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Impact of Emotions on Test of Variables of Attention(TOVA) Performance in a Pediatric Clinical Population: A Retrospective Study

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Abstract

Background: Continuous Performance Tests, like the Test of Variables of Attention (TOVA), are commonly used to assess attention processes in clinical settings. Although a few previous studies have explored the effects of emotions on the outcome of such tests, the results are scarce and contradictory at times.
Objective: Through this retrospective study, we aimed to explore the correlation between performance on the TOVA and parent-reported emotional symptoms in youth.
Methods: We used preexisting datasets of Mood and Feelings Questionnaire, Screen for Child Anxiety Related Disorders, and Vanderbilt Attention-Deficit/Hyperactivity Disorder Diagnostic Rating Scale as well as preexisting results from the TOVA test from 216 patients aged between 8 and 18 years. Pearson's correlation coefficients, as well as linear regression models, were computed to examine the association between depressive and anxiety symptoms and the four indices of TOVA (response time variability, response time, commission errors, and omission errors). Additionally, we used generalized estimating equations to determine whether the reported emotional symptoms affect the TOVA outcome differently as the test progresses.
Results: Our results showed no significant effect of the reported emotional symptoms on the TOVA results even when controlling for sex or reported inattention and hyperactivity.
Conclusion: TOVA results do not seem to be affected by emotional symptoms in youth. This being said, future studies should also explore other factors that can affect the performance on the TOVA, like motor disability, sleepiness, or neurodevelopmental disorders affecting cognitive abilities.

Keywords: Test of variables of attention; Anxiety; Depression; Attention-deficit disorder with/without hyperactivity; Neuropsychological assessment

Introduction

Several studies have described the effect of emotion on cognition, making a strong case for a bidirectional flux of influence. The nature and range of influential emotionality is broad, including mood and anxiety states or traits, stresses of daily living, and clinical depression, all of which have been shown to have significant effects on cognition (Wong et al., 2012). One relationship that has been heavily studied is the effect of emotions on attention.

Studies looking at mood states or traits demonstrated that positive mood was correlated with better performance on a sustained attention task, with the opposite—negative mood correlating with worse performance—also being true. For example, Smallwood, Fitzgerald, Miles, and Phillips (2009) used video clips to induce a negative or positive mood in participants. The authors showed that negative mood led to more errors on the Sustained Attention to Response Task (SART) than positive mood. In addition, selective visual attention, assessed by target finding tasks, was also significantly weaker in depressed young children when compared to healthy controls (Barrera-Valencia, Calderón-Delgado, Trejos-Castillo, & O'Boyle, 2017).

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Studies have also explored the effect of anxiety states and traits on attention. Although a significant correlation between anxiety and compromised attention was generally corroborated, results seemed contradictory at times. In fact, some research found anxiety, with its stimulating and invigorating properties, to improve performance on vigilance tasks (Easterbrook, 1959; Grillon, Robinson, Mathur, & Ernst, 2016; Lang, Bradley, & Cuthbert, 1992; Langner & Eickhoff, 2013). For example, one study induced anxiety by threat of shock, which reportedly facilitated performance on the SART by reducing errors of commission on the no-go trials. This effect was seen predominantly in those with poor attentional control on tests before submitting them to an arousal task (Easterbrook, 1959; Grillon et al., 2016; Lang et al., 1992; Langner & Eickhoff, 2013). However, other findings suggest that anxiety could also worsen top-down cognitive control of intrusion by task-irrelevant stimuli, both internal and external. For example, a meta-analysis of 172 studies (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Eysenck, Derakshan, Santos, & Calvo, 2007; Forster, Nunez Elizalde, Castle, & Bishop, 2015) revealed that threat-related attentional bias consistently appeared in anxious children and adults even under various experimental conditions and when different experimental paradigms were adopted.

Despite the well-established effect of mood and anxiety on attention, this aspect is rarely taken into account by clinical test developers. In this study, we investigate the presence of these effects on a widely used sustained attention test: the Test of Variables of Attention (TOVA). The TOVA is a computerized Continuous Performance Test (CPT), which uses visual stimuli in the form of geometric figures. Targets are presented infrequently during the first half of the test and are then presented frequently thereafter over a period of 21 min (Zelnik, Bennett-Back, Miari, Goez, & Fattal-Valevski, 2012). Thus, the ability to pay attention is best measured during the first half of the test, and impulsivity control is best measured during the second half of the test (Greenberg, Holder, Kindschi, & Dupuy, 2020). The result outcome provides information about four different indexes: response time variability (RTV; i.e., changes in response speed), response time (RT; i.e., overall speed of response), commission errors (CE; i.e., response to a non-target), and omission errors (OE; i.e., no response to a target).

Although the use of TOVA as a proxy for real-life inattention/hyperactivity is still considered controversial due to its limited ecological validity (Díaz-Orueta et al., 2014; Rizzo et al., 2000), this test is still commonly used to assess attention processes in clinical settings, especially in patients suspected to present with an Attention-Deficit/Hyperactivity Disorder (ADHD). Nevertheless, there are limited data investigating the impact of reported anxiety or low mood on TOVA performance. In a clinical setting, this possible impact could affect the interpretation of the TOVA results and alter some conclusions, thus leading to overdiagnosis or underdiagnosis of inattention. Although Mesquita and colleagues (2016) showed no correlation between self-reported depression traits and CPT scores in college students, Ruf, Bessette, Pearlson, and Stevens (2017) reported a negative correlation between self-reported anxiety traits in adolescents and indices of sustained attention, reaction time, and motor variability. The authors suggested that pathological levels of anxiety were not needed to positively affect performance in that population. This study tries to replicate the previous results but in a pediatric clinical population that was referred to the Psychological Assessment Center (PAC) between 2014 and 2019. Our aim was to explore the correlation between parent-reported emotional symptoms in their children and these children's performance on the TOVA. We hypothesize that reported anxiety symptoms, but not those of depression, would affect the TOVA outcome.

Methods

Subjects

This is a retrospective study based on a chart review from patients previously assessed at the PAC of the Psychiatry Department at the American University of Beirut Medical Center (AUBMC) in Lebanon between January 2014 and January 2019. The scanned raw data that were generated following the assessment were accessed using the files from the hospital's electronic medical recording EPIC after receiving the appropriate consent from the AUBMC IRB. The reasons for assessment varied among participants and were mainly related to academic or attention difficulties. All assessments were mostly conducted in Lebanese dialect, and scales were provided either in English or in their Arabic-validated version.

From the existing database, we selected children and adolescents for the current study based on the following criteria: aged between 8 and 18 years, underwent a TOVA, had all scores for the target scales, and full-scale IQ > 70. Any patient who did not fulfill all selection criteria was excluded.

Procedure

For this study, we accessed data from rating scales and from a computerized attention test, which were all completed on the same assessment day. At the time of testing, parents had been provided with either the English or the adapted and validated Arabic version of the scales depending on their language preferences.

Scales.

- Vanderbilt Attention-Deficit/Hyperactivity Disorder Diagnostic Rating Scale (Wolraich et al., 2003): This is a behavioral rating scale designed to measure the severity of inattention and hyperactivity/impulsivity based on DSM criteria. It was filled by the parents. Each item was answered on a 4-point Likert scale, ranging from 0 (never), 1 (occasionally), 2 (often), and 3 (very often). A score of 2 or 3 warrants 1 point toward the total score. Accordingly, the total score for the inattention and the hyperactivity–impulsivity subscales ranges between 0 and 9.
- Screen for Child Anxiety Related Disorders (SCARED; Birmaher et al., 1997): This is a scale that screens for anxiety disorders in children and adolescents. It assesses for panic disorder, generalized anxiety disorder, separation anxiety disorder, social anxiety disorder, and school avoidance. The SCARED was completed by parents/guardians of children and adolescents aged 8–18 years, and cutoff scores previously established in the Lebanese population were used. A child or adolescent was considered to screen positive for an anxiety disorder if the score was >24.
- Mood and Feelings Questionnaire (MFQ): This is a 33-item measure of depressive symptoms among children/adolescents aged 8–18. Parents completed the parent-form that consists of 33 one-sentence items, which were rated on a 3-point Likert type scale. The previously validated Arabic version along with previously established cutoff scores in the Lebanese population were used (Tavitian et al., 2014). A child or adolescent was considered to screen positive for depression if the score was >22.

TOVA scores.

- Total and quartile standard scores from a computerized sustained visual attention test, the TOVA, and for all four indexes (RTV, RT, CE, OE). These scores have a mean (*SD*) of 100 (Mesquita et al., 2016) and have been computed while controlling for age. A higher score means a better performance on each index.

Statistical Analysis

Continuous variables are presented as mean (*M*) and standard deviation (*SD*), whereas categorical variables are presented as number and percentage. Independent-sample *t*-test was used to examine if there was association between sex and each of the TOVA indexes and emotional variables. Pearson's correlation coefficients were used to examine correlation among all TOVA indexes and emotional variable.

Then, four linear regression models were performed to examine the impact of the reported anxiety (SCARED score) and depression (MFQ score) on each of the four TOVA indexes while controlling for Vanderbilt inattention and hyperactivity scores. The latter decision was made to control for a possible confounding effect of inattention and hyperactivity on the TOVA outcome. Each model had one of the four TOVA indexes ("RT total index score," "RTV total index score," "CE total index score," and "OE total index score") as a dependent variable. In addition, each model included MFQ scores and SCARED scores as two independent variables and controlled for sex, Vanderbilt total hyperactivity score, and Vanderbilt total inattention score.

Finally, and because target presentation varies over time, we decided to use generalized estimating equations (GEE) to examine whether the change in each of the TOVA index scores over the four quartiles was affected by MFQ or SCARED scores differently. The GEE models are an extension of generalized linear models in that they allow adjusting for correlations between observations (i.e., the correlation between each of the TOVA index scores over the four quartiles; Ziegler & Vens, 2010). A GEE model was computed for each of four TOVA indexes ("RTV index score," "RT index score," "CE index score," and "OE index score"). In addition, each model had the following independent variables: time (quartile), sex, MFQ score, SCARED score, Vanderbilt total hyperactivity score, and Vanderbilt total inattention score. Moreover, each of the four previous GEE models was repeated twice with one time adding an interaction term between MFQ and time, and the other time adding and interaction term between SCARED and time. The interaction terms were conducted to examine whether variation of the TOVA index scores over time, if present, was affected by variation in MFQ or SCARED scores.

IBM SPSS 27 was used to perform statistical analysis. The *p*-values $< .05$ were considered to be statistically significant.

Results

Out of 442 children aged 8–18 years, who were seen at the PAC, 216 satisfied all inclusion criteria. There was no difference between those who were excluded and those who were included with respect to age (11.6 ± 2.7 vs. 11.5 ± 2.4 years, $p = 0.41$), gender (70.8% vs. 73.1% being males, $p = 0.58$), or IQ (86.7 ± 13.9 vs. 86.4 ± 12.5, $p = 0.84$). Out of 216, 48 individuals (22.1%) scored >24 on SCARED and 23 individuals (10.6%) scored >22 on MFQ. Means and standard deviation of SCARED, MFQ total, and TOVA indexes are presented in Table 1.

Table 1. Mean ± *SD* for total sample, for participants with SCARED > 24 or MFQ > 22, and by gender

	All participants				
	Total sample, $N = 216$, mean ± *SD*	Males, $n = 158$, mean ± *SD*	Females, $n = 58$, mean ± *SD*	*t*, *df*	*p*-Value
RT variability total	75.97 ± 22.37	77.3 ± 22.44	72.36 ± 21.97	1.44, 214	0.15
RT total	86.46 ± 22.48	87.27 ± 22.08	84.26 ± 23.6	0.87, 214	0.38
CE total	93.45 ± 19.95	94.47 ± 19.31	90.69 ± 21.51	1.24, 214	0.22
OE total	76.66 ± 26.21	81.99 ± 24.13	62.22 ± 26.38	5.2, 94.4	<0.001
Vanderbilt attention	4.84 ± 2.83	4.97 ± 2.76	4.48 ± 2.99	1.12, 214	0.26
Vanderbilt hyperactivity	2.66 ± 2.69	2.97 ± 2.68	1.81 ± 2.54	2.85, 214	<0.01
SCARED	16.15 ± 12.64	15.36 ± 12.4	18.29 ± 13.12	−1.52, 214	0.13
MFQ	9.70 ± 9.79	10.2 ± 10.17	8.34 ± 8.61	1.24, 214	0.22
	Participants with SCARED > 24 or MFQ > 22				
	Total sample, $N = 56$, mean ± *SD*	Males, $n = 40$, mean ± *SD*	Females, $n = 16$, mean ± *SD*	*t*, *df*	*p*-Value
RT variability total	73.55 ± 22.91	75.68 ± 22.55	68.25 ± 23.67	1.10, 54	0.28
RT total	88.00 ± 22.39	89.50 ± 19.47	84.25 ± 28.83	0.67, 20.7	0.51
CE total	91.55 ± 19.59	93.98 ± 17.24	85.50 ± 24.06	1.48, 54	0.14
OE total	75.45 ± 24.49	81.25 ± 22.55	60.94 ± 23.70	3.0, 54	<0.01
Vanderbilt attention	5.64 ± 2.38	5.80 ± 2.30	5.25 ± 2.60	0.78, 54	0.44
Vanderbilt hyperactivity	3.39 ± 2.71	3.75 ± 2.63	2.50 ± 2.80	1.58, 54	0.12
SCARED	32.27 ± 10.91	32.03 ± 11.24	36.38 ± 9.67	−1.36, 54	0.18
MFQ	20.02 ± 12.12	21.08 ± 12.97	17.38 ± 9.53	1.03, 54	0.31

RT, response time; CE, commission error; OE, omission error.

Table 2. Pearson's correlation coefficients among TOVA variables, SCARED, and MFQ

	RT variability total	RT	Commissions	Omissions	SCARED	MFQ	Vanderbilt attention
RT variability total	1.00						
RT total	0.67**	1.00					
Commission total	0.29**	−0.11	1.00				
Omission total	0.56**	0.32**	0.37**	1.00			
SCARED	−0.05	0.05	−0.10	−0.03	1.00		
MFQ	−0.06	0.08	−0.10	−0.03	0.58**	1.00	
Vanderbilt attention	−0.14*	−0.01	−0.07	0.02	0.16*	0.24**	1.00
Vanderbilt hyperactivity	−0.19**	−0.06	−0.17*	−0.09	0.09	0.25**	0.45**

RT, response time.
*p-value < .05. **p-value < .01.

Pearson's correlation coefficients between the TOVA indexes and SCARED and MFQ scores are presented in Table 2 and were not significant.

Controlling for sex, Vanderbilt total hyperactivity score, and Vanderbilt total inattention score, neither MFQ score nor SCARED score was significantly associated with TOVA total RTV, RT, CE, or OE (Table 3). Sex, on the other hand, was significantly associated with RTV ($b = 0.14$, $p = 0.05$) and OE ($b = 0.38$, p-value < 0.001). To further assess how the reported ADHD symptoms affected our results, we ran a sensitivity analysis by rerunning the models without controlling for those symptoms. The results remained the same.

The regression models were repeated while limiting the analysis to a subsample of participants with elevated emotion scores (i.e., SCARED > 24 or MFQ > 22). Again, neither MFQ score nor SCARED score was significantly associated with TOVA total RTV, RT, CE, or OE while controlling for sex, Vanderbilt total hyperactivity score, and Vanderbilt total inattention score.

Using GEE model (Table 4), there was a significant decrease in the RTV score over the four quartiles ($B = -2.74$, p-value < 0.001). However, there was no significant interaction between quartile and MFQ scores ($B = 0.006$, p-value = 0.94) or SCARED scores ($B = 0.06$, p-value = 0.27), suggesting that the change in RTV score over the four quartiles was not due to MFQ or SCARED scores. Similarly, using GEE model, the OE score significantly decreased over the four quartiles ($B = -4.04$, p-value < 0.001) but with no interaction with MFQ scores ($B = -0.02$, p-value = 0.65) or SCARED scores ($B = 0.01$, p-value = 0.73).

Table 3. Examining impact of SCARED and MFQ on each of the four TOVA total scores while controlling for gender, hyperactivity, and inattention

	The four regression models							
	RT variability		RT		Commissions		Omissions	
	Beta	*p*-Value	Beta	*p*-Value	Beta	*p*-Value	Beta	*p*-Value
Gender	0.14	0.05	0.07	0.32	0.12	0.10	0.38	0.00
Vanderbilt attention	−0.06	0.46	0.00	0.98	0.03	0.71	0.09	0.24
Vanderbilt hyperactivity	−0.20	0.01	−0.10	0.19	−0.19	0.01	−0.19	0.01
SCARED	−0.01	0.93	0.00	0.97	−0.06	0.47	0.05	0.54
MFQ	0.00	0.99	0.10	0.24	−0.03	0.73	−0.06	0.43

RT, response time.

Table 4. Four GEE models with the four TOVA variables as the outcomes

	The four GEE models							
	RT variability		RT		Commissions		Omissions	
	Beta	*p*-Value	Beta	*p*-Value	Beta	*p*-Value	Beta	*p*-Value
Gender	5.8	0.06	−3.74	0.52	5.6	0.03	16.86	<0.001
Vanderbilt attention	−0.05	0.93	−0.58	0.5	0.37	0.35	0.55	0.3
Vanderbilt hyperactivity	−1.77	0.007	−0.79	0.21	−1.01	0.02	−1.82	0.002
SCARED	−0.14	0.32	−0.22	0.27	−0.12	0.25	0.09	0.47
MFQ	0.04	0.8	0.34	0.07	−0.09	0.46	−0.12	0.47
Quartiles	−2.74	<0.001	0.84	0.48	0.49	0.31	−4.04	<0.001
Adding interaction								
SCARED ∗ quartiles	0.06	0.27	−0.05	0.63	0.02	0.65	0.01	0.73
MFQ ∗ quartiles	0.006	0.94	−0.06	0.49	−0.02	0.71	−0.02	0.65

RT, response time.

On the other hand, there was no significant change over the four quartiles in RT score ($B = 0.84$, p-value $= 0.48$) or CE score ($B = 0.49$, p-value $= 0.31$). In addition, there was no significant interaction between quartiles and either MFQ or SCARED for either model.

The GEE models were repeated while limiting the analysis again to the subsample of participants with elevated SCARED score (i.e., score > 24) or MFQ score (i.e., score > 22). There was a significant increase in the "RT index" ($B = 1.8$, $p = 0.03$) and decrease in the "OE index" score significantly over the four quartiles ($B = -3.5$, p-value < 0.001), but there was no interaction between quartile and either MFQ or SCARED scores for either model. In addition, there was no significant change over the four quartiles in "RTV index" score ($B = -1.06$, p-value $= 0.38$) or "CE index" score ($B = 0.27$, p-value $= 0.77$), and there was no significant interaction between quartiles and either MFQ or SCARED for either model.

Discussion

Contrary to our predictions, when controlling for sex and for the severity of ADHD symptoms (as indicated by the Vanderbilt scores), our results showed no association between emotional symptoms (as indicated by SCARED or MFQ scores) and attentional performance (as indicated by the TOVA scores). The results also remained unchanged when we removed the Vanderbilt scores from the list of controlled variables. This suggests that the reported emotional symptoms do not seem to affect participants' total performance on the TOVA, regardless of sex, or the severity of the reported inattention and hyperactivity/impulsivity. In addition, when we explored the changes in performance over time, we did not see any significant changes over the four quartiles in RT scores or CE scores. Nevertheless, we noted a significant decrease in the RTV and the OE scores over the four quartiles but with no significant interaction between these quartile changes and MFQ or SCARED scores. Even if these results suggest some decrease in performance over time due to fatigue or changes in the presentation of the stimuli, this decrease is not explained by the reported emotional symptoms of our participants.

In summary, the reported emotional symptoms of participants did not affect performance on the TOVA after controlling for sex and reported inattention and hyperactivity. These results support previous findings in adults, showing that depression did not worsen the impairment on CPT performance (Fasmer et al., 2016; Mesquita et al., 2016). However, the absence of a significant correlation between reported anxiety symptoms and performance on the TOVA scores for our group does not necessarily reflect

an absence of effect on the individual level: In fact, previous studies have reported contradictory findings, suggesting an increase of performance on attention tasks for some participants and a decrease of performance for others (Bar-Haim et al., 2007; Easterbrook, 1959; Eysenck et al., 2007; Forster et al., 2015; Grillon et al., 2016, 2017; Lang et al., 1992; Langner & Eickhoff, 2013; Ruf et al., 2017). One could still argue that the findings only apply to a youth population with low emotional distress because the average scores of both the SCARED and the MFQ scales were relatively low in our population. However, when the same analyses were run on a subsample of the population with elevated emotion scores (i.e., SCARED $>$ 24 or MFQ $>$ 22), there were no changes in the results, thus rejecting the argument.

In conclusion, our results suggest that performance on the TOVA is immune to reported negative emotional symptoms in youth, which makes the TOVA a sturdy and reliable tool for the assessment of attentional issues in a clinical setting. Nevertheless, this study has some limitations, some of which are inherent to most retrospective studies: Our sample comes from a clinical setting, which explains the higher number of men versus women. This reflects the higher number of neurodevelopmental disorders typically reported in men (Copyright, 2022). It also raises questions about other comorbid conditions that could possibly affect performance on the TOVA, like motor disorders, although this has not been addressed in the literature. Moreover, inattention, hyperactivity/impulsivity, anxiety, and depression were measured using parent-reported scales, which could increase the chances of underreporting or overreporting. In fact, previous studies have shown comparable parent and youth reporting for internalizing and attention problems with equal or fewer parent-reported pathologies and externalizing behaviors (Chen, Ho, Lee, Wu, & Gau, 2017; Herpertz-Dahlmann, Kruse, Ziegert, & Neuss, 2002; Sourander, Helstelä, & Helenius, 1999), Additionally, these scales covered the emotional state prior to the assessment and could not reflect the actual emotional state of the patients during the assessment. Finally, we encountered a high number of missing data, which reduced the total number of included participants. We believe that future research should be conducted to investigate more thoroughly other non-emotional factors that could also affect performance on the TOVA, such as motor disability, sleepiness, or neurodevelopmental disorders affecting cognitive abilities. Being able to interpret test results with greater accuracy and confidence, therefore affording greater interventional direction, and improving clinical impact, are all intrinsic to the mission of neuropsychological assessment.

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No funding was received for this study.

Data availibility

The data that support the findings of this study are available from the corresponding author, MB, upon request.

Conflict of Interest

None declared.

Ethics

This study was approved and exempted from consent forms by the Institutional Review Board of the American University of Beirut.

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