Impact of intelligence on performance on the Test of Variables of Attention in children with Attention-Deficit/Hyperactivity Disorder or Attention Deficit Disorder.

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ABSTRACT

Introduction: Test of Variables of Attention (TOVA) is used as a diagnostic tool in the assesment of Attention-Deficit/Hyperactivity Disorder (ADHD) and Attention Deficit Disorder (ADD). Existing literature suggests that intelligence may influence performance on TOVA, however research on this topic is limited. The purpose of this study was to identify whether there exists a correlation between Full Scale Intelligence Quotient (FSIQ) and TOVA scores among children with ADHD or ADD. A second aim was to investigate if IQ index scores correlated with TOVA scores in the same group of children.

Methods: Hospital records of children aged six to 17 years with ADHD or ADD who attended the Department of Child and Adolescent psychiatry, Aalborg University Hospital from 1st June 2014 to 31st May 2015 were collected. To be included, the child had to have completed both an intelligence test and a TOVA test. Data were analyzed using descriptive statistics, Pearson's correlation test and Kruskal Wallis test.

Results: The sample comprised 75 children. There were significant correlations between FSIQ and all TOVA variables except from response time (RT). Additionally, IQ index scores correlated with some of the TOVA variables as well. Correlations were positively associated and weak to moderate in strength. Significant differences in some TOVA variables were demonstrated when children were grouped according to IQ.

Discussion and conclusion: Intellectual functioning significantly influenced TOVA performance. Children with low IQ performed significantly poorer than children with high IQ of whom some despite ADHD/ADD passed the TOVA test. This questions sensitivity and specificity of the test. A small sample size, no appropriate control group and lack of a limited time span between conduction of the intelligence- and TOVA test impaired results, thus results must be interpreted with caution.

DANSK RESUMÈ

Baggrund: Test of Variables of Attention (TOVA) er en neuropsykologisk test, der anvendes som et led i diagnostikken af Attention-Deficit/Hyperactivity Disorder (ADHD) og Attention Deficit Disorder (ADD). Eksisterende litteratur peger på, at intelligens muligvis påvirker udfaldet af testen, men viden på området er til stadighed begrænset, hvorfor yderligere forskning er nødvendig for at klarlægge sammenhængen. Formålet med studiet var, at undersøge om Total IQ på Wechslers Intelligence Scale korrelerede med TOVA variable hos børn med ADHD eller ADD. Sekundært ønskede vi, at undersøge om IQ indeks scorerne korrelerede med TOVA variablene.

Metode: Vi indhentede journaloplysninger på børn i alderen seks til 17 år med ADHD og ADD, som var set i Børne Ungdomspsykiatrisk regi Aalborg Universitetshospital i perioden 01.06.2014 til 31.05.2015. Barnet skulle have gennemført en intelligenstest og en TOVA test for at blive

inkluderet. Data blev analyseret ved brug af deskriptiv statistik. Pearson's korrelations analyse beskrev sammenhængen mellem IQ og TOVA præstation. Tilmed udførtes Kruskal Wallis test for, at undersøge om der var signifikante forskelle på TOVA præstationen, når børnene blev grupperet efter IQ. Signifikansniveauet var accepteret ved en p-værdi <0.05.

Resultater: 509 børn var set I Børne- og Ungdomspsykiatrisk regi i inklusionsperioden, hvoraf 75 børn opfyldte inklusionskriterierne. Pearsons korrelations analyse viste, at Total IQ korrelerede signifikant med alle TOVA variable fraset reaktionstid parameteren (RT). Korrelationsstyrken var svag til moderat og varierede fra 0.279 til 0.473. Ligeledes blev analysen udført for IQ-indeksene, hvor arbejdshukkommelses-, forarbejdsningshastigheds- og verbalforståelses indeks korrelerede signifikant med flere af TOVA variablene. Korrelationerne var signifikante, men svage til moderate i styrke, idet de rangerede fra 0.248 til 0.417. Kruskal Wallis test påviste signifikante forskelle i TOVA variablene commission errors (impulsivitetsfejl), omission errors (uopmærksomhedsfejl) og attention performance index (ADHD score), når børnene blev grupperet efter IQ.

Diskussion og konklusion: Total IQ korrelerede signifikant med alle TOVA parametre med undtagelse af RT. Korrelationen viste en positiv kurve af svag til moderat styrke, hvilket indikerer, at præstationen på TOVA forbedres i takt med intellekt, hvorfor vi med rette kan konkludere, at intelligens påvirker TOVA performance. Yderligere påviste vi, at flere af TOVA variablene korrelerer signifikant med IQ indeksene verbalforståelse, arbejdshukkommelse og forarbejdsningshastighed. På baggrund af resultaterne bør det fremtidigt overvejes, om TOVA skal revideres, så testen foruden alder og køn også standardiseres med IQ. TOVA vil da formidle et mere korrekt billede af barnets eventuelle opmærksomhedsproblemer, hvorved forekomsten af fejldiagnosticering af ADHD eller ADD vil mindskes. Yderligere forskning kræves på området pga.

tvivlsom repræsentativitet i dette studie samt en række andre fejlkilder, hvor blandt andet mangel på en kontrolgruppe er en væsentlig. Fejlkilderne reducerer resultaternes validitet, hvorfor konklusioner fra dette studie må fortolkes med forsigtighed.

ABBREVIATIONS:

ADHD	Attention-Deficit/Hyperactivity Disorder
ADD	Attention Deficit Disorder
TOVA	Test of Variables of Attention
RTV	Response Time Variability
RT	Response Time
CE	Commission Errors
OE	Omission Errors
API	Attention Performance Index
WISC	Wechsler's Intelligence Scale for Children
WAIS	Wechsler's Intelligence Scale for Adults
FSIQ	Full Scale Intelligence Quotient
VCI	Verbal Comprehension Index
PRI	Perceptual Reasoning Index
WMI	Working Memory Index
PSI	Processing Speed Index.

BACKGROUND: The neuropsychological test Continuos Performace Test (CPT) is widely used for evaluating children suspected for deficits in attention functioning e.g. attention-deficit/hyperactivity disorder (ADHD) and attention deficit disorder (ADD). CPT, developed by Rosvold, Mirsky, Sarason, Brandsome and Beck (1956), was originally aimed at detecting brain damage in children and adults. Presently, CPT is used in the diagnostic process of detecting ADHD and ADD due to findings of Rosvold et al., as their research indicated that brain damaged subjects performed inferiorly on the test compared to controls due to lack of alertness.

More types of CPTs exist and one of them is Test of Variables of Attention (TOVA). TOVA differentiates from other CPTs by its simplicity, as no letters or auditory stimuli challenge the child, thereby avoiding confounding factors as e.g. language difficulties and short-term memory problems (Forbes 1998). Furthermore, time duration of the test is extended challenging the attention functioning of the child. These features are considered advantageous when identifying children with ADHD or ADD

TOVA test results must be interpreted in agreement with the additional test battery when evaluating ADHD or ADD. This typically consists of clinical observation, questionnaires about ADHD symptoms replied by parents and teachers and additional parental interviews (Naglieri et al. 2005). Subjectivity mainly characterizes such information, hence integration of neuropsychological test is of great importance due to its objective perspective.

However, there is disagreement about the use of TOVA because of a potential correlation to intelligence. Studies have investigated the relationship of TOVA and intellectual functioning, but no overall consensuses have been reached, as results are few and conflicting.

Naglieri et al. (2005) investigated whether consistency between diagnostic tools used in the evaluation of ADHD existed. The sample group comprised 117 children aged six to 16 years. They reported only few significant correlations between CPT and Wechsler Intelligence Scale for Children third edition (WISC-III), indicating that intellect did not affect performance on CPT. In contrast, another study found all variables in the TOVA test to significantly correlate with IQ in a group of 138 elementary students aged six to ten years. This result indicated that intelligence influenced performance on the TOVA test (Hurford et al. 2014).

In a clinical setting, it makes it uncertain and difficult to interpret TOVA results in relation to the child's intellectual functioning, thus more research is required to establish consistency.

The aim of this study was therefore to clarify whether there exists a significant correlation between Full Scale Intelligence Quotient (FSIQ) and TOVA scores among children with ADHD or ADD. A second aim was to identify, whether any IQ index scores significantly correlated with TOVA test scores.

We hypothesized that children with high IQ performed superiorly compared to children below average intelligence.

MATERIALS AND METHODS

Participants

Hospital records from children aged six to 17 years diagnosed with ADHD or ADD who attended the Department of Child and Adolescent psychiatry, Aalborg University Hospital, Denmark from 1st June 2014 to 31st May 2015 were collected. Only children who had both completed the TOVA and an intelligence test were included. In each electronic hospital record we searched for the following words "Test of Variables of Attention", or "TOVA" or "T.O.V.A" and "Wechsler's Intelligence

Scale for Children" or "WISC" or "Wechsler's Intelligence Scale for Adults" or "WAIS" or "Intelligence Quotient" or "IQ" or "Intelligence" or "Giftedness". Patients were excluded from the study due to misdiagnosing of ADHD/ADD, lack of intelligence test and discontinued TOVA test, or no obtainable TOVA test in the hospital record. The above-described criteria resulted in the data pool, which formed the foundation for this analysis. To validate our method, a random sample of ten hospital records was examined, to assure that none of the excluded subjects had conducted a TOVA test.

Test of Variables of Attention

TOVA was administered by professionals at the start of the day, somewhere between 6:00 am and 1:00 pm. None of the children were on central stimulating medicine or norepinephrine reuptake inhibitor during the test. The child was given test instructions, and was allowed to practice for a few minutes, until the task was understood.

TOVA is a computerized 21.6 minutes test stratified by age and gender, used for evaluation of attention in children and adults four to 80+ years of age (Lawrence M. greenberg et al. 2013). It consists of two phases with alternating frequency of target stimuli and non-target stimuli. A white square containing a small black square either at the top or at the bottom represents target- and non-target stimuli respectively. The child responds by pressing a button on a microswitch, when the stimulus is presented.

In the first phase most non-target stimuli are presented, challenging the child to sustain attention. The exact frequency is 3.5:1 between non-target stimuli and target stimuli. If the child is inattentive it will miss the target stimuli, which is reported errors of omission (OE). In the second phase the relationship between non-target stimulus and target stimulus is reversed, so most target stimuli are

presented, with a frequency of 3.5:1. The child must react more often, but also restrict oneself from responding to non-targets stimuli that are rarely presented. If the child responds to a non-target stimulus it reflects impulsivity, because of the lack of ability towards inhibition, and it is registered errors of commission (CE). Children with ADHD usually tend to make more errors of omission and commission than their peers (Munkvold et al., 2014, Keith & al, 2003). The TOVA test also measures the time duration from presenting stimulus to pressing the button, representing response time (RT), and response time variability (RTV), which is the standard deviation of response time.

Important measures of TOVA are total scores and attention performance index (API). API is a score representing the child's overall performance, when compared to a group of subjects with ADHD. It is calculated on the basis of RT from the first half of the test, response sensitivity (*d'*) from the second half of the test, Total-RTV and a calibration constant of 1.80. When the API score is below 0 it indicates impaired function of attention (Hughes 2008).

TOVA results are reported as standard scores, where 100 is average standard with a standard deviation of 15. Scores above 85 are within normal limits. Scores in the range from 80 to 85 constitute a borderline area, and scores below 80 indicates an abnormal outcome. (Lawrence M. greenberg et al. 2013)

Wechsler's Intelligence Scale

Wechsler's Intelligence Scale is used for evaluation of intellectual functioning in children and adults. It is considered reliable, and explores different facets of intellectual abilities due to the many different types of tasks it includes.

Wechsler's Intelligence Scale for Children (WISC) is available in a third- (WISC-III) and a fourth (WISC-IV) edition, which is aimed at children aged six to 16 years. Likewise, Wechsler's Adult

Intelligence Scale (WAIS) exists in a third (WAIS-III) and fourth (WAIS-IV) edition, and is used to test adolescents and adults aged 16 to 89 years.

WISC-III and WAIS-III are divided into FSIQ, Verbal IQ (VIQ) and Performance IQ (PIQ), which are calculated on the basis of scores obtained from ten subtests. WISC-IV and WAIS-IV have replaced above-mentioned IQ scores with Verbal Comprehension Index (VCI), Perceptual Reasoning index (PRI), Working Memory Index (WMI), Processing Speed Index (PSI), FSIQ and General Ability Index (GAI) (Andersen & Jensen 2015). Furthermore all measured variables in WISC-IV are equally weighted, whereas WISC-III does not consider WMI and PRI as important as the other variables measured. Therefore, WMI and PRI are not as heavily weighted as the other variables when FSIQ is calculated (Garcia 2009). In this study the majority of subjects had completed WISC-IV or WAIS-IV and only a small number was evaluated with WISC-III.

Statistical analysis

SPSS version 23.0 was used for analysis. Data were reported as means ± standard deviations (SD) and frequencies. Pearson's correlation coefficient *r* was computed to identify correlations between intelligence- and TOVA variables. The correlations were made only for Total-RTV, Total-RT, Total-CE, Total-OE and API. Significance was accepted at the level of $p<0.05$.

Based on scores of FSIQ, children were categorized into four IQ groups: Very low IQ (0-69, n=2), low IQ (70-84, n=25), normal IQ (85-115, n=45) and high IQ (≥116, n=3). Kruskal Wallis test investigated whether there existed statistical significant differences between the IQ groups according to TOVA performance.

RESULTS

A total of 509 patients in the age from six to 17 years with ADHD or ADD attended the Department of Child and Adolescent Psychiatry during the inclusion period. Of these, 99 patients had conducted a TOVA test. In the sample of 99 patients, four were misdiagnosed with ADHD/ADD, seven had no intelligence test carried out, eight did not complete the TOVA test, and five of the TOVA tests were not obtainable in the hospital record. In total 75 patients were included in the study.

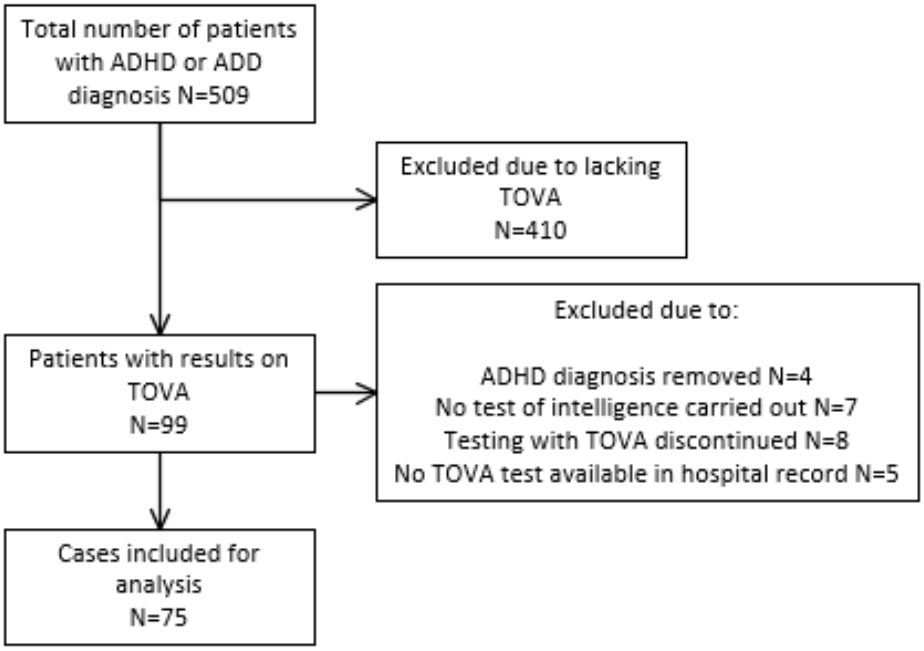

Figure 1 Flowchart of selected subjects within this study.

Demographics

A complete description of the sample is available in table 1. The sample comprised 47 (62.7%) male subjects and 28 (37.3%) female subjects with a mean age of 13.5 years ±2.7 SD, ranging from 7.8 to 17.7 years of age. Most children were Danish (n=73, 97.3%) and the remainders were Thai (n=1, 1.3%) or Icelandic (n=1, 1.3%). All children had an ICD-10 diagnosis, which was either Hyperkinetic Disorder (F90.0) (n=56, 74.7%), or Hyperkinetic Conduct Disorder (F.90.1) (n=6,

8%) or ADD (F.98.8C) (n=13, 17.3%). The majority of children had one or more comorbidities (n=40, 53.3%) and (n=35, 46.7%) had none.

Table 2 represents means and standard deviations for WISC/WAIS- and TOVA scores. The average IQ of the children was 89 ±11.8 in the range from 68 to 118 IQ points.

Table 1 Description of children included

ICD-10 diagnoses	**n**	**(%)**
F90.0, F90.1, F98.8 ADHD subtypes	75	100
Comorbidities		
F40-49 Nervous and stress related conditions and conditions with psychologically induced physical symptoms	15	19.9
F80-89 Psychological developmental disturbances	19	25.2
F92 -F98.9 Behavioral and emotional disturbances occurred in childhood or adolescence	13	17.2
ADHD-RS Parents		
Inattention at home to a great extent (>70)	42	56
Hyperactivity at home to a great extent (>70)	28	37.3
Behavioral problems at home to a great extent (>70)	33	44
ADHD-RS Teachers		
Inattention at school to a great extent (>70)	24	32
Hyperactivity at school to a great extent (>70)	28	37.3
Behavioral problems at school to a great extent (>70)	18	24
Educational level		
Parents with short higher education	7	8
Parents with medium long higher education	19	25.3
Parents with long higher education	5	6.7
Pregnancy		
Mothers who smoked during pregnancy	19	25.4
Mothers who drank during pregnancy	13	17.3

Note. ADHD-RS = Attention-Deficit/Hyperactivity Disorder – Rating Scale

Table 2 TOVA- and WISC/WAIS performance (N=75)

	Mean	**Minimum**	**Maximum**	**SD**
IQ-scale (points)				
FSIQ	89	68	118	11.8
VCI	90.9	59	126	13.2
PRI	96.5	66	128	12.1
WMI	86.2	63	110	11.7
PSI	90.3	68	118	11.8
TOVA (points)				
RTV-Total	76.3	40	116	21.6
RT-Total	95.8	49	126	16.3
CE-Total	86.5	40	125	21.7
OE-Total	74.6	40	112	26.2
API	-1.9	-9.1	4.02	2.9

Note. FSIQ =Full scale Intelligence Quotient, VCI= Verbal Comprehension Index, PRI = Perceptual Reasoning Index, WMI= Working Memory Index, PSI= Processing Speed Index, RTV=Response Time Variability, RT= Response time, CE=Commission errors, OE= Omission errors, API= Attention Performance Index

Pearson's Correlations

Table 3 represents all correlations in the sample. Values marked with * were statistical significant with a p-value <0.05, and those marked with ** had a p-value <0.01. Figure 2 shows only significant correlations.

FSIQ and TOVA correlation

FSIQ showed a positive statistically significant correlation with all variables of TOVA except from RT. FSIQ was associated with RTV (r=0.379, *p*=0.001), CE (r = 0.328, *p*=0.005), OE (r=0.279, *p*=0.019) and API (r=0.450, *p*=0.000). Correlations varied from weak (0.1-0.2) to moderate (0.3-0.6) in strength (Brace et al. 2006).

IQ index scores and TOVA correlation

WMI and PSI accounted for most significant correlations between IQ index- and TOVA scores. WMI was associated with RTV (r=0.349, *p*=0.004), RT (r=0.248, *p*=0.043) and API (r=0.417, *p*=<0.001). Likewise, PSI correlated with RT (r=0.253, *p*=0.037) and API (r=0.358, *p*=0.002), but was also associated with OE (r=0.258, *p*=0.034). VCI only showed significant correlation with API (r=0.249, *p*=0.038). GAI correlated with CE (r=0.282, *p*=0.04). Correlations between IQ index- and TOVA scores varied from weak to moderate in strength.

Table 3 Pearson's correlation analysis between scores of TOVA and WISC/WAIS

IQ measures	RTV		RT		CE		OE		API	
	r	p	r	p	r	p	r	p	r	p
FSIQ	0.379**	0.001	0.204	0.087	0.328**	0.005	0.279*	.019	0.450**	<0.001
VCI	0.211	0.084	0.118	0.336	0.204	0.095	0.172	0.160	0.249*	0.038
PRI	0.161	0.191	0.04	0.749	0.178	0.147	0.123	0.319	0.164	0.176
WMI	0.349**	0.004	0.248*	0.043	0.177	0.152	0.098	0.430	0.417**	<0.001
PSI	0.227	0.063	0.253*	0.037	0.155	0.205	0.258*	0.034	0.358**	0.002
GAI	0.218	0.117	0.072	0.607	0.282*	0.04	0.168	0.231	0.238	0.081

Note. *p<0.05, **p<0.01, r= Pearson's correlation coefficient, RTV= Response Time Variability, RT = Response Time, CE = Commission Errors, OE = Omission Errors, API = Attention Performance Index, WISC/WAIS = Wechsler's Intelligence Scale for Children/Adults, FSIQ = Full Scale Intelligence Quotient, VCI = Verbal Comprehension Index, PRI = Perceptual Reasoning Index, WMI= Working Memory Index, PSI = Processing Speed Index.

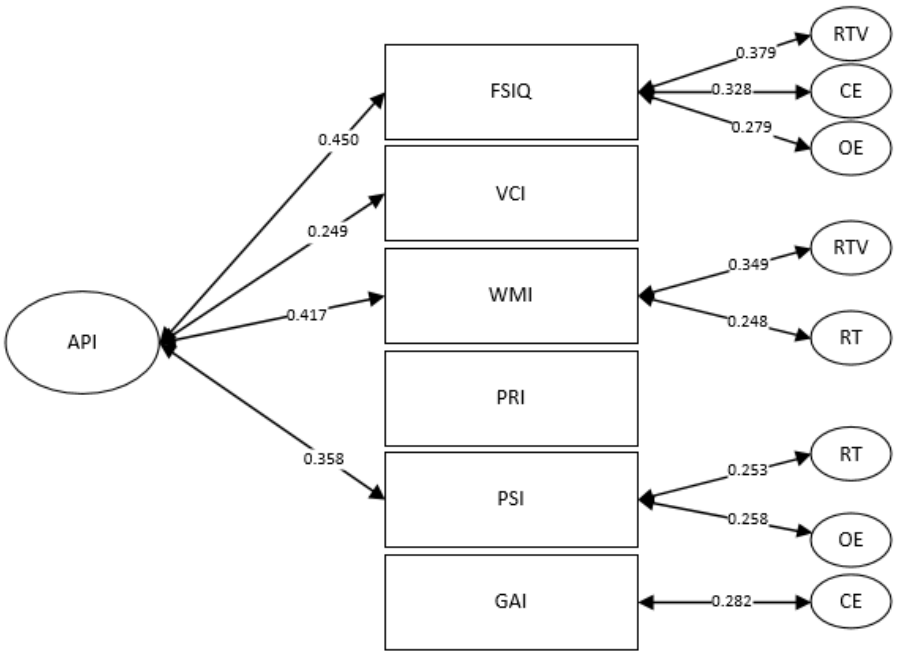

Figure 2 Statistical significant correlations between TOVA variables and intelligence parameters

Correlations were all positively associated, indicating when one variable increases in value the second variable increases correspondingly i.e. when FSIQ increases in value the scores of TOVA variables increase as well (Brace et al. 2006).

Kruskal Wallis Test

Figure 3 illustrates TOVA scores distributed according to IQ. Children with very low- (0-69) and low IQ (70-84) performed inferiorly on all TOVA variables except from RT, which was the only variable within normal limits. Interestingly, the group with very low IQ (0-69) made fewer CE compared to children in the IQ group (70-84). The IQ group (85-115) obtained scores within normal limits of RT and CE, but remaining variables of TOVA were in the abnormal area. Children with high IQ (>116) performed superiorly on all TOVA variables.

Kruskal Wallis test was conducted to identify significant differences between the IQ groups in relation to TOVA performance. The test showed significant differences of the variables CE, OE and

API. $\chi^2(3, n=71)= 13.15$, $p< 0.05$ for CE, $\chi^2(3, n=71)= 11.77$, $p<0.05$ for OE and $\chi^2(3, n=74)= 9.02$, $p< 0.05$ for API.

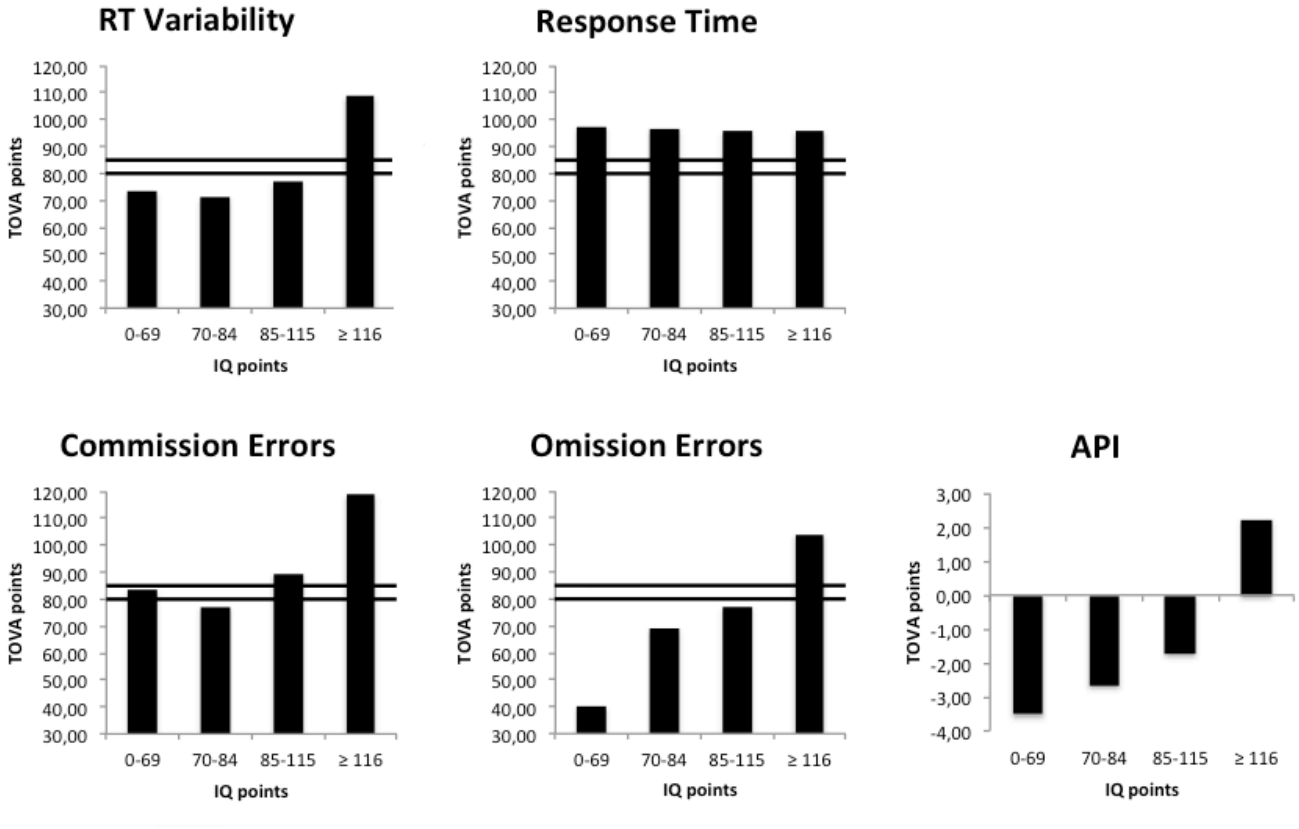

Figure 3 Distribution of scores of Response Time Variability, Response Time, Errors of Commission and Errors of Omissions within the IQ groups. The lines drawn indicate areas of normal, borderline and abnormal scores. Scores ≥85 are within normal limits, while scores of 80-85 are in the borderline area, and scores below 80 are abnormal.

DISCUSSION

The purpose of this study was to investigate if FSIQ from Wechsler's Intelligence Scale significantly correlated with TOVA variables and secondly investigate if any of the IQ index scores correlated with scores on the TOVA test.

In total 30 correlations were computed using Pearson's correlation, in which 12 were statistically significant. FSIQ correlated with all of the TOVA variables except from RT. The correlations were significant, but weak to moderate in strength as they varied in range from 0.279 to 0.450. Since all correlations were positively associated, performance on the TOVA test increased correspondingly with FSIQ. Furthermore, significant differences in scores of OE, CE and API between IQ groups were identified using Kruskal Wallis test. These findings suggested that FSIQ significantly influenced the majority of the TOVA variables.

The IQ indexes VCI, WMI, PSI and GAI were significantly associated with some of the TOVA variables. PSI and WMI correlated with RT, indicating that processing speed and working memory are essential factors when it comes to tasks, which requires rapidity. PSI was the only variable, which correlated with OE, indicating that processing speed affects the number of omission errors. PSI, VCI and WMI correlated with API, thereby influencing the overall performance in TOVA. Additionally, API was the variable, which was influenced most by intelligence parameters, as the correlations were most, strongest and approached highest level of significance. Correlations were weak to moderate in strength ranging from 0.248 to 0.417.

Andersen & Jensen (2005) conducted a meta-analysis of five papers, which explored the correlation between intelligence and performance on CPT in children aged seven to 16 years. Male subjects comprised the largest percentage of included children. In most cases Conner's CPT were used, which is not directly comparable to TOVA parameters. Results reported were almost similar to findings of this study. A significant correlation between FSIQ and RTV, RT and OE existed, but they could not conduct correlation analysis for API, as it was not obtainable in the investigated studies, except from one study, where no significant correlation was found. Correlations for FSIQ

and TOVA scores were all weakly associated and in the range from -0.203 to -0.285. Only one included study had a control group, thereby diminishing validity of their results.

None of our findings regarding IQ index scores were consistent with the findings in the meta-analysis. Besides FSIQ, PSI was the only variable associated with sustained attention, whereas the meta-analytic findings revealed that almost all other indexes of IQ, being PIQ, PRI, WMI and PSI were associated with OE.

Correlations of this study were all positively associated while meta-analytic correlations were negatively associated. This difference might be due to comparison of different TOVA scores. We used TOVA scores that were already processed and standardized, whereas the meta-analysis used raw test scores of TOVA. Still, results agreed that TOVA performance depended on FSIQ.

This study differs from others, by including all children despite IQ, thereby providing a wider clinical understanding of the relationship between intellectual functioning and TOVA performance. Most other studies excluded children with an IQ below 80, which is a problem as it reduces knowledge about how children in both ends of the IQ spectrum perform on TOVA.

Only a minority of patients entered the IQ groups very low- (0-69) and high IQ (≥116), namely n=2 and n=3 respectively, which makes the interpretation difficult and conclusions can barely be made. However, correlations indicated that children at the low end of the IQ spectrum performed significantly poorer on all variables of TOVA except from RT compared to children with high IQ, as hypothesized.

This may indicate that the test is too difficult for children below average intelligence. These children are at risk of being misdiagnosed with ADHD/ADD if the clinician is not aware of TOVA's relation to intelligence. In contrast, a third of children diagnosed with ADHD pass CPTs. (Naglieri et al. 2005). A reasonable explanation could be that children with high IQ's might

compensate by overexerting themselves in order to remain focused and attentive during the test to do well. With this knowledge in mind, it is vital to critically question the sensitivity and specificity of the TOVA test, which needs to be studied further. Forbes (1998) investigated whether TOVA could differentiate children with ADHD from children with other diagnoses, but did not take IQ into consideration. TOVA was reported to correctly identify 80% of children with ADHD. In addition, another study reported the sensitivity and specificity to be 85.7% and 70% respectively, thus 30% of children in the control group were incorrectly identified with attention problems (Schatz et al. 2001).

Currently, the TOVA test is stratified by age and gender. Prospectively, it should be considered to also stratify it by intelligence, as FSIQ correlated with all variables of TOVA except from RT. In this way the TOVA test would provide a more accurate assessment of the child. Before implementing such a suggestion further studies must be carried out with a larger sample group of children. Also the fact that correlations only were weak to moderate in strength indicates the need for further research. A larger sample group would probably contribute to stronger associations, and presumably more significant results.

Another strength of this study is that all types of children were included. The sample group was heterogeneous due to no exclusion criteria for comorbidities or family circumstances, which is advantageous rather than disadvantageous. It provides a representative and real picture of the general population, however risk of confounders, which can impact results, and thus be a limitation.

Limitations

In this study a number of limitations were present. Our sample comprised only 75 patients out of 509 in total. This sample is small and may not be representative for the entire ADHD population. Also the fact that included children were all clinical referred in the region of Northern Jutland and none were from the general population questions the representativity of the results. A larger sample group and inclusion of children from more regions across the country would provide more generalizable results.

Absence of an appropriate control group reduces validity of our results. Prospectively, a control group consisting of children without ADHD or ADD is needed to fully clarify the correlation between IQ and performance on the TOVA test.

Another limitation of this study was an infinite time span between conduction of the two neuropsychological tests TOVA and WISC/WAIS was allowed. IQ is an unstable factor over time, and it typically improves with age. If the time span was too large, the child might have an improved IQ, higher than assumed at the time testing with TOVA, which would make discrepancies in the results. For improvement of the study, a time limitation between the two tests is required. This was not feasible in our study as this would result in a massive reduction of the sample size.

CONCLUSION

FSIQ correlated significantly with RTV, CE, OE and API. The IQ indexes, being VCI, WMI, PSI and GAI did also correlate with some of the TOVA variables. API accounted for most and strongest correlations. These results indicate that the TOVA test is influenced by intelligence. The TOVA test

must be interpreted with caution and with the child's IQ in mind. This especially applies for children with low IQ, as they are at greater risk of being misdiagnosed with ADHD or ADD, when using TOVA. However, some intellectual gifted children with ADHD or ADD pass the TOVA test. This questions sensitivity and specificity of TOVA, and emphasizes a potentially need for revision. A small sample size and no control group questions the representativity and validity of our findings, hence they must be interpreted with caution.

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