescents between ages 14 to 18+ yr. (n = 100), developed for a Danish language test for assessing interactions between language and executive functions.[48] For healthy adolescents, who had reached maturity, the mean and SD for alternating color-then-form were 41 s and 10 s, respectively.[48] For participants in Phase 2, the mean and SD (79 s and 28 s) for alternating naming were substantially larger than for mature adolescents. The AQT-A mean alternating cost quotient was 30 s and SD 5 s for healthy adolescents (ages 14-18). In the Phase 2 sample, the mean alternating cost quotient and SD (49 s and 28 s) were substantially larger than for healthy adolescents.[48] The CCPT-3 T-scores for the ADHD adult group in Phase 2 ranged from low average to above average and SDs tended to be slightly larger than those in the normative population Table 2.[5]

Table 2: Descriptive statistics for AQ-A naming times (s) and CCPT-3 T-scores (n = 69)

AQT-A	Mean	SD	Skewness
Color naming	27.13	6.21	0.78
Form naming	33.81	7.80	0.99
Color-Form naming	75.78	20.54	0.56
Shift cost	15.33	15.08	1.30
Alternating naming	78.96	28.92	0.49
Shift-cost Quotient	49.28	27.13	0.93
CCPT-3			
Detectability (*d'*)	60.10	11.68	0.15
Omissions	53.76	12.95	0.30
Commissions	61.04	11.39	0.03
Perseveration	58.55	15.72	1.06
Hit RT	39.22	10.45	0.77
HRT SD	57.0 9	12.27	0.96
Variability	54.88	12.80	0.98
HRT Block	48.89	11.99	-0.72
HRT ISI	51.38	10.63	0.39

Correlations between AQT and AQT-A and CCPT-3 components

Spearman Rank correlations (Rho) identified the degree of association between the original AQT and AQT-A time measures and CCPT-3 component T-scores for Phase 1 and Phase 2. In Phase 1 (n = 42), AQT color naming (s) and the CCPT-3 reaction-time statistics HRT and HRT SD, were statistically associated ($p < .01$). The associations between color naming and CCPT-3 error types proved statistically insignificant ($p > .05$). Associations between AQT form naming (s) and CCPT-3 reaction-time statistics, HRT SD, and

Variability, were also significant ($p < .01$) and indicated medium-to-large effect sizes. AQT form naming (s) was also associated with the CCPT-3 error type, Omissions ($p < .01$), with a medium effect size. Associations between AQT color-form naming (s) and CCPT-3 reaction times, HRT SD ($p < .01$) and Variability ($p< .05$), indicated a medium and small effect size. AQT shift costs (overhead) and CCPT-3 error types, Detectability, Omissions, and Perseverations, were statistically associated ($p < .05$) with small to medium effect sizes. Shift costs and CCPT-3 reaction-time statistics, HRT SD, and Variability, were also associated ($p < .05$), but with small effect sizes Table 3.

Table 3: Pearson Rank correlations RHO, t, and p-values for AQT (s) and CCPT-3 T-scores (n = 42)

AQT vs. CCPT-3	Rho	T	p-value
Color vs. Detectability (*d'*)	0.17	1.06	.295
Color vs. Omissions	0.15	0.97	.338
Color vs. Commissions	0.07	0.42	.678
Color vs. Perseveration	0.19	1.22	.231
Color vs. Hit RT	0.42	2.90	.006**
Color vs. HRT SD	0.39	2.66	.011**
Color vs. Variability	0.30	1.98	.054
Color vs. HRT Block Change	-0.20	-1.29	.204
Color vs. HRT ISI	0.04	0.26	.793
Form vs. Detectability (*d'*)	0.30	1.99	.053
Form vs. Omissions	0.38	2.56	.014*
Form vs. Commissions	0.11	0.69	.496
Form vs. Perseverations	0.27	1.79	.080
Form vs. Hit RT	0.47	3.36	.001**
Form vs. Hit RT SD	0.62	4.95	.000**
Form vs. Variability	0.39	2.69	.010**
Form vs. HRT Block Change	-0.11	-0.67	.507
Form vs. HRT ISI	0.07	1.40	.168
Color-Form vs. Detectability (*d'*)	0.24	1.58	.123
Color-Form vs. Omissions	0.24	1.58	.122
Color-Form vs. Commissions	0.11	0.69	.496
Color-Form vs. Perseverations	0.25	1.61	.114
Color-Form vs. Hit RT	0.28	1.85	.072
Color-Form vs. Hit RT SD	0.45	3.16	.003**
Color-Form vs. Variability	0.34	2.26	.029*
Color-Form vs. HRT Block	-0.19	-1.23	.226
Color-Form vs. HRT ISI	0.07	0.44	.659
Shift-cost vs. Detectability (*d'*)	0.37	2.50	.017*
Shift-cost vs. Omissions	0.33	2.19	.034*
Shift-cost vs. Commissions	0.28	1.87	.069
Shift-cost vs. Perseverations	0.30	1.96	.040*
Shift-cost vs. Hit RT	-0.07	-0.44	.60.57
Shift-cost vs. Hit RT SD	0.31	2.09	.043*
Shift-cost vs. Variability	0.35	2.36	.023*

In Phase 2 (n = 69), the AQT-A color-naming time (s) and CCPT-3 error types, Detectability (*d'*) and Commissions, were significantly associated ($p <. 05$), but with small effect sizes. Color naming times (s) and HRT SD reaction times were also associated ($p < .01$) with a medium effect size. Form naming was not associated with any of the CCPT-3 error types but was statistically associated with the CCPT-3 reaction-time statistics, HRT SD ($p < .01$) and HRT Block Change ($p < .05$), with medium and small effect sizes respectively. Color-form naming (s) correlated significantly with only one CCPT-3 reaction-time statistic, HRT SD ($p < .01$), with a medium effect size. There were no statistically significant correlations between the shift costs (overhead) and any of the CCPT-3 components ($p > .05$). Alternating color-then-form naming times (s) correlated significantly with the CCPT-3 error types, Detectability (d') and Omissions ($p < .05$), but with small effect sizes. Alternating naming also correlated with the CCPT-3 reaction-time statistics, Hit RT SD, and Variability ($p < .01$), and with medium effect sizes. The AQT-A alternating cost quotient indicated statistical associations with CCPT-3 Detectability (*d'*) ($p<.05$) and Omissions ($p<.01$), but with small effect sizes. The cost quotient correlated significantly with the CCPT-3 reaction-time statistics, HRT SD, and Variability ($p < .01$), with medium effect sizes Table 4.

Table 4: Rank correlation Rho, t, and p-values for AQT-A (s) and CCPT-3 T-scores (n = 69)

AQT-A vs. CCPT-3	Rho	t	p-value
Color vs. Detectability (*d'*)	0.24	2.02	.047*
Color vs. Omissions	0.18	1.49	.141
Color vs. Commission	0.24	2.03	.046*
Color vs. Perseveration	0.17	1.39	.169
Color vs. Hit RT	0.20	1.67	.099
Color vs. HRT SD	0.32	2.74	.008**
Color vs. Variability	0. 17	1.35	.181
Color vs. Block Change	0.09	0.69	.493
Color vs. HRT ISI	-0.01	-0.04	.975
Form vs. Detectability (*d'*)	0.19	1.56	.124
Form vs. Omissions	0.20	1.66	.101
Form vs. Commissions	0.07	0.61	.545
Form vs. Perseverations	0.00	0.02	.986
Form vs. Hit RT	0.20	1.65	.104
Form vs. Hit RT SD	0.35	3.00	.004**
Form vs. Variability	0.14	1.11	.270
Form vs. HRT Block Change	0.25	2.04	.045*
Form vs. HRT ISI	0.07	0.57	.570
Color-Form vs. Detectability (*d'*)	0.22	1.82	.073
Color-Form vs. Omissions	0.20	1.67	.099
Color-Form vs. Commissions	0.11	0.93	.354
Color-Form vs. Perseverations	0.01	0.08	.933
Color-Form vs. Hit RT	0.18	1.48	.144
Color-Form vs. Hit RT SD	0.33	2.83	.006**
Color-Form vs. Variability	0.23	1.89	.063
Color-Form vs. HRT Block	0.01	0.11	.914
Color-Form vs. HRT ISI	0.01	0.10	.917
Shift-cost vs. Detectability(*d'*)	0.13	1.09	.281
Shift-cost vs. Omissions	0.11	0.87	.386
Shift-cost vs. Commissions	0.07	**0**.60	.548
Shift-cost vs. Perseverations	-0.04	-0.34	.735
Shift-cost vs. Hit RT	-0.06	-0.50	.615
Shift-cost vs. Hit RT SD	0.10	0.86	.395

Shift-cost vs. Variability	0.08	0.60	.548
Shift-cost vs. HRT Block	-0.10	-0.84	.401
Shift-cost vs. HRT ISI	0.01	0.08	.936
Alternating vs. Detectability (*d'*)	0.24	2.04	.045*
Alternating CF vs. Omission	0.28	2.34	.023*
Alternating CF vs. Commissions	0.14	1.17	.245
Alternating CF vs. Perseverations	0.18	1.50	.137
Alternating CF vs. Hit RT	0.04	0.29	.769
Alternating CF vs. Hit RT SD	0.38	3.37	.001**
Alternating CF vs. Variability	0.35	3.02	.003**
Alternating CF vs. HRT Block	-0.19	-1.56	.123
Alternating CF vs. HRT ISI	-0.15	-1.22	.227
Shift-cost Q vs. Detectability (*d'*)	0.25	2.09	.040**
Shift-cost Q vs. Omission	0.29	2.45	.017**
Shift-cost Q vs. Commissions	0.15	1.23	.224
Shift-cost Q vs. Perseverations	0.19	1.55	.126
Shift-cost Q vs. Hit RT	-0.02	-0.19	.853
Shift-cost Q vs. HRT SD	0.37	3.23	.001**
Shift-cost Q vs. Variability	0.36	3.04	.003**
Shift-cost Q vs. HRT Block	-0.17	-1.35	.181
Shift-cost Q vs. HRT ISI	-0.09	-0.74	.463

*p<.05; **p<.01; *** p <.001

Contingency measures

The degree of contingency between informed judgments of probable presence/absence of ADHD symptomatology, based on the AQT or CCPT-3 components, was evaluated with Chi-Square (X2 2 x 2) tests. In Phase 1 (n = 42), 26 (62%) revealed clear evidence of ADHD (AQT Yes – CCPT-3 Yes), and 7 (17%) revealed no evidence of probable ADHD (AQT No - CCPT-3 No). Opposing judgments were obtained for nine participants. Four (9%) received AQT Yes - CCPT-3 No judgments, and five (12%) AQT No - CCPT-3 Yes judgments. This resulted in a X2 contingency statistic of 18.62 (1, p-value .000, p < .01), with a substantial effect size index (w = .666), and with Yates correction of 15.63 (1, p-value .000, p < .01), with a similar effect size index (w = .610). The results indicated a significant and clinically relevant degree of agreement between informed judgments based on the original AQT time scores (s) for color, form, color-form combination naming, and shift costs (overhead) and CCPT-3 T-scores for components.

In Phase 2 (n = 69), 44 participants (64%) obtained informed clinical judgments of ADHD (AQT Yes – CCPT-3 Yes), while seven (10%) revealed no evidence of probable ADHD (AQT No – CCPT-3 No). Opposing judgments based on the AQT-A and CCPT-3 components occurred for 18 (26%) participants. Of these, 14 (20%) received Yes judgments based on AQT-A and No on CCPT-3 T-scores, while four (6%) received No judgments on AQT-A and Yes on CCPT-3. This resulted in a Chi-Square statistic of 6.81 (1, p-value .009, p < .01) with a medium effect size index (w = .314), and with Yates correction of 5.08 (1, p-value .024, p < .05), with a slightly lower effect size index (w = .271).

AQT time (s) and CCPT-3 T-scores for the total sample (n = 111).

Differences in the Chi-Square contingency measures between informed judgments in Phase 1 suggested that the original AQT version might serve as a valid screening measure. We questioned if a larger validation sample (n =111), with the combined totals for color, form, color-form naming, and shift costs (overhead), would show correlations (Rho) and contingency measures that were like those in Phase 1 (n = 42). Mann-Whitney U statistics indicated no significant differences between the two samples for the AQT time measures and CCPT-3 T-scores and supported a null-hypothesis (p > .05) Table 5.

Table 5: Comparison of AQT and CCPT-3 mean scores for Phases 1 (n = 42) and 2 (n = 69).

AQT & CCPT-3	Mean (s)	SD (s)	Mann-Whitney U	Significance (2-tailed)
Color 1	30.12	16.18	1,387.0	0.705
Color 2	27.13	6.21		
Form 1	37.86	22.50	1,422.5	0.871
Form 2	33.64	7.43		
Color-Form 1	76.55	32.64	1,329.0	0.465
Color-Form 2	74.78	20.54		
Overhead 1	16.59	21.19	1,425.0	0.883
Overhead 2	15.10	15.32		
Detectability (*d'*) 1	57.38	9.01	1,262.0	0.255
Detectability (*d'*) *2*	60.10	11.68		
Omissions 1	53.81	11.38	1,338.5	0.763
Omissions 2	53.76	12.95		
Commissions 1	57.64	10.63	1,213.5	0.151
Commissions 2	61.04	11.39		
Perseveration 1	55.10	13.24	1,107.5	0.076
Perseveration 2	58.54	15.72		
Hit RT 1	42.31	11.73	1,227.5	0.216
Hit RT 2	39.22	10.45		
HRT SD 1	57.40	11.56	1,402.5	0.977
HRT SD 2	57.09	12.27		
Variability 1	47.95	9.54	1,284.0	0.519
Variability2	48.89	11.99		
HRT Block 1	47.95	9.54	1,284.0	0.519
HRT Block 2	48.89	11.98		

Spearman Rank correlations (Rho) first identified the degree of association between the original AQT time measures and CCPT-

3 component T-scores for the combined sample (n=111) Table 6. AQT color naming was associated with three CCPT-3 reaction-time measures, Hit RT, HRT SD, and variability, with medium size effects, but not with any of the error type measures. Form naming was associated with the CCPT-3 Detectability (*d'*) and Omissions, and with the reaction-time measures, Hit RT, HRT SD, and Variability, with low or medium effect sizes. Color-form naming was associated with the Detectability (*d'*), Omissions, HRT SD, and Variability components, with medium and low effect sizes. The shift cost (overhead) measure was also associated with Detectability (*d'*) and Omissions, and with HRT SD, but with low effect sizes Table 6.

Table 6: Pearson Rank correlations RHO, t, and p-values for the combined sample and CCPT-3 T-scores (n= 111)

AQT vs. CCPT-3	Rho	t	p-value
Color vs. Detectability (*d'*)	0.20	1.06	.036
Color vs. Omissions	0.15	1.55	.124
Color vs. Commissions	0.17	1.84	.069
Color vs. Perseveration	0.18	1.92	.057
Color vs. Hit RT	0.22	2.38	.019*
Color vs. HRT SD	0.36	2.38	.000**
Color vs. Variability	0.25	2.67	.008**
Color vs. HRT Block Change	-0.20	-0.26	.797
Color vs. HRT ISI	0.04	0.40	.688
Form vs. Detectability (*d'*)	0.24	2.56	.012**
Form vs. Omissions	0.26	2.56	.006**
Form vs. Commissions	0.11	1.20	.234
Form vs. Perseverations	0.13	1.33	.187
Form vs. Hit RT	0.22	2.36	.020*
Form vs. Hit RT SD	0.47	5.57	.000**
Form vs. Variability	025	2.68	.008**
Form vs. HRT Block Change	0.12	1.22	.226
Form vs. HRT ISI	0.15	1.53	.130
Color-Form vs. Detectability (*d'*)	0.24	2.63	.009**
Color-Form vs. Omissions	0.23	2.39	.018*
Color-Form vs. Commissions	0.14	1.52	.132
Color-Form vs. Perseverations	012	1.22	.085
Color-Form vs. Hit RT	0.12	1.30	.195
Color-Form vs. Hit RT SD	0.39	4.36	.000**
Color-Form vs. Variability	0.27	2.86	.005*
Color-Form vs. HRT Block Change	-0.04	-0.40	.689
Color-Form vs. HRT ISI	0.05	0.55	.583
Shift-cost vs. Detectability (*d'*)	0.24	2.62	.009**
Shift-cost vs. Omissions	0.23	2.41	.017*
Shift-cost vs. Commissions	0.17	1.78	.077
Shift-cost vs. Perseverations	0.12	1.27	.208
Shift-cost vs. Hit RT	-0.12	-1.22	.022
Shift-cost vs. Hit RT SD	0.20	2.08	.039*
Shift-cost vs. Variability	0.18	1.84	.068
Shift-cost vs. HRT Block Change	-0.06	-0.47	.638
Shift-cost vs. HRT ISI	0.05	0.50	.645

*p<.05; **p <.01

In the total sample (n = 111), 67 (60%) of participants showed evidence of probable moderate-severe ADHD and 17 (15%) showed no evidence of probable ADHD, based on the AQT time measures (s) and CCPT-3 T-scores. Twenty-seven adults (24%) showed opposing evidence of probable ADHD. Of these, 17 (15%) obtained AQT Yes and CCPT-3 No and 10 (9%) AQT No and CCPT-3 Yes judgments based on the clinical criteria. This resulted in a X2 contingency statistic of 17.55 (1, p-value .000, p < .01) and with Yates correction of 15.60 (1, p-value .000, p < 01) with effect sizes like those reported for the Phase 1 study (n = 42).

Discussion

In this clinical register study, we compared the outcomes of the administration of an established neuropsychological test, Conners Continuous Performance Test 3rd Edition (CCPT-3), and A Quick Test of Cognitive Speed (AQT), used in regional psychiatric centers in Sweden.[1,2,5] Participants in the study were referred for in-depth neuropsychological evaluation after a basic intake evaluation provided inconclusive or opposing evidence of presence or absence of probable attention deficit/hyperactivity disorders (ADHD). All AQT and CCPT-3 test results were obtained as part of the ongoing, regular clinical practice at the centers, without support from external funding. We recognize that this is a limitation that suggests a need for future randomized, double-blind studies for independent validation. It is also a limitation that 22 participants (19.8%) maintained their regular schedule of non-ADHD medications and that possible positive/negative effects were not controlled. AQT has been validated with rCBF and fMRI neuroimaging to establish posterior temporal-parietal cortical and subcortical activation patterns in healthy adults during execution of the rapid processing and naming tasks.[1,2] Due to lack of funding, the alternating naming test, featured in AQT-Advanced (AQT-A), has not yet been norm referenced or validated with current neuro-imaging techniques.

When the study was started, we anticipated that the referrals for neuropsychiatric evaluations might or might not result in quantitative evidence of the probable presence of ADHD symptomatology. We also expected that factors other than ADHD, such as gender bias, might have led to the referral. In Phase 1, there were 13 females to 29 males, a common gender ratio, while the gender ratio in Phase 2 of 43 females to 26 males was unusual. In the total sample of 111 participants, the gender ratio of 56 females and 55 males was, however, balanced. Research to develop normative data for AQT with healthy adult American and Scandinavian language speakers has repeatedly reported absence of gender bias.[1,2,10,30,31] To account for possible, uncontrolled bias in the two groups, Mann-Whitney *U* statistics evaluated the differences between the AQT and AQT-A color, form, color-form, and shift cost (overhead) measures (s) and CCPT-3 T-scores. The comparisons supported a null hypothesis (p > .05), indicated (a) no statistical differences between the performance measures, (b) that the two clinical groups represented the same population, and (c) that the results for the samples could be combined for further analyses.

AQT and AQT-A and CCPT-3 error types

Pearson Rank correlations (Rho) provided evidence of the statistical significance of associations between the color, form, color-form, and shift cost (overhead) measures (s) and CCPT-3 test components in Phase 1 (n= 42), Phase 2 (n = 69), and for the combined sample (n=111). We hypothesized that none of the AQT naming measures, color, form, or color-form combinations, or shift costs, would show significant correlations with any CCPT-3 error- type component. This hypothesis was validated with a few exceptions.

In Phase 1 (n = 42), AQT single color naming was not associated with any CCPT-3 error type components, whereas form naming (s) was associated with CCPT-3 Omissions ($p < .01$). However, in Phase 2 (n =69), color naming was statistically associated with CCPT-3 Detectability (*d'*) and Commissions, with small effect sizes ($p<.05$). Form naming was not associated with any of the CCPT-3 error measures. In the combined group (n = 111), color naming was not associated with any CCPT-3 error types, whereas form naming was associated with CCPT-3 Detectability (*d'*) and Omissions, with small to medium effect sizes. Single color and form naming require rapid, accurate visual perception, and automatic retrieval and production of labels for the stimuli (i.e., reactive attention). During rapid, continuous naming of colors or forms, self-corrected errors and inconsistencies in response rates may result in atypical, prolonged naming times compared to norms for healthy adults.[1,2,30,31] Shorter than expected naming times (s) may result from omissions, perseverations, and impulsively fast responding. The finding that the single color or form naming task in Phases 1 and 2, and in the combined sample (n = 111) were statistically associated with CCPT-3 error types, suggests that in future screening or dose monitoring applications of these tasks, the number of errors in responding should be accounted for by examiners or by digital administration.

AQT and AQT-A color-form combination naming requires active attention, engaging central executive functions that reflect attention and working memory, set shifting, and added time used for co-articulation. In Phases 1 and 2, neither color-form combination naming nor the derived shift cost (overhead) measures were statistically associated with CCPT-3 error types. The associations between color-form naming and shift cost (overhead) and CCCPT-3 components did not follow a similar pattern in the combined group (n = 111). Color-form combination naming and the derived shift costs were statically associated with CCPT-3 Detectability (*d'*) and Omissions, with low to medium effect sizes. The shift cost measure appears associated with the level of inattention and/or reduced processing efficiency at the visual-perceptual, cognitive, and/or word retrieval levels. In earlier clinical studies that monitored methylphenidate dose effects in adults with ADHD, the shift cost/overhead measure (s) was prominent in determining progressive judgments of dose effectiveness and stabilization.[8,9,11,36] Stabilization in those studies repeatedly coincided with the methylphenidate dosage at which the gap between the sum of color and form and color-form combination naming was closed and the shift costs approached or were within the normative size for healthy adults. The findings supported the additive AQT model, which was established in normative studies of healthy adults.[48-50]

In Phase 2, AQT-A alternating naming of colors-then-forms (s) and the shift-cost quotient, newly developed measures, were not hypothesized to be significantly associated with any CCPT-3 error-types. Results, however, revealed that both measures were associated with the CCPT-3 Detectability (*d'*) and Omissions, but with small effect sizes. These findings suggest that the new AQT-A measures may provide tentative evidence of impulsivity as well as inattentiveness of adults with ADHD, an aspect that warrants further exploration through validation studies and potential neuroimaging.

AQT and AQT-A and CCPT-3 reaction-time measures

We hypothesized that each of the AQT and AQT-A naming-time measures (s) would show significant associations (Rho) with one or more CCPT-3 reaction-time statistics. In Phase 1, several of the original AQT measures showed significant associations with CCPT-3 reaction-time statistics. AQT single color naming correlated significantly with the reaction-time statistics Hit RT and HRT SD, with medium effect sizes. Form naming correlated with Hit RT, HRT SD, and Variability, with medium to large effect sizes. Color-form combination naming and the derived shift costs (overhead) correlated with HRT SD and Variability, with medium effect sizes. The findings supported our hypothesis and validated the use of the AQT processing-speed construct. The degree and significance of the associations support previous findings that AQT can be used as an individual screening test in advance of referrals for intensive neuropsychological evaluations or to monitor methylphenidate or other treatment effects.[8,9,10,36]

In Phase 2, AQT-A color, form, as well as color-form combination naming correlated positively with the CCPT-3 reaction-time statistic HRT SD, with medium effect size. Form naming also correlated with HRT Block Change, but with a small effect size. There were no significant correlations between the derived shift-cost (overhead) measures and CCPT-3 reaction-time statistics. The new alternating color-then-form naming task and the derived shift-cost quotient correlated significantly with the CCPT-3 reaction-time measures, Hit RT, HRT SD, and Variability, with medium effect sizes. In the sample, three participants (4%) could not perform the alternating color-then-form naming task after several trials. After referral and stabilization with methylphenidate, all completed alternating naming and met criteria for average normal performance compared to healthy adolescents.[46] The associations with the greatest level of significance ($p < .01$) and largest relative effect sizes occurred between AQT color-form naming, AQT-A alternating color-then-form naming, and the derived shift-cost quotient and the CCPT-3 reaction-time statistics HRT SD and Variability. The reaction-time statistics, HRT SD and Variability, probe inconsistencies in reaction

time over the recorded time and across stimulus blocks. Both measures are considered behavioral indicators of the variables, Inattentiveness, and/or Impulsivity, according to CCPT-3 criteria.[5]

Contingency measures

We anticipated that AQT-A, with alternating color-then-form naming, would provide relatively higher levels of contingency than AQT between informed judgments of probable ADHD and CCPT-3 components. However, the contingency statistics for Phase 1 reached more substantive significance levels with larger effect sizes than the contingency statistics for Phase 2. It was also unexpected that the AQT-A alternating shift-cost (overhead) measures in Phase 2 did not show significant associations with any CCPT-3 reaction-time variables. The shift cost (overhead) measures were prominent in Phase 1, with significant correlations with error types and reaction-time statistics. We therefore anticipated that the measure would retain significance in Phase 2. Three random examples from among participants in Phase 2, who were judged by AQT and AQT-A and CCPT-3 to exhibit probable ADHD, illustrate the AQT-A clinical criteria for informed judgments.

Case 1. This male, age 21, with ADHD received the following naming-time measures (s) for the AQT-A rapid processing and naming tasks: (a) color 34 s; (b) form 31 s; (c) combined color-form 103 s; (d) shift cost (overhead) 38 s; (e) alternating naming 117 s; and (f) shift-cost quotient 85 s. The color and form naming measures are considerably larger than the normal limit of 25 s (+1SD of the mean), and may reflect reductions in attentiveness, visuo-spatial processing, or word retrieval.[1,2,30,31] The stand-out feature is that color-form naming, and shift-costs are in the atypical range at +3 SDs of the normative means, suggesting probable severe ADHD symptomatology. Alternating color-then-form naming and the large shift-cost quotient may reflect greater impulsivity/less inhibition, as they are in the atypical range compared to healthy adolescents (age 18+) in the Danish SEF sample.

Case 2. This male, age 39, received the following AQT-A scores: (a) color 30 s ; (b) form 32 s; (c) color-form 113 s; (d) shift cost/overhead +51 s; (e) alternating naming 71 s; and (f) shift-cost quotient 40. The critical features are that color-form naming, and shift costs are in the atypical range, whereas the alternating naming measure and shift-cost quotient are in the average range, compared to norms for mature adolescents.[47] This may suggest an ADHD symptomatology primarily with inattentiveness, but with minimal impulsivity tendencies.

Case 3. For this female, age 29, the AQT-A scores were: (a) color 21 s; (b) form 25 s; (c) color-form 57 s; (d) shift cost/overhead 11 s; (e) alternating naming 56 s, and (f) shift-cost quotient 33. At a first glance, the typical response times for color, form and color-form naming may suggest that this woman exhibits non-ADHD functionality.[30,31,47] The distinctive deviation from a typical, healthy adult profile is the amount of shift cost (11 s), which approaches +2 SDs of the normative mean.[1,2,30,31] This anomaly may in part be caused by the relatively fast naming speed for single colors and forms, or may reflect uncontrolled variables, and might warrant follow-up test-treatment trials. The same performance pattern, with the only indicator of possible ADHD being the size of the shift cost (overhead) was reported for a female with ADHD and substance abuse in a forensic case study.[36]

Analyses of the AQT performance measures and levels of associations with CCPT-3 of the combined sample (n = 111) essentially concurred with the respective measures from the Phase 1 (n = 42) and 2 (n = 69) samples. In the total sample there were four statistical associations that were not significant in the Phase 1 and 2 samples. Thus, color naming correlated with Variability ($p < .01$), form naming with Detectability (d') ($p < .01$), and color-form naming with Detectability (d') ($p < .01$) and Omissions ($p < .05$). From a clinical perspective, the added statistical associations with CCPT-3 provided data that might have been captured by AQT if the number of naming errors had been counted during execution.

The AQT test version has been used and validated in controlled research of adults with ADHD for, among others, monitoring methylphenidate dose effects and establishing optimal performance with minimal side effects.[8-11] This study appears to provide validation of the AQT and the AQT-A processing-speed tests, as short screening or clinical measures for establishing baselines and monitoring the effects of pharmaceutical or other treatment.[3,4,10,36] Further neuropsychiatric evaluation with broader psychological and neuropsychological measures is recommended in clinical follow-up after screening for probable ADHD symptomatology with AQT or AQT-A.[5,48] The screening tests can provide repeated quantitative measures to establish a baseline and chart improvements or regressions in performance levels during pharmacological or other clinical treatments. They can also monitor effects of pharmacological interventions until optimal performance levels have been achieved.[34-36] Among clinically relevant features of the AQT and AQT-A tests are that they can be administered quickly, in less than 10 min, by trained allied professionals, using easily, portable printed, computer, or tablet formats. The tests do not require literacy skills and can be used for bilingual speakers and speakers of diverse languages for which there are established norms.[30-33] AQT has not been found to introduce gender or educational bias in cultures, where educational standards for women and men are similar.

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Conflict of Interest

Regarding the publication of this article, the authors declare that they have no conflict of interest.

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