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Adult attention deficit/hyperactivity disorder among the prison inmates: An investigation of the executive function differences and comorbidity effects

Mohammad Hamzeloo,[1] Ali Mashhadi,[2] Javad S. Fadardi,[2,3,4] and Melika Ghahremanzadeh[2]

[1]Research Center of Gorgan Prison, Gorgan and [2]Department of Psychology, Ferdowsi University of Mashhad, Mashhad, Iran, [3]School of Psychology, Bangor University, Bangor, Wales, UK and [4]School of Community and Global Health, Claremont Graduate University, Claremont, California, USA

Abstract

Objective: Attention deficit/hyperactivity disorder (ADHD) is one of the most prevalent psychiatric disorders that often persist into adulthood. ADHD is associated with a high percentage of comorbid psychiatric disorders. Studies indicate that ADHD is prevalent among inmates. The aim of the present study was to evaluate the executive functions (EFs), that is, inhibition and working memory among inmates with and without ADHD after controlling for comorbidity effects. **Method:** Through stratified sampling method, 60 adult male inmates (30 with ADHD and 30 without ADHD) were selected on a voluntary basis and were matched for age and education. We compared the groups on measures of neuropsychological tests battery and self-rated comorbidities. **Results:** Prior to controlling for the effects of comorbid disorders, the ADHD and non-ADHD groups showed significant differences on several measures of attention; however, only the classic Stroop test interference score remained significant after controlling for the effect of the comorbid disorders. The group comparisons on the measures of memory remained unaffected from before to after controlling for the effects of the six comorbid disorders. **Conclusions:** Specific comorbid disorders may exacerbate the poor performance of prison inmates with ADHD on the tests of attention, but their performance on the tests of memory could remain unaffected by their comorbidity symptoms. We recommend replicating the study with ADHD participants with no criminal history.

Key words: ADHD, adult inmates, comorbidity, neuropsychological deficits

Attention deficit/hyperactive disorder (ADHD) is considered as one of the most prevalent neuropsychological disorders among children and adolescents. The disorder can be observed among 3–7% of the school-age children. ADHD is usually associated with three main chronic problems including attention control, hyperactivity, and impulsivity (American Psychiatric Association, 2013). Such symptoms can be usually observed at early ages, especially among children aged less than 13 years (American Psychiatric Association, 2013). Longitudinal studies have shown that ADHD can often persist into adulthood (Barkley, Fischer, Smallish, & Fletcher, 2002), with a prevalence of 2–4.40% among adults (Fayyad et al., 2007; Kessler et al., 2006; Park et al., 2011).

Correspondence: Ali Mashhadi, PhD, Department of Psychology, Ferdowsi University of Mashhad, Azadi Square, 9177948974 Mashhad, Iran. Email: mashhadi@um.ac.ir;

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Considering the behavioural problems and consequences among adults with ADHD and the disorder's comorbidity with other problems (e.g., antisocial personality disorder and drug-related disorders), it is reasonable to expect that ADHD among adult prisoners is more common than the normal population. Evidences shows that 10–70% of prisoners in different countries suffer from the disorder (Ghanizadeh, Mohammadi, Akhondzadeh, & Sanaei-Zadeh, 2011; Gudjonsson, Sigurdsson, Young, Newton, & Peersen, 2009; Hamzeloo, Mashhadi, & Fadardi, 2016). The result of a recent meta-analysis estimating the prevalence of ADHD in incarcerated populations was 25.5% with no significant differences for gender and age (Young, Moss, Sedgwick, Fridman, & Hodgkins, 2015). Inmates with ADHD were at greater risk of suffering from behavioural problems and psychiatric comorbidities (e.g., substance use disorders, conduct disorder, mood disorders, anxiety disorders, and personality disorders) compared with inmates without ADHD (Hamzeloo et al., 2016; Young, Adamou, et al., 2011b; Young, Wells, & Gudjonsson, 2011a). The result of a recent meta-analysis showed that the risk of all psychiatric comorbidity has increased among adult inmate with ADHD. The results of this study also suggested that the highest psychiatric comorbidity associated with adult with ADHD was, up to 74%, for substance use disorders and the lowest psychiatric comorbidity was for conduct disorder (Young, Sedgwick, et al., 2015).

Many longitudinal and cross-sectional studies in adults with ADHD have reported consistent executive dysfunctions from childhood to adulthood, including inhibitory control, flexibility, and working memory as well as divided and sustained attention (Alderson, Kasper, Hudec, & Patros, 2013; Dige, 2010; Dramsdahl, Westerhausen, Haavik, Hugdahl, & Plessen, 2011; Salomone, Fleming, Bramham, O'Connell, & Robertson, 2016; Schweitzer, Hanford, & Medoff, 2006; Sobanski, Sirtl, Alm, Hennig, & Banaschewski, 2015). Executive functions (EFs) are defined as neurocognitive processes such as verbal fluency, inhibitory control, working memory, planning, and problem solving that maintain an appropriate way to attain a future goal (Welsh & Pennington, 1988). The meta-analysis of studies on adults with ADHD indicated that they were significantly impaired on executive tasks (e.g., continuous performance test, trail making test, the classic Stroop test, WAIS digit span) in comparison with the individuals in the control groups, with the effect sizes in the medium range for the majority of the deficits (Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Structural and functional imaging studies in subjects with ADHD suggested that the abnormalities in frontal–striatal–cerebellar networks were associated with the integrity of EFs (Vaidya, 2011). Besides, compared with the control group, the prison inmates with ADHD showed poorer results on several measures of EFs and during controlling for IQ (Ginsberg, Hirvikoski, & Lindefors, 2010). However, some investigations have indicated that the executive dysfunctions are not consistently found in those with ADHD (Engelhardt, Nigg, Carr, & Ferreira, 2008; Epstein, Johnson, Varia, & Conners, 2001; King, Colla, Brass, Heuser, & von Cramon, 2007; Saboya, Coutinho, Segenreich, Ayrão, & Mattos, 2009); they have also revealed that cognitive deficits, especially problems with inhibitory processes, do not stretch far into adulthood. Moreover, many psychiatric disorders that are associated with ADHD are also related to executive dysfunctions (Pennington & Ozonoff, 1996; Seidman, Biederman, Faraone, Weber, & Ouellette, 1997); and this makes it difficult to determine whether the dysfunctions are attributable to ADHD, the presence of comorbid disorders or both. A few comorbid disorders associated with ADHD, which are also related to executive dysfunctions include bipolar disorders (Ryan et al., 2012), anxiety disorders (Fujii et al., 2013), borderline personality disorders (Hagenhoff et al., 2013), and antisocial personality disorders (De Brito, Viding, Kumari, Blackwood, & Hodgins, 2013). Although a few studies have evaluated the EF deficits in adults with ADHD during controlling for comorbidities (Bramham et al., 2012; Marchetta, Hurks, Krabbendam, & Jolles, 2008; Nigg et al., 2005; Silva et al., 2013), the findings of a study suggest that Wisconsin Card Sorting Test (WCST) impairment among patients with ADHD seems to be strongly attributable to comorbid bipolar disorder (Silva et al., 2014). Addressing the issue in inmates with ADHD seems even more complicated because they report more ADHD symptoms (Ginsberg et al., 2010) and more comorbid disorders (Rösler et al., 2004) than the ADHD individuals with no criminal history. In sum, the main aim of the present study was to compare the EFs among a group of adult male inmates with and without ADHD after controlling for comorbid disorders. We hypothesised that prison inmates with ADHD show higher executive dysfunctions than those without ADHD, even after controlling for psychiatric comorbidities in both groups.

METHOD

Participants

The sampling method was non-randomised. Participants were 60 adult male inmates between 20 and 49 years of age; of this population, 30 inmates suffered from ADHD and the others did not. Participants were selected on a voluntary basis through a three-step diagnostic procedure from an earlier study (Hamzeloo et al., 2016). The study was conducted at Gorgan Central Prison, Golestan Province, Iran from July 2011 to October 2012. This study was granted ethical approval by ethical committee of Department of Psychology, Ferdowsi University of Mashhad and Golestan State Prison Research Council. All participants gave written informed consent prior to their participation. The section below describes the diagnostic procedure for screening the inmates. The two groups were matched with respect to their ages (M = 29.38, standard deviation (SD) = 6.10; range: 20–49) and education (M = 7.78, SD = 2.48). The inmates' participation or refusal to participate in the study remained totally unrelated to the services that they received routinely at the prison.

Diagnostic procedure for ADHD

A three-step diagnostic procedure was used to select the participants with ADHD. First, we assessed the presence or absence of current ADHD symptoms by administering the Adult ADHD Self-Report Scale (ASRS), (Adler, Kessler, & Spencer, 2003). Second, those who scored high on ASRS (indicating as very likely to have ADHD) took part in a retroactive, clinical unstandardised interview in order to ensure the existence of ADHD symptoms during their childhood based on the criteria provided in the Diagnostic and

Statistical Manual of Mental Disorders (fourth ed., DSM-IV). Third, the diagnosis of ADHD was confirmed by an experienced, board-certified psychiatrist. There was no need to divide the present sample into subtypes of adult ADHD because the existing evidence suggested that there were no differences among the ADHD subtypes with regard to the EFs (Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2005; Nigg, Blaskey, Huang-Pollock, & Rappley, 2002).

Assessment of psychiatric comorbidity

Psychiatric comorbidity symptoms for both groups were evaluated through the following instruments:

(1) *The Millon Clinical Multiaxial Inventory—III (*Chegini, Delavar, & Garrayi, 2013; Millon & Davis, 1998). MCMI-III is a 175-item true–false self-report questionnaire that measures 10 clinical syndromes and 14 personality disorders based on the Axis I and II categories of the diagnostic system of the DSM-IV. MCMI-III consists of 24 scales as follows: (1) 14 clinical personality patterns scales including Schizoid, Avoidant, Depressive, Dependent, Histrionic, Narcissistic, Antisocial, Sadistic, Compulsive, Negativistic, Masochistic, and (three severe personality pathology scales) Schizotypal, Borderline, and Paranoid; (2) 7 clinical syndrome scales consisting of Anxiety, Somatoform, Bipolar (Manic), Dysthymia, Alcohol Dependence, Drug Dependence, and Posttraumatic Stress Disorder; and (3) 3 severe clinical syndrome scales comprising of Thought Disorder, Major Depression, and Delusional Disorder. There are also three modifying indices and a validity scale that are used to detect the presence of response sets and invalid profiles. Scores ≥ 85 propose the disorders of clinical significance (i.e., primary diagnosis) while a score of 75–84 indicates the characteristics of the disorder.

(2) *Beck Depression Inventory—second edition* (BDI-II) (Beck, Steer, & Brown, 1996; Ghassemzadeh, Mojtabai, Karamghadiri, & Ebrahimkhani, 2005), is a 21-item self-report measure that evaluates the severity of depression symptoms. Answers on each item are rated on a 4-point Likert scale (ranging from 0 to 3), with higher scores on the scale representing greater severity of depressive symptoms.

(3) *Beck Anxiety Inventory* (BAI), (Beck, Steer, & Carbin, 1988; Kaviani & Mousavi, 2008) is a 21-item self-report questionnaire evaluating common symptoms of clinical anxiety. Each symptom is scored on a 4-point Likert scale (ranging from 0 to 3), with higher scores corresponding to higher level of anxiety.

EFs test battery

Wechsler digit span subtest Digit-span task was used to measure verbal working memory capacity for number storage. Completing the test requires the participants to pay a lot of attention to the number sequence, keep them in mind for a short period, do some calculations, and reproduce them (Kessels, van den Berg, Ruis, & Brands, 2008). The test has a good internal consistency (Cronbach's α = 0.65) and test–retest reliability (r = 0.83) for Iranian population (Orangi, Atefvahid, & Ashayeri, 2002).

Corsi Block-Tapping Task A computer version of Corsi Block-Tapping Task (Corsi, 1972) was used to measure the visuospatial, short-term working memory. The test requires maintaining a visuospatial pattern and a movement chain. Keeping a chain of sequencing movements in mind is also required for the successful completion of the task. Although this test is applied broadly for measuring the spatial working memory in neuropsychological studies, there is little information about its reliability and validity (Kessels et al., 2008). However, Kessels et al. showed that forward and backward Corsi Block-Tapping Task and Wechsler digit span subtest had the same level of difficulty and required similar cognitive systems to complete them. The authors reported a point less than the fifth percentile for detecting the impaired performance. The test gives two measures: (1) *Block span* which shows the longest sequence that has been correctly reproduced (at least twice) by the participant; and (2) *visual–spatial memory span* which displays the participant's spatial working memory capacity.

The Stroop test There is general consensus that Stroop test (Stroop, 1935) is a measure of cognitive inhibition and interference control (MacLeod, 1991). The test contains a series of congruent colour-words (e.g., red in *red*) and incongruent colour-words (e.g., red in *blue*) in response to which the participants are asked to ignore the meaning of the words and respond to the colour of the words as accurately and quickly as possible (Cox, Fadardi, & Pothos, 2006). In the computerised Persian version of the test used in the current study (Fadardi & Ziaei, 2010), four colour words (green, red, yellow, and blue) were presented 96 times, 50% of which were congruent and 50% were incongruent. Each word stayed on a PC screen for 2 s during which a key should be pressed on the keyboard (otherwise, a '*no response*' was recorded by the computer); a fixation crosses '+' with an inter-trial interval of 800 ms dispersed the word stimuli.

Go/No Go task Go/No Go task is used broadly for measuring sustained attention, response control, and movement inhibition (Wodka et al., 2007). The task gives two separate scores: (1) *Commission errors* (i.e., responding to instead of ignoring a stimulus) which are considered as an index of problems with inhibition, and (2) *omission errors* (i.e., ignoring instead of responding to a stimulus) which are indices of inattention. In the current study, geometrical shapes were used (i.e., circle, square, oval, triangle, rectangle, and trapezoid). The triangle (go trial; 70 out of 100) was chosen and randomly presented among other shapes (no-go trials). The participants were required to press the space bar on the keyboard as soon as they saw a triangle on the monitor screen. Each stimulus stayed on the monitor for 500 ms, and the inter-trial interval between the stimuli was 500 ms.

Stop-signal task The stop-signal task is a reliable measure of behavioural inhibition. We used a freely available version of the task titled 'Stop It' (Verbruggen, Logan, & Stevens, 2008). The task has two steps: (1) The practice step includes 32 trials to help participants to learn about the test's instructions and how to respond to the stimuli; and (2) the experimental step consists of three blocks, each of which contains 64 tries. The task presents two different stimuli (i.e., a circle and a square) in the center of a computer display and participants should press one of the allocated keys on the right or left hand side of the keyboard (i.e., '/' or 'z'). On some trials, the stop signal (i.e., a beep sound) plays randomly right after a stimulus, which means the participant must not respond to that particular stimulus. Stopping the response in this condition requires a quick controlling mechanism to prevent executing the motor response (Verbruggen & Logan, 2008b).

The program records the participants' responses and their reaction times. Output measures are based on the probability of responding on stop signal serials (p(r|s)), stop-signal delay (SSD), stop-signal reaction time (SSRT), mean reaction time on signal-respond trials (SR-RT), mean reaction time on no-signal trials (NS-RT), and mean percentage of correct responses on no-signal trials (NS-HIT). Among the indices, SSRT and p(r|s) are more widely used to address issues related to cognitive control and inhibition (Verbruggen & Logan, 2008a, 2008b).

Table 1 Demographic characteristics of inmates with and without ADHD

	With ADHD		Without ADHD	
Variable	*F*	%	*F*	%
Marital status				
Single	14.00	46.70	9.00	30.00
Married	13.00	30.43	19.00	63.30
Divorced	3.00	10.00	2.00	6.70
Type of crime				
Drug-related	11.00	36.67	15.00	50.00
Robbery	7.00	23.34	6.00	20.00
Murder	3.00	10.00	2.00	6.67
Assault and battery	3.00	10.00	2.00	6.67
Rape and adultery	3.00	10.00	3.00	10.00
Abduction	2.00	6.67	1.00	3.34
Mahrieh[a]	1.00	3.34	1.00	3.34

[a] *Mahrieh* is an amount of money or something else that is mutually agreed to be paid by the groom to the bride at the time of marriage (nikah) or after the bride's request. In Iran, the payment is not normally demanded by the bride unless there are serious marital problems.

Procedure

Participating in the study was voluntary, and the participants were not entitled to any advantages or disadvantages in the prison. The objectives of the study were explained verbally and through the study information sheet. The volunteers had the opportunity to ask questions at any step of the study, and they were told that they could withdraw from the study at any time without incurring any negative consequences. After giving their informed consent, the participants were all given a demographic questionnaire to complete. Then, they completed a series of EF tests which were administered individually via a PC computer with a 17″ display in a quiet room allocated to the study. Consistent verbal instructions were given to all participants on each measure.

Data analysis

Four methods of data analyses were used. First, one-way analyses of variance (ANOVAs) were conducted to examine any significant differences that might exist between the two groups in comorbid disorders. Second, multivariate analyses of covariance (MANCOVAs) were conducted to test any differences in EFs between the two groups, during controlling for comorbidities as covariates. Third, Pearson correlational analyses were performed to determine the strength of the relationships among comorbidities and EFs. Fourth, linear regression analyses were conducted in order to determine the extent to which comorbidity symptoms could predict the executive dysfunctions among the inmates with ADHD. Prior to conducting each data analysis, all the prerequisite assumptions for the fitness of the model were tested. No violations of the assumptions were detected for any of the models.

RESULTS

Table 1 shows the frequency and percentage of the participants regarding their marital status and crime type in the experimental (i.e., with ADHD) and control (i.e., without ADHD) groups, respectively.

Table 2 shows the means, the *SD*s, and the results of ANOVA testing the two groups' differences in comorbid symptoms—as measured by the study tools (i.e., ASRS, BAI, BDI-II, and MCMI-III) and their subtests. Table 2 also shows significant differences between the inmates with and without ADHD across all measures of comorbidities.

Table 3 shows the means, the *SD*s and the results of two MANCOVAs. The first analysis (Model 1) tested the study hypotheses about the participants' EFs (i.e., scores on

Table 2 Means and standard deviations for the participants' comorbidity symptoms, and the results of ANOVA for significant comparisons

	With ADHD		Without ADHD			
Variable	*M*	*SD*	*M*	*SD*	$F(1, 59)$	*p*-value
Inattention symptoms[a]	25.50	3.35	14.50	5.02	99.78	.0001
Hyperactivity symptoms[a]	24.90	3.97	15.53	3.87	85.56	.0001
Combined symptoms[a]	50.40	5.67	30.03	7.77	134.45	.0001
Anxiety symptoms[b]	50.40	5.67	32.73	10.54	65.38	.0001
Depression symptoms[c]	41.70	9.55	33.50	9.66	10.94	.002
Bipolar disorder[d]	68.50	15.48	60.67	11.36	4.99	.029
Posttraumatic stress disorder[d]	72.60	16.93	62.20	16.58	5.78	.019
Antisocial personality disorder[d]	74.73	16.58	66.40	12.99	4.70	.034
Borderline personality disorder[d]	72.43	17.83	63.40	16.56	4.13	.047

[a] Evaluated by ASRS.
[b] Evaluated by BAI.
[c] Evaluated by BDI-II.
[d] Evaluated by MCMI-III.

Go/No Go, Stop It, and Stroop test), and the second analysis tested the study hypotheses about the participants' memory capabilities (i.e., scores on Corsi Block-Tapping Task, Wechsler digit span subtest). In both models, the main effects were tested after controlling for the effects of comorbid symptoms (i.e., anxiety, depression, bipolar,

Table 3 Means and standard deviations for the participants' inhibition (Model 1) and working memory (Model 2) scores, and the results of MANCOVA comparisons between prisoners with and without ADHD, controlling for anxiety, depression, bipolar, posttraumatic stress disorder, antisocial, and borderline personality disorder symptoms as covariates

						Without covariates			With covariates		
						Wilk's Γ ($p < .05$) Group main effect .52; $F(49,9) = 4.86$; $\eta^2 = .47$			Wilk's Γ ($p < .05$) Bipolar disorder* 0.63, $F(43,9) = 2.82$; $\eta^2 = .37$ Group main effect .57; $F(43,9) = 3.60$; $\eta^2 = .43$		
		With ADHD		Without ADHD							
Model 1	Test variable	*M*	*SD*	*M*	*SD*	*F*	*p*	η^2	*F*	*p*	η^2
Go/No Go	Commission Error	2.70	2.57	1.23	1.99	5.56	**.022**	.089	0.019	0.89	0.001
	Omission error	15.33	10.78	7.57	7.87	10.14	**.002**	.15	15.79	**0.001**	0.24
	RT of correct response	260.09	20.45	258.97	16.76	.19	.661	.003	0.021	0.88	0.001
	RT of commission error	359.91	48.03	307.55	48.13	7.07	**.010**	.11	2.67	0.11*	0.050
Stop It	*p*(rls)	47.67	7.87	49.73	14.35	.52	.474	.009	0.18	0.67	0.004
	SSRT	318.09	86.11	258.59	114.97	6.43	**.014**	.10	2.87	0.096	0.053
Stroop	Congruent RT	1,018.84	212.54	958.61	178.93	2.18	.145	.03	4.92	**0.031**	0.088
	Incongruent RT	1,156.12	262.85	1,054.22	192.55	3.85	.055	.06	6.41	**0.014**	0.11
	Interference score	150.03	96.09	98.63	53.22	6.39	**.014**	.10	6.42	**0.014***	0.11

						Without covariates			With covariates		
						Wilk's Γ ($p < .05$) Group main effect .482; $F(54,5) = 11.54$; $\eta^2 = .51$			Wilk's Γ ($p < .05$) Borderline personality disorder (BPD) 0.80, $F(47, 5) = 2.50$; $\eta^2 = .21$ Group main effect .54; $F(47, 5) = 7.99$; $\eta^2 = .46$		
		With ADHD		Without ADHD							
Model 2	Test variable	*M*	*SD*	*M*	*SD*	*F*	*p*	η^2	*F*	*p*	η^2
Corsi Blocks	Block span	4.17	1.23	5.57	0.89	25.25	**.0001**	.30	16.33	**0.001***	0.24
	Total correct score	23.77	13.69	41.57	13.71	25.30	**.0001**	.30	17.18	**0.0001***	0.25
	Total correct trials	5.17	2.04	7.73	1.14	36.26	**.0001**	.38	24.02	**0.0001***	0.32
	Memory span	3.58	1.02	4.87	0.57	36.26	**.0001**	.38	24.02	**0.0001***	0.32
Digit span	Forward	4.27	1.66	7.37	1.67	51.98	**.0001**	.47	35.18	**0.0001**	0.40
	Backward	3.57	1.22	6.43	2.50	31.81	**.0001**	.35	23.37	**0.0001**	0.31
	Total score	7.83	2.69	13.80	3.93	47.002	**.0001**	.45	33.76	**0.0001**	0.39

Note. RT = reaction time; SSRT = stop-signal reaction time; *p*(rls) = probability of responding on stop-signal trials.
*Significance of the covariate effect.; Bold indicates the significance *p* values of $p < .05$

posttraumatic stress disorder, antisocial, and borderline personality disorder symptoms). The results of the first MANCOVA model (Table 3) showed that (1) the only significant covariate was bipolar disorder, Wilk's $\Gamma = 0.63$, $F(43, 9) = 2.82$; $p = .011$; $\eta^2 = .37$; (2) group had a main effect, Wilk's $\Gamma = .57$; $F(43, 9) = 3.60$; $p = .002$; $\eta^2 = .43$; and (3) in comparison with non-ADHD group, the ADHD group made more omission errors and showed higher reaction times for congruent and incongruent stimuli and hence larger Stroop interference scores.

The second MANCOVA model (Table 3) showed that (1) the only significant covariate was borderline personality disorder, Wilk's $\Gamma = 0.80$, $F(47, 5) = 2.50$; $p = .43$; $\eta^2 = .21$; (2) group had a main effect, Wilk's $\Gamma = .54$; $F(47, 5) = 7.99$; $p = .001$; $\eta^2 = .46$; and (3) in comparison with non-ADHD group, the ADHD group performed worse on all measures of memory. That is, the ADHD group had lower scores than the non-ADHD group on the Corsi Block Tapping Task's Block Span; total correct score; visuospatial memory span; and lower scores on the Wechsler digit span's forward and backward forms and the subtest's total score (Table 3).

Next, we calculated a correlation matrix among the EFs various scores and the participants' comorbidities for both ADHD and non-ADHD prison inmates separately. As Table 4 shows, 13.56% of correlations among the EFs indices and the measures of the comorbidities were significant for the ADHD group—in comparison to 7.29% of significant correlations in non-ADHD group.

Finally, a series of standard multiple regressions were conducted to examine whether the comorbidities could be predicted by the main EFs in inmates with ADHD. To avoid problems with collinearity, the subtests of each measure were not entered into the models. Table 5 shows the results of three significant regression models for the two groups for depression disorder and bipolar disorder.

DISCUSSION

This study aimed to compare the EFs among a group of adult male inmates with and without ADHD before and after controlling for the scores of six comorbid disorders. Although Go/No Go commission error, the Stop Signal task SSRT, and the classic Stroop test interference score were significantly different across the two groups, only the classic Stroop test interference score remained significant after controlling for the effect of the comorbid disorders. However, the group comparisons on the measures of memory remained unaffected from before to after controlling for the effects of the six comorbid disorders. Finally, and after controlling for the covariate, significant differences between the two groups were observed in their working memory, as measured by Wechsler digit span subtest, Corsi Block-Tapping Task, inattention, as measured by the Go/No Go commission errors, and inhibition and interference control, as measured by the classic Stroop test.

In comparison with the adult inmates without ADHD, adult inmates with ADHD performed poorer on the classic Stroop test as a measure of inhibition and interference control. However, the ADHD group did not score higher on all indices of the Stop Signal task or on the Go/No Go commission error as other measures of inhibition; in fact they made more omission errors (as a measure of inattention) in comparison with adult inmates without ADHD. Declarations of inconsistent findings in inhibition tasks can be made with regard to their differences. For example Eagle, Bari, and Robbins (2008) provide evidence from human and rodent studies indicating that different brain loci and pathways are involved in the Go/No Go and Stop Signal tasks (e.g., SSRT) that implicates different mechanisms of control in the tasks of inhibition. Cohen et al. (2014) reported similar results indicating that participants' performance on Go/No Go and the classic Stroop tests my tap different cognitive and neural mechanisms (Morooka et al., 2012). They quote Barkley (1997) suggesting that the Go/No Go task tests inhibition of prepotent responses, whereas the Stroop task combines inhibition of proponent responses and interference control. In other words, it seems that the classic Stroop task is more potent to uncover difficulties with inhibitory processes. We need to clarify that in our discussion of groups' differences in inhibitory processes, we actually refer to their performance on the classic Stroop test (Barkley, 1997). Our findings cannot fully support previous meta-analyses on adults with ADHD, indicating that they are significantly impaired on working memory, attention, and measures of inhibition in comparison with control group (Boonstra et al., 2005; Willcutt et al., 2005).

In the first MANCOVA model, only one out of six covariates, i.e., bipolar disorder had a significant effect on the classic Stroop test interference score as an index of cognitive inhibition, differentiating the ADHD group from the non-ADHD group. Our findings suggested that the two groups' differences on the classic Stroop test (i.e., inhibition and interference control) were not attributable to the participants' anxiety, depression, posttraumatic stress disorder, antisocial personality, and borderline personality disorder, except for bipolar disorder. The results were consistent with pervious findings (Bramham et al., 2012; Garcia et al., 2012; Marchetta et al., 2008; Nigg et al., 2005; Salomone et al., 2016; Sobanski et al., 2015). Silva et al. (2013) and Silva et al. (2014) indicated that the problem of inhibition can be considered as a significant component in ADHD and bipolar disorder. In addition, the impulsivity characteristic seen in both disorders can imply a component of emotional dysregulation in both abnormalities. However, the ADHD and non-ADHD group's performance on the measures of memory were not significantly affected by their scores on

Table 4 The correlation matrix among the executive functions and the comorbidities, separately for prison inmates with and without ADHD

Comorbidities	Go/No Go task				Stop It		Classic Stroop test			Digit span task			Corsi block-tapping task			
	CE	OE	RTCR	RTCE	*p*(r|s)	SSRT	CRT	ICRT	Int.S	FW	BW	TS	BS	TS	TCT	MS
ADHD																
Depression disorder	−.11	.071	.016	.11	.24	.099	.17	.079	−.11	−.52*	−.39*	−.50*	−.18	−.22	−.21	−.21
Anxiety disorder	.160	.041	−.010	.134	.168	−.050	−.156	−.294	−.42*	−.006	.083	.034	.113	.060	.051	.051
Bipolar disorder	.266	−.293	.236	.44*	−.197	.047	−.14	−.34*	−.46*	−.039	.25	.091	−.125	−.075	−.098	−.098
PTSD	.033	−.38*	.25	.032	−.20	−.18	−.34*	−.31	−.076	.11	.076	.10	.017	.037	.085	.085
Antisocial PD	.11	−.47*	.47*	.27	−.31*	−.27	−.38	−.36*	−.084	−.079	.064	−.020	.051	.098	.10	.11
Borderline PD	.18	−.27	.14	.10	−.19	−.15	−.092	−.14	−.14	−.19	−.050	−.13	−.16	−.061	−.048	−.048
Non-ADHD																
Depression disorder	−.29	.055	.14	−.18	.17	−.002	.064	.018	−.083	.006	−.14	−.087	−.050	−.007	−.027	−.027
Anxiety disorder	−.14	−.19	−.082	−.13	.14	.040	−.17	−.19	−.11	−.046	−.14	−.11	−.081	.077	.011	.011
Bipolar disorder	−.085	−.25	.007	.32*	−.025	−.087	−.18	−.22	−.11	−.42*	.21	−.31*	.19	.26	.32*	.32*
PTSD	−.047	−.10	.11	.008	.241	−.004	.072	.030	−.079	−.19	−.18	−.19	−.24	−.16	−.21	−.21
Antisocial PD	−.11	−.32*	−.097	.001	.33*	.020	−.12	−.12	−.021	−.14	−.19	−.18	−.17	.076	−.055	−.055
Borderline PD	−.25	−.081	−.14	−.30	−.17	−.053	−.25	−.22	.014	.24	.092	.16	−.002	−.066	.30	.30

Note. ADHD = attention deficit/hyperactivity disorder; antisocial PD = antisocial personality disorder; borderline PD = borderline personality disorder; BS = block span; BW = backward; CE = commission error; CRT = congruent reaction time; FW = forward; ICRT = incongruent reaction time; Int.S = interference score; MS = memory span; OE = omission error; *p*(r|s) = probability of responding on stop-signal trials; RTCE = reaction time of commission error; RTCR = reaction time of correct response; SSRT = stop-signal reaction time; TCT = total correct trial; TS = total score.

$^{*}p < .05$.

the comorbidity measures, as indicated in the second MANCOVA model. Therefore, it seems that when comparing adults with and without ADHD on popular tests of inhibition and cognitive control, special attention should be paid to the role of comorbid disorders such as borderline personality.

The findings of study showed that the ADHD group performed poorer than the non-ADHD group on the Stroop test (as a measure of cognitive inhibition and interference control). This finding supported the results of previous studies (dos Santos Assef, Capovilla, & Capovilla, 2007; Holmes et al., 2010; King et al., 2007), and the results of a research conducted by Milwaukee and the University of Massachusetts Medical School Studies (UMASS) (Barkley, Murphy, & Fischer, 2010) that showed adults with ADHD had deficits in their interference control and resistance to distraction. In contrast to our findings, van Mourik, Oosterlaan, and Sergeant (2005) did not find such a difference and suggested that the classic Stroop test could not be a proper measure of interference control in ADHD (van Mourik et al., 2005); hence, they suggested using other measures of cognitive inhibition.

Study findings showed the significant differences between the two groups in verbal and visuospatial working memory. These findings, in the line with the results of the previous meta-analysis studies, confirm the weakness of working memory in individuals with ADHD (Alderson et al., 2013; Boonstra et al., 2005; Willcutt et al., 2005). ADHD participants showed poorer performance than those in the control in visuospatial working memory; the finding supports those reported by Milwaukee and UMASS (Barkley et al., 2010; Boonstra et al., 2005; Willcutt et al., 2005). However, evidence (Brown, Reichel, & Quinlan, 2009) suggests that the difference between ADHD and non-ADHD participants' visual–spatial working memory vanishes after controlling for their intellectual abilities. Therefore, it seems that performance on visual–spatial tasks is less automatic and adults with ADHD need more mental and verbal struggling to complete items on IQ tests that engage working memory (Westerberg, Hirvikoski, Forssberg, & Klingberg, 2004). Given the Wechsler digit span subtest, and by measuring working memory, we found a significant difference between the two groups, with the ADHD participants showing smaller verbal memory span in both forward and backward forms than the participants without ADHD. The deficit of working memory leads to sustained problems in time management, organisation, and attention to related information for problem solving (Alderson et al., 2013; Barkley, 1997; Schweitzer et al., 2006; Willcutt et al., 2005).

Table 3 shows that, in the first model, the only significant covariate was manic-depression, and in the second model, the only significant covariate was borderline personality disorder, whereas in Table 4, four out of the six comorbid

Table 5 Regression models predicting depression and bipolar disorders from executive functions, separately for ADHD and non-ADHD groups

	Depression disorder								Bipolar disorder							
	B		*SE*		*β*		*t*		*B*		*SE*		*β*		*t*	
	A	N-A	A	N-A	A	N-A	A	N-A	A	N-A	A	N-A	A	N-A	A	N-A
Block tapping total	.123	−.010	.28	.29	.094	−.009	.430	−.034	−.176	.07	.19	.21	−.17	.085	−.89	.34
Commission error	1.48	−1.25	1.34	1.55	.21	−.17	1.10	−.80	.88	−.195	.93	1.093	.146	−.034	.948	−.18
Omission error	−.045	−.37	.42	.401	−.027	−.202	−.11	−.92	−.76	−.304	.29	.28	−.53	−.21	−2.59*	−1.077
Stop It *p*(rls)	1.028	.157	.53	.25	.45	.16	1.93	.63	.14	.056	.368	.175	.073	.071	.391	.319
SSRT	−.060	.003	.051	.030	−.28	.020	−1.16	.083	.044	−.019	.035	.021	.25	−.19	1.25	−.900
Stroop interference	−.087	−.053	.035	.070	−.47	−.19	−2.49*	−.76	−.073	−.030	.024	.049	−.45	−.139	−3.20*	−.59
Forward digit span	−1.97	1.92	2.91	3.019	−.18	.22	−.68	.64	−3.95	5.24	2.011	2.12	−.42	.771	−1.97	2.47*
Backward digit span	3.45	−1.95	4.035	2.026	.24	−.34	.85	−.96	7.79	−2.099	2.79	1.42	.62	−.46	2.78*	−1.47

Note. A = ADHD group; ADHD = attention deficit/hyperactivity disorder; N-A = non-ADHD group.
*$p < .05$.

disorders show significant correlations with measures of inhibition and two with measures of memory—interestingly, in Table 4, borderline personality disorder is not significantly correlated with any of memory scores. The discrepancy needs explanation. The MANCOVA models test group differences across a series of dependent variables while controlling for intercorrelations among the covariates and the dependent variables. Although tests of the MANCOVA models' fitness (Tabachnick & Fidell, 2012) conducted in this study proved a lack of multicollinearity problem, the existence of some degrees of collinearity among the variables lead to patterns of significant correlations that are different from mere bivariate correlations. This is a reason for not observing the same significant correlations between the covariates in the MANCOVA models as opposed to bivariate correlations that have been reported in Table 4, separately for the ADHD and non-ADHD group. We also calculated a correlation matrix for the six covariates (i.e., scores for the comorbid variables) for the two groups combined and only bipolar disorder showed four significant correlations with other covariates.

The results of regression analyses showed that among the comorbid disorders, only depression disorder and bipolar disorder could predict neuropsychological deficits in prison inmate adult with ADHD. A review of studies on similarities between depression and bipolar disorders and ADHD in their neuropsychological functions indicated that they might share deficits in emotional dysregulation (Hegerl & Hensch, 2014) and sustained attention (Silva et al., 2013, 2014; Young, Sedgwick, et al., 2015). Since depression disorder and bipolar disorder as the two comorbidity disorders are the most commonly used to predict the problems of adult prison inmates with ADHD, it is important to consider the need for assessment as well as the related interventions, including cognitive-behavioural therapy focusing on behavioural activation and improving cognitive processes of these individuals. The results suggest that although comorbidity symptoms with ADHD may cause significant deficits in the behavioural and cognitive performance of prisoners with ADHD, they have a small proportion in predicting the executive dysfunctions of the inmates with ADHD.

In sum, we found that, compared with the prisoners without ADHD, the adults with ADHD showed some deficiencies in their EF, resembling EF dysfunctions in children with ADHD (i.e., problems with attention, inhibition, interference control, and verbal and non-verbal working memory). Our findings supported the neuropsychological theories addressing the importance of deficits in inhibitory processes and working memory in ADHD (Engelhardt et al., 2008), the deficits that could stretch far into adulthood. Although some comorbid psychiatric disorders were related to deficits in inhibition and working memory, it seemed that the deficits could not be accounted for by the comorbid disorders; rather, the deficits could constitute a commonality of ADHD with the other comorbid psychiatric disorders. As far as the development of criminal behaviours was concerned, the consequences of suffering from ADHD could be exacerbated when it was also associated with executive dysfunctions.

However, the interpretation of these findings should be conceived in the context of some limitations. Our sample was from a state prison in the province of Golestan (located in the north of Iran). Hence, our findings might not be representative of the prison populations in other provinces or countries. In addition, we used a selective battery of EF and working memory measures; a more comprehensive battery of the measures could shed more light on the relationship between the EF dysfunctions and the prevalence of adult ADHD among inmates. Also as learning disorders were comorbid with ADHD, and in a prison sample with ADHD, the presence of learning disorders that might be even more pronounced possible effect of learning disorders on EFs, such as on working memory functions, would have been considered in the future study. Finally, the study did not measure and controlled for IQ differences across the two samples due to some methodological problems. However, the two samples were matched in terms of education which could partially compensate for the limitation. This study added to literature regarding EFs and comorbid disorders of prison inmate adult with ADHD and the findings had some implications for assessment and clinical interventions including: (1) Assessing the EFs of these individuals at the entrance to the prison, (2) developing and implementing therapeutic protocols based on EFs for prison inmate adult with ADHD; and (3) performing cognitive-behavioural interventions based on EFs with particular attention to the issue of mood disorders.

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