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Difference in Cognitive Dysfunction Between Adult ADHD and Neurotic Patients in the Korean Population: A Preliminary Research

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Adulthood Attention-Deficit Hyperactivity Disorder (ADHD) debilitates high-level executive functioning, attention and impulse control. There is a lack of consensus regarding the specific cognitive markers for ADHD compared with other psychiatric disorders that show attention-related problems as secondary symptoms. This study aimed to aid clinicians in utilizing existing tools for intelligence and cognitive function by investigating the key variables that differentiate ADHD from other mental disorders. As preliminary research, the study compared the performances of 35 patients with ADHD and 26 patients diagnosed with other neurotic disorders on the Korean Wechsler Adult Intelligence Scale-IV (K-WAIS-IV), Conners Continuous Perceptual Test 3rd Edition (CPT 3) and Conners Continuous Auditory Test of Attention (CATA). The ADHD group performed significantly lower on the Verbal Comprehension Index (VCI) and Working Memory Index (WMI) of K-WAIS-IV; the difference was significant in Similarity, Vocabulary and Arithmetic subtests. Perceptual Reasoning Index (PRI) and VCI differed significantly in the ADHD group unlike their neurotic counterpart. Of the variables in CPT 3, only detection differentiated ADHD from other neurotic disorders. Our results implicate there are novel standards and key variables that should be considered when differentiating ADHD from other psychiatric disorders.

Keywords: ADHD, CPT, K-WAIS-IV, attention, diagnostic differentiation

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is characterized by deficits in maintaining attention and selective attention, lack of concentration, hyperactivity, and impulsivity. Approximately half of those diagnosed with ADHD as a child persist into adulthood ADHD – specifically symptoms of inattention, poor concentration, lack of planning, and impulsivity (Adler et al., 2017; Kessler, Adler, Barkley et al., 2005; Kessler et al., 2010). Diagnosing ADHD in adults presents several challenges. Deficits in attention and impulsivity control are symptoms of not only ADHD but also other psychopathological disorders (Adler, Spencer, Stein, & Newcorn, 2008; Gentile, Atiq, & Gillig, 2006). While structural interviews and self-reported questionnaires such as Structured Clinical Interview for DSM-5 and Adult ADHD Self-Report Scale-V.1.1 Symptoms Checklist (ASRS-V1.1) have been actively utilized for diagnosis (Kessler, Adler, Ames, et al., 2005; Osório et al., 2019), this may not be suffice when patients report a myriad of symptoms and life events that do not precisely rule out other diagnoses.

This limitation called for objective cognitive data. Neuropsychological tests aid in diagnosing and obtaining individualized characteristics of ADHD, usually by observing deficits related to executive dysfunction (Du Rietz et al., 2016; Gualtieri & Johnson, 2005; Homack & Reynolds, 2005). K-WAIS-IV is a tool regularly used to

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measure cognitive domains, including verbal comprehension, perceptive construction and reasoning, working memory, and processing speed (Kim & Kim, 2017). CPT 3 & CATA are performance-measuring computerized tools, devised to measure vigilance and sustained attention (Conners, 2014). They are most commonly used in South Korea and other countries as they are believed to provide objective data tailored to assess the patient's characteristic weaknesses regarding attention (Homack & Reynolds, 2005; Park et al., 2019; Won, Choi, & Kim, 2020). However, there is still an ongoing debate as to how these tools can be used practically (Hall et al., 2016).

Numerous studies have investigated the differences in cognitive function between adult ADHD patients and healthy controls using WAIS and CPT 3. In the initial standardization of the American WAIS-IV (Wechsler, 2008), Pearson Assessments reported that adults with ADHD showed poor performance in Arithmetic (AR), Coding (CD), and Matrix Reasoning (MR) which are subtests comprising Perceptive Reasoning (PRI), Working Memory (WMI) and Processing Speed Index (PSI). Meanwhile, a meta-analytic study stated that adults with ADHD differed from non-ADHD adults in both verbal and performance IQ on WAIS-III (Bridgett & Walker, 2006). While some studies reported that adults with ADHD and the healthy controls showed differences in CPT performance, there is no consensus regarding which of the measured variables is statistically signficiant (Advokat et al., 2007; Boonstra et al., 2005; Malloy-Diniz et al., 2007). While these studies contributed to conceptualizing the cognitive characteristics of adults with ADHD compared to those of healthy controls, such differentiation was not sufficient as clinicians in practice are responsible to not only for differentiating adults with ADHD from the normal population but also for making a differential diagnosis. Patients with other psychopathological disorders show cognitive impairment in areas that are known to be deficient in ADHD. Several studies have reported that adults with depression have significantly lower PSI, memory, psychomotor skills, and attention on WAIS-III and WAIS-IV (Gorlyn et al., 2006; Kim & Park, 2020; Marazziti, Consoli, Picchetti, Carlini, & Faravelli, 2010; Wechsler, 2008). Overlapping patterns of dysfunction that exist among different disorders complicate diagnostic differentiation, leaving room for further exploration.

When comparing ADHD to other psychiatric disorders, studies have found mixed results for the efficiency of the tools intended to measure various areas of cognitive functioning. A recent study by Guo et al. (2020) used several executive function-related tasks to differentiate adults with ADHD from adults with other psychiatric disorders, ranging from simple mood disorders to schizoaffective disorders. They found neuropsychological impairments in both groups, but failed to define a pattern specific to adults with ADHD. Another study using CPT, measures of attention, psychomotor speed, executive function and arithmetic skills reported no difference in performance between clinical groups (Walker, Shores, Trollor, Lee, & Sachdev, 2000). They compared the ADHD group with a psychiatric group consisting of 15 individuals with mood disorders, 10 with anxiety disorders, and 5 with mixed mood and anxiety disorders. Other studies have reported differing results, as they found that the ADHD group to showed impairment in the verbal memory, concept shifting, and processing speed unlike other psychiatric/healthy controls (Marchetta, Hurks, Krabbendam, & Jolles, 2008; Wiig & Nielson, 2012). When ADHD and mood disorders were compared, two studies found that CPT significantly differentiated the two, with no consensus on which variables differentiated them (Fasmer et al., 2016; Pettersson, Söderström, & Nilsson, 2018). In contrast, studies have questioned the competence of CPT in diagnosing children with ADHD when it was found that children with ADHD did not have higher CPT scores than psychiatric/healthy controls (McGee, Clark, & Symons, 2000; Riccio & Reynolds, 2001). While prior studies have attempted to target the cognitive areas for clinicians when discerning ADHD from other mental disorders, limitations for generalization exist.

This study aims to provide a perspective for clinicians on how to utilize cognitive and attention-related tests in terms of understanding the differences between attention deficit of ADHD and other mental disorders. This was done by examining and comparing cognitive dysfunction patterns in adult with ADHD and those with other neurotic mental disorders. The neurotic patient group comprised disorders including depression, anxiety, and bipolar II disorders. K-WAIS-IV, CPT 3, and CATA, which are commonly used assessment tools to measure cognitive abilities and attentional problems of ADHD in South Korea, were used (Park et al., 2019; Won, Choi, & Kim, 2020). CPT 3 & CATA were selected for this study because despite the controversy regarding their effectiveness

in differentiating ADHD from non-ADHD disorders, they are still considered useful tools for ADHD diagnosis by many clinicians (Matier-Sharma, Perachio, Newcorn, Sharma, & Halperin, 1995; Slobodin, 2020; Tallberg, Råstam, Wenhov, Eliasson, & Gustafsson, 2019). However, due to the relatively small sample size and the exploratory nature of the study, this study was considered preliminary research.

Methods

Participants and Procedures

Initially, 64 patients above age 18 who were prescribed CPT 3 & CATA between March 2017 and August 2020 were included in this study. At their initial intake, they were psychologically examined and diagnosed by trained psychiatrists according to the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-5; American Psychiatric Association, 2013) at Kangbuk Samsung Hospital, South Korea. As a retrospective study, only patients reporting subjective memory complaints were eligible for CPT 3 & CATA prescriptions. Therefore, our study consisted of subjects representing the hurdles that clinicians expect in their daily practices. Of these participants, those who had other neurological dysfunctions, symptoms of psychosis, or severe physical ailments were excluded. After the initial intake, clinical psychologists certified or under-training performed psychological examinations, including K-WAIS-IV, CPT3, and CATA. As the study was preliminary, the number of subjects fit Johanson and Brooks's (2010) recommendation of a minimum of 24 subjects per group to achieve a high Bootstrap confidence level.

The study was approved by the Institutional Review Board of Kangbuk Samsung Hospital.

Measures

K–WAIS–IV

K-WAIS-IV, standardized by Hwang, Kim, Park, Chey, and Hong (2012), is an individually administered, comprehensive clinical instrument for assessing intelligence. It provides index scale scores representing intellectual functioning in specified cognitive areas and a full scale intelligent quotient (FSIQ) that represents general intellectual ability. Four index scales ($M = 100$, $SD = 15$) are comprised of 2-3 core subtests ($M = 10$, $SD = 3$). The test was developed based on Cattell-Horn-Carroll theory (CHC) classification. Table 1 lists the index scale and its subtests. Difference between PRI and VCI was additionally observed in this study to obtain more means for clinical use.

CPT 3

CPT 3 was used to assess variables regarding attention, including sustained attention, impulsivity control, vigilance and inattentiveness using visual cues (Conners, 2014). Using the laptop, the participant responded to any letter except for letter X by pressing the space bar. The task consisted of 6 blocks, with 3 sub-blocks each consisting of 20 trials (total = 360 trials for 14 minutes). Within each block, sub-blocks with different inter-stimulus intervals (ISI) of 1, 2 and 4 seconds were used with a display time of 250 milliseconds. T-score above 70 can be interpreted as very elevated or atypically slow, 60–69 as elevated or slow, 55–59 as high average or a little slow, 45–54 as average, 40–44 as low or a little fast, and below 40 as atypically fast. The variables presented using the program is provided in Table 2. The number of patients with T-scores above or equal to 60 in any variable (CPT 3 ≥ 60) was also counted for group comparison.

CATA

CATA assesses the auditory attention-related problems (Conners, 2014). Using headphones, the participant pressed the space bar when the high tone was paired with a low tone. Participants did not respond when a high tone was heard alone. The assessment ran for 14 minutes with 200 trials divided into 4 blocks. Table 2 presents the resulting variables. Patients with T-scores above or equal to 60 in any variable (CATA ≥ 60) were counted for group comparison.

ASRS–V1.1.

ASRS-V1.1. is an instrument that consist of 18 DSM-IV TR criteria. Of the 18 questions, Part A consisted of 6 questions that were most predictive of symptoms consistent with ADHD. Four or more marks in Part A are warranted for further investigation of ADHD (Adler, Kessler, Spencer, & World Health Organization, 2013; American Psychiatric Association, 1980; Barkley & Poillioin, 1994; Bieder-

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Table 1. *K-WAIS-IV Subtests, Description, and CHC Classification*

Subtests	Definition and what it measures	CHC abilities
Verbal Comprehension Index (VCI)	Composed of subtests measuring verbal abilities that require reasoning, comprehension, and conceptualization	
Similarities (SI)	The participant is presented with two words that represent common objects of concepts and is asked what their core similarity is. It is designed to measure verbal concept formation, verbal reasoning, lexical knowledge, induction.	Gc, Gf
Vocabulary (VC)	The participant is asked to define a given word. It is designed to measure word knowledge and verbal concept formation.	Gc
Information (IN)	The participant is asked to answer questions that address a broad range of general knowledge topics. It is designed to measure the ability to acquire, retain, and retrieve general factual knowledge.	Gc
Perceptual Reasoning Index (PRI)	Composed of subtests measuring nonverbal reasoning and perceptual organization	
Block Design (BD)	The participant is asked to arrange given blocks according to a given picture as fast as they can within a time limit. It is designed to measure the ability to analyze and synthesize abstract visual stimuli.	Gv
Matrix Reasoning (MR)	The participant is given an incomplete matrix or series of images and is asked to find the option that completes the series. It involves fluid intelligence, broad visual intelligence, classification and spatial ability, knowledge of part-whole relationships, simultaneous processing, and perceptual organization.	Gf
Visual Puzzles (VP)	The participant is asked to choose 3 puzzle piece like images that can be arranged to the given completed puzzle image within a time limit. It is designed to measure nonverbal reasoning and the ability to analyze and synthesize abstract visual stimuli.	Gv
Working Memory Index (WMI)	Composed of subtests measuring working memory, attention and concentration	
Digit Span (DS)	The participant is given a series of numbers and is asked to recall them either by the same order, in reverse order, or in ascending order. It is designed cognitive flexibility, mental alertness, learning and memory, attention, encoding, and auditory processing, and mental manipulation.	Gsm
Arithmetic (AR)	The participant is given a series of mathematical problems to solve within a time limit. It involves mental manipulation, concentration, attention, short- and long-term memory, numerical reasoning ability, and mental alertness.	Gf, Gsm, Gq
Processing Speed Index (PSI)	Composed of subtests measuring the speed of mental and graphomotor processing	
Symbol Search (SS)	The participant is to scan a search group and indicate whether one of the symbols in the target group matches within a time limit. It involves processing speed, short-term visual memory, visual-motor coordination, cognitive flexibility, visual discrimination, speed of mental operation, attention, and concentration.	Gs
Coding (CD)	The participant copies symbols that are paired with numbers within a time limit using a key. It involves processing speed, short-term visual memory, learning ability, psychomotor speed, visual perception, visual-motor coordination, visual scanning ability, cognitive flexibility, attention, concentration, and motivation.	Gs

Note. Gc = Crystallized intelligence; Gf = Fluid reasoning; Gv = Visual processing; Gsm = Short-term memory; Gq = Quantitative knowledge; Gs = Processing speed (Weschler et al., 2008).

man et al., 1993).

Statistical Analyses

Descriptive statistics on participant characteristic were performed using an independent t-test for continuous variables and Pearson's chi-square test for categorical variables, as appropriate. Participants who showed performance below or above the range identified by multiplying the interquartile range by 1.5 across all variables were identified as outliers and were exempted from the research sample. Paired t-test was performed to examine within-group differences between VCI and PRI. Levene's test was performed to compare the variance in certain variables between the two groups. Coefficient of variance (CV) was calculated by dividing the standard deviation by the average and multiplying it by 100. Chi-square test was used to determine whether the ratio of CPT 3 ≥ 60 and CATA ≥ 60 was statistically different between the two groups. To examine group differences, controlling for age, analysis of covariance (ANCOVA) using univariate general linear modeling was performed. A two-

Table 2. *Variables of CPT3 & CATA*

Variables	Definition
CPT 3 & CATA	
Detectability (*d'*)	Measurement of how well the respondent discriminates non-targets from targets
Omission	Missed targets
Commission	Incorrect responses to non-targets
Hit Reaction Time (HRT)	Mean response speed for all non-perseverative responses
HRT Standard Deviation (HRT SD)	Consistency of response speed to targets of the entire administration
HRT Block Change	Slope of change in HRT across the 6 blocks of the assessment
CPT 3 only	
Perseveration	Responses made in less than 100 milliseconds following the presentation of a stimulus
Variability	Mmeasure of response speed consistency within sub-blocks
HRT Inter-Stimulus Interval (ISI) Change	Slope of change in reaction time across the 3 ISIs.
CATA only	
Perseverative Commissions	Recorded when the participant incorrectly responds after a low tone, but before the high tone.

tailed *p*-value of less than .05 was considered statistically significant. IBM SPSS Statistics 24 was used for all statistical analyses.

Results

Descriptive Statistics

In the recruitment stage, 36 adult patients with ADHD and 28 neurotic patients were recruited for the study. However, one patient from the ADHD group and two patients from the neurotic patient group were identified as outliers and excluded. The two outliers in the neurotic patient group were diagnosed with Bipolar II disorder. The single outlier in the ADHD group was primarily diagnosed as Persistent motor tic disorder with ADHD as a secondary diagnosis. This resulted in a research sample of 35 ADHD patients and 26 neurotic patients. We were not able to retrieve CATA performance data for two ADHD patients and four neurotic patients due to patients' refusal or computer-related technical problems. Both groups did not statistically differ in age, sex ratio, and education, although ADHD participants (23.71 ± 6.68 years) were generally younger than the neurotic patient group (28.19 ± 11.12 years). Both groups included more males than females. More than half of the patients in the neurotic group were primarily diagnosed with unipolar mood disorder: 10 Adjustment disorders, 6 Major depressive disorder, 5 Persistent depressive disorder, 3 Bipolar II disorder, 1 Social anxiety disorder, and 1 Panic disorder (Table 3). For ASRS-V1.1, the ADHD group reported significantly more ADHD symptoms (4.06 ± 1.66) than the neurotic patients (2.96 ± 1.97) (t_{56} = -2.31, p = .025).

Table 3. *Demographic Data*

	ADHD patients (n = 35)	Neurotic Patients (n = 26)	*p*-value
Age (Mean ± SD)	23.71 ± 6.68	28.19 ± 11.12	.055
Sex (male:female)	23:12	18:8	.777
Education	12.43 ± 1.27	12.69 ± 2.26	.564
Distribution of psychopathology (n (%))			
ADHD	35 (100%)		
Major depressive disorder		5 (19.23)	
Mild		3 (11.54)	
Moderate		2 (7.70)	
Persistent depressive disorder		6 (23.08)	
Adjustment disorders		10 (38.46)	
Bipolar		3 (11.54)	
Social Anxiety		1 (3.85)	
Panic disorder		1 (3.85)	
ASRS-V1.1	4.06 ± 1.66	2.96 ± 1.97	**.025**

Note. *p*-values less than .05 are in bold print.

FSIQ and subtest scores in K-WAIS-IV were within the average range, except for VCI subtest SI, PSI subtests SS and CD (Table 4). While the ADHD group showed average performance in SI, the neurotic patient group scored above average. Both groups showed lower than average performance on SS, while only those with ADHD showed lower than average performance for CD. The difference between PRI and VCI was also examined for each group. PRI was statistically significantly higher than VCI for adults with

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Table 4. *Group Difference in K-WAIS-IV performances*

	ADHD patients	Neurotic patients	*p*-value
	Estimated mean (se)	Estimated mean (se)	
FSIQ	99.28 (2.47)	104.63 (2.88)	.170
VCI	101.55 (1.96)	108.41 (2.28)	**.028**
SI	10.72 (0.36)	12.03 (0.42)	**.023**
VC	9.77 (0.44)	11.39 (0.51)	**.022**
IN	10.00 (0.49)	10.65 (0.57)	.397
PRI	107.79 (2.58)	106.40 (3.01)	.731
BD	10.77 (0.64)	10.42 (0.75)	.725
MR	11.41 (0.41)	11.76 (0.48)	.594
VP	11.22 (0.475)	10.51 (0.55)	.336
WMI	96.93 (2.94)	107.48 (3.42)	**.025**
DS	9.40 (0.57)	10.54 (0.66)	.202
AR	9.32 (0.66)	11.88 (0.76)	**.015**
PSI	90.82 (2.60)	92.85 (3.03)	.618
SS	8.02 (0.61)	7.79 (0.71)	.810
CD	7.83 (0.53)	9.11 (0.62)	.129
PRI-VCI	6.24 (2.40)	-2.01 (2.80)	**.031**

Note. FSIQ = Full Scale Intelligence Quotient; VCI = Verbal Comprehension Index; SI = Similarity; VC = Vocabulary; IN = Information; CO = Comprehension; PRI = Perceptual Reasoning Index; BD = Block Design; MR = Matrix Reasoning; VP = Visual Puzzle; PCm = Picture Completion; WMI = Working Memory Index; DS = Digit Span; AR = Arithmetic; PSI = Processing Speed Index; SS = Symbol Search; CD = Coding; PRI-VCI = difference between PRI and VCI. *p*-values less than .05 are in bold print.

ADHD (t_{34} = -2.481, p = .018), while the difference between VCI and PRI was not statistically significant for the neurotic patient group (t_{25} = -0.263, p = .795).

When averaged, neither group showed atypical performance on CPT 3 & CATA. However, statistically significant difference in variance was observed between certain CPT 3 variables: the variance for d' (F(1,59) = 7.87, p = .007), omissions (F(1,59) = 9.77, p = .003), and commissions (F(1.59) = 7.48, p = .08). The ADHD group exhibited significantly higher variance in d' and commissions, while the neurotic patient group showed higher variance for omissions for CPT 3 (Table 5). CATA did not show such significant evidence.

Cognitive Differences Between ADHD and Neurotic Disorders

In terms of K-WAIS-IV, ADHD and neurotic patients showed statistically significant differences in VCI (p = .028), SI (p = .023), VC (p = .022), WMI (p = .025) and AR (p = .015). The ADHD group showed lower performance in all of the aforementioned indices and subtests compared to the neurotic patient group (Table 4). There was no significant group difference in CD, although the ADHD group generally showed lower than average performance, whereas the neurotic patient group reported average performance. Patients with ADHD and neurotics also showed significant differences when the discrepancy between PRI and VCI was compared. Adults with ADHD had higher PRI scores than VCI scores, whereas neurotic adults did not.

For CPT 3, the group significantly differed in terms of d' (p = .044). The ADHD group showed poorer performance than the neurotic patient group in correctly identifying and responding to the target stimulus. There were no significant group differences in any of the CATA variables in terms of average (Table 5). When the patterns of CPT 3 & CATA performances were examined individually, it was difficult to find a singular performance pattern that could represent each group. Therefore, we counted CPT 3 ≥ 60 and CATA ≥ 60. CPT 3 ≥ 60 was 0.63 for the ADHD group, while it was a comparatively small ratio of 0.42 for the neurotic patient group. However, this difference was not statistically significant. CATA ≥ 60 was relatively the same between the two groups; it was 0.33 for the ADHD group and 0.30 for neurotic group. The variance per group was further examined by calculating the CV per variable (Table 5). Regarding CPT 3, except for Omissions, HRT and HRT ISI Change, the ADHD group showed higher variance in most of the variables than the neurotic patient group. The difference was statistically significant only for d', omissions and commissions. This tendency for the ADHD group to have a larger variance compared to the neurotic patient group was not clearly observed for CATA. In contrast, the neurotic patient group showed a significantly higher CV than the ADHD group for perseverative commissions.

Discussion

Our study aimed to provide a guideline for clinicians to utilize K-WAIS-IV, CPT 3, and CATA to understand the difference in cognitive deficits between ADHD and other psychotic disorders with subjective attentional complaints. Our study showed an interesting difference between adult patients with ADHD and neurotic patients. Previous studies could not draw consensus on the specific cognitive areas in which ADHD differs from other patients

Table 5. *Group Difference in CPT 3 & CATA Performances*

	ADHD patients	Neurotic patients	*p*-value
	Estimated mean (se)	Estimated mean (se)	
CPT 3			
d'	49.37 (1.74)	43.81 (2.03)	**.044**
Error type			
Omissions	50.13 (1.53)	45.64 (1.79)	.065
Commissions	51.53 (1.69)	46.74 (1.97)	.074
Perseverations	48.06 (0.61)	46.85 (0.71)	.206
Reaction time			
HRT	44.74 (1.51)	47.96 (1.76)	.177
HRT SD	44.41 (1.30)	42.95 (1.52)	.476
Variability	46.33 (1.25)	43.07 (1.44)	.098
HRT Block Change	50.30 (1.69)	49.16 (1.91)	.659
HRT ISI Change	47.25 (1.38)	48.21 (1.58)	.656
Ratio of patients with T score ≥ 60 in any variable	0.63 (22:35)	0.42 (11:26)	.111
Coefficient of Variance (%) of CPT 3			
d'	23.43	17.75	**.007**
Error type			
Omissions	22.55	76.84	**.003**
Commissions	22.55	17.28	**.008**
Perseverations	21.50	7.19	.426
Reaction time			
HRT	7.61	21.53	.149
HRT SD	17.65	17.15	.495
Variability	17.76	14.51	.152
HRT Block Change	16.71	17.79	.850
HRT ISI Change	20.50	18.19	.642
CATA			
d'	48.84 (1.33)	47.88 (1.64)	.654
Error type			
Omissions	46.72 (0.48)	46.10 (0.59)	.426
Commissions	49.05 (0.97)	48.39 (1.19)	.673
Perseverative commissions	47.37 (1.41)	50.99 (1.74)	.116
Reaction time			
HRT	42.71 (1.37)	39.75 (1.68)	.183
HRT SD	47.61 (1.29)	46.18 (1.59)	.494
HRT Block Change	52.85 (1.57)	52.64 (1.94)	.935
Ratio of patients with T score ≥ 60 in any variable	0.33 (11:33)	0.30 (7:23)	.819
Coefficient of Variance (%) of CATA			
d'	14.08	18.11	.282
Error type			
Omissions	7.33	3.07	.246
Commissions	9.61	13.34	.481
Perseverative commissions	7.74	23.40	**.013**
Reaction time			
HRT	19.09	17.75	.309
HRT SD	14.23	17.60	.873
HRT Block Change	15.48	19.62	.378

Note. *d'* = detectability. *p*-values less than .05 are in bold print.

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(Advokat et al., 2007; Boonstra et al., 2005; Malloy-Diniz et al., 2007). Our study found differences between verbal comprehension and arithmetic. Verbal comprehension is defined as an individual's ability to correctly convey how one understands and comprehends verbal information. Arithmetic measures the ability to mentally sustain and proficiently manipulate auditory information using mathematical knowledge. It requires not only the capacity to self-monitor and sustain attention and concentration but also fluid reasoning. Our results concede with prior studies in certain aspects since low performance on AR can represent low performance in verbal working memory (Marchetta et al., 2008; Schoechlin & Engel, 2005; Wechsler et al., 2008; Woods, Lovejoy, & Ball, 2002). However, our study differed in that participants showed significant differences in verbal comprehension and did not show differences in processing speed. This difference may be because the disorders used as the control group differ from study to study (Marchetta et al., 2008; Walker et al., 2020; Wiig & Nielson, 2012).

The results of our study raise the question of why differences in cognition between the disorders are observed, considering that non-ADHD psychiatric patients are also known to show deficits in executive function, memory and attention (Castaneda et al., 2011; Marazziti et al., 2010; Solé et al., 2011; Tsourtos, Thompson, & Stough, 2002). Based on our results, however, it may be hypothesized that the severity of deficiency among those with ADHD and neurotic disorders differs according to cognitive area. While those with ADHD and neurotic disorders both show deterioration in their processing speed, it may be that the severity of dysfunction in terms of working memory is worse in ADHD. This is likely because the two groups did not differ in their performance on DS and PSI but differed in their AR performances. While DS requires simple memory recall of a series of auditory stimuli, AR requires more subjective effort to understand the question and to logically induce the relationship between numbers to retrieve the answer. AR has also been shown to correlate with fluid reasoning (Wechsler, 2008). Two studies on children with ADHD have shown that these children perform worse on mathematics and tests relevant to fluid reasoning than the healthy controls (Semrud-Clikeman, 2012; Tamm & Juranek, 2012). The process required to show good performance in AR seems to be closely linked to deficits caused by ADHD.

In our results, the ADHD group showed lower performance in areas of verbal comprehension and this performance was significantly compared to their performance in visual spatial reasoning. Most existing studies do not report a major difference in verbal comprehension (Gorlyn et al., 2006; Kim & Park, 2020; Marazziti et al., 2010; Wechsler et al., 2008). However, a recent study comparing ADHD and non-ADHD children using Wechsler Intelligence Scale for Children 4th edition (WISC-IV) showed statistically significant differences in SI along with other WMI and PSI subtests (Ünal et al., 2021). Another study using WISC-III reported that children with ADHD showed significantly lower VC scores compared to their normal controls (Andreou, Agapitou, & Karapetsas, 2005). A study examining Taiwanese participants using the Chinese version of WISC-IV also indicated that their PRI scores were significantly higher than their VCI scores among children with ADHD (Yang et al., 2013). Such findings may indicate that children with ADHD have difficulty acquiring crystallized abilities earned through education, experience and socialization. This difficulty seems to persist into adulthood. While other studies have suggested that adults with ADHD show deficits in PRI, WMI, and PSI with relatively stable VCI (Gorlyn et al., 2006; Kim & Park, 2020; Marazziti et al., 2010; Theiling & Petermann, 2016; Wechsler et al., 2008), a number of reports have shown that adults with ADHD continue to show lower performance in verbal comprehension regardless of age than the healthy controls (Barkley & Fischer, 2011; Biederman et al., 2010; Bridgett & Walker, 2006). A review by Van Lieshout, Luman, Buitelaar, Rommelse, and Oosterlaan (2013) found that both children and adults with ADHD show low intelligence, with lower verbal rather than performance IQ. It may be hypothesized that in comprehending verbal information adults with ADHD fail to pinpoint the gist of the definition of given words and instead hastily report a shallow impression of them. The aforementioned studies also seem to show that the difference between VCI and PRI observed in our study accounts more for the fact that adults with ADHD show less than expected performance on the VCI subtest than them performing superior on the PRI subtests. This phenomenon can be utilized by clinicians when searching for signs of adult ADHD using K-WAIS-IV.

Of the variables provided by CPT 3 and CATA, d' from CPT 3 was the only variable showing a significant difference between the

ADHD and the neurotic patient groups. *D*' is the core variable provided by CPT 3 as it measures whether the participant can differentiate the target from non-target stimuli and react accordingly. It is difficult to conclude whether this finding is consistent with previous findings since they also failed to find a consistent pattern in the task performance of patients with ADHD. The average performance in CPT3 & CATA from our study fell within the limits of "average performance." It appears that the averaged data failed to reflect the nature of the patients' heterogeneous performance. The ADHD group also showed higher variance in certain CPT 3 variables than the neurotic patient group. This can be understood as the ADHD group having more individuals scoring on either spectrum of extremities compared to the neurotic patient group (Table 5). Heterogeneity in their performance may indicate that ADHD encompasses different subtypes of disorders (e.g. inattentive type vs. hyperactive type). This may serve as a basis to emphasize the importance of subtyping ADHD at a diagnostic level. While the ADHD group showed a higher variance for *d*' and commissions, the neurotic patient group showed a higher variance for omissions. This may indicate that while patients with ADHD report similar complaints regarding attention, individual differences exist in their pattern of attention. This may be further analyzed by subtyping ADHD in future research. Omissions may better demonstrate differences in individuals' attentional difficulties in neurotic mental disorders. However, a future study with a larger sample size to better represent each psychiatric disorder is needed to support this hypothesis. Although the difference in CPT $3 \geq 60$ between the two groups was not statistically significant, the difference may become more evident if a larger sample size is acquired. The results from CATA were less discriminant.

This study provides particular signs of cognitive deficiency specific to adult ADHD that can be easily applied in a South Korean clinical setting. However, this study had several limitations. Since the study was exploratory with a relatively small number of subjects, post-hoc statistical analyses were not available. A follow-up study with more participants for each psychiatric disorder will help in further statistical validation of the results of this study. Another limitation is that the study could not utilize the results of the subtests within DS of K-WAIS-IV. This information may have allowed for further understanding of the working memory of ADHD and non-ADHD patients. In addition, as this was a retrospective study, the results from the DS subtests were not reported in the patients' psychological assessment reports making them ethically impossible for research utilization. Furthermore, the study only utilized the primary diagnosis of patients. Considering the possible impact comorbid disorders can have on cognitive function in the ADHD group, this could be another limitation of this study.

The goal of our study was to explore attention-related characteristics that differ between ADHD and other neurotic disorders using assessments commonly used in clinical practice. Although the results are preliminary, we succeeded in identifying the key variables that showed major differences between the two groups. We also illustrated a realistic portrait of how results of CPT 3 and CATA are not uniform among adults with ADHD and suggest how these results can be used to further understand individualized ADHD symptoms. Therefore, in the light of our findings, clinicians may gain practical insights into how to interpret patients' test.

Author contributions statement

SC, intern at Kangbuk Samsung Hospital, collected and analyzed the data, and prepared the manuscript. JL, a clinical psychologist and supervisor at Kangbuk Samsung Hospital, supervised the research process. DS, a psychiatrist at Kangbuk Samsung Hospital, supervised the medical examination of the participants. All the authors provided critical feedback, participated in the revision of the manuscript and approved the final submission.

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