



# Examining the structural equation modeling between intrinsic-motivation, emotion regulation and ADHD: the mediating role of problem-solving, time-management, and behavioral-inhibition

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## Abstract

Although Executive Functions has been considered as the main correlation of ADHD few studies have examined the effect of EFs on ADHD symptoms, in the samples with ADHD. This study aimed to examine the structure of EFs on ADHD students in a hypothesized model. After careful screening of ADHD among 1368 university students (with stratified and multistage cluster sampling), out of them, 211 students with ADHD diagnosis were selected purposefully. They received scales on their emotion regulation, motivation, adult ADHD, deficits in EFs, and diagnostic interview. Emotion regulation and intrinsic motivation were considered as input; behavioral-inhibition, time-management, and problem-solving were the mediators and ADHD subscales were as the output variables. Results showed that the model adequately fit the data. The model fit indices were  $\chi^2 = 27.081$ ,  $df = 1$ ,  $CFI = 0.99$ ,  $GFI = 0.97$ , and  $PGFI = 0.02$ . The direct effects of intrinsic-motivation and emotion-regulation on all three mediators and indirect effects of them to ADHD subscales were significant. Based on the results, time-management mediated the relationship between motivation and emotion regulation and ADHD. Among EFs, emotion-regulation and intrinsic-motivation had fundamental influence to other aspects of EFs factors such as behavioral-inhibition, time-management, problem-solving, and attention deficit/hyperactivity disorder.

**Keywords** ADHD · Behavioral-inhibition · Emotion-regulation · Intrinsic-motivation · Problem-solving · Time-management · Structural equation modeling

## Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the neurodevelopmental disorders that greatly disrupt a person's life in adulthood. It is now well-established that ADHD comprises more deficits than its defining symptoms

of inattention, hyperactivity, and impulsivity. Based on the latest edition of the DSM-IVTR (2022) inattention describes ADHD as wandering off task, failing to follow through on instructions or finishing work or chores, having difficulty sustaining focus, and being disorganized and is not attributable to defiance or lack of comprehension. Hyperactivity refers to excessive motor activity (such as a child running about) when it is characterized by inappropriateness, excessive fidgeting, tapping, or talkativeness in adults. Hyperactivity may manifest itself through extreme restlessness or wearing others out with activity and moreover, However, signs of hyperactivity maybe differ from excessive activity and have been demonstrated as low level of energy Alta ble and Diaz Moreno (2022). Impulsivity refers to hasty actions that occur in the moment without forethought and can potentially harm to the individual (e.g., darting into the street without looking).

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Although the symptoms of the ADHD are introduced in this way and it seems that the knowledge in this regard is sufficient, there is no detailed information and sufficient study about the correlates of ADHD in suffering adults. Studying the correlates of ADHD is vital in the sense that it can be considered very important and fundamental in the process of treating adults with ADHD. Especially, in a recent study (Schein et al., 2022) the need to prepare and adjust a treatment protocol for adults with ADHD has been seriously mentioned, and the lack of long-lasting treatment for ADHD is considered a scientific weakness. One of the correlates of ADHD, which has been investigated in many studies, is Executive Functions (EFs). Currently, it is evident from the conducted studies that people suffering from ADHD have fundamental problems in EFs and the deficiency of EFs in the absence of main symptoms of ADHD is even known as one of the most sensitive and important predictors. That is, some studies have even pointed to EFs defects as the cause of behavioral problems (Brocki et al., 2010; Kim et al., 2013; Silverstein et al., 2020). Nevertheless, a growing body of evidence has shown that ADHD is deeply related to the shortcomings of the individual's EFs (Bolden et al., 2019; Mohamed et al., 2021; Weyandt et al., 2017; Zhang et al., 2021).

## Executive functions (EFs)

EFs refer to a set of neurocognitive top-down mental conscious functioning that allow for cognitive control of the organization of behavior across time so as to achieve goals (Barkley, 2010). There is not a general agreement about the main EFs. However, according to studies three domains such as inhibition, working memory and cognitive flexibility are the core of EFs (Lehto et al., 2003). Later studies pointed to reasoning, problem solving, and planning as the EFs resulting from these areas (Collins & Koechlin, 2012). Based on the basic study in this regard, EFs include behavioral-inhibition, time-management, problem-solving, emotional self-regulation, and self-motivation as the main EFs factors (Barkley, 1997). The development of EFs begins very early in life and applying them is effortful.

## Inhibition

Inhibition is defined by deliberately confining immediate responses on cognitive, emotional, and behavioral tasks that need postponed impulses, stopping ongoing behavior up to the suitable situation, and overcoming with unrelated stimuli (Barkley, 1997). Inhibition allows for the individual to make decisions and respond correctly by providing time lag. Actually, it refers to not acting or the ability to restrain and resist cognitive-emotional-behavioral actions. It is discussed that inhibition is in

the service of working memory (Barkley, 2001). Deficiency in effortful attempt over stopping impulsive behavior and unthinking habits could be result in very hasty and unsuitable behavior. An individual with ADHD barely could delay the impulses and postpone the action due to weak inhibitory system. Since a person with ADHD has low ability in recognizing the errors based on previous experiences or predicting the potential outcomes of behavior. In-fact, inhibition is not limited to behavioral aspect, and in cognitive and emotional dimensions also play a critical role which could be even named internal mental inhibition. The indirect challenges of poor inhibition in ADHD people manifest in social and academic settings.

## Self-regulation

Self-regulation can be defined as goal-directed behaviors with achieving instead of avoiding or even controlling. Perchance, self-control broadly use as self-regulation definition, while, self-control needs a low degree of self-regulatory behaviors and it should not be assumed the same. Since, self-control is usually used to designate a narrower subset of self-regulation (Hofmann et al., 2012). Self-regulation produces some kind of flexibility that allows individuals to behave appropriately in the new and unfamiliar situations. As Kopp (1982) argues, self-regulation makes it possible to have flexibility and moving in the dynamic context. On the other hand, the most important drivers of self-regulation failure are negative emotions (Sinha, 2009). In-fact, negative emotions alter the level of attention that could end in to distraction from goal-directed behavior and thus, the process of self-regulation would be lost (Ward & Mann, 2000). Along with these studies, the new EF-SR theory by Barkley (2021), discussed about the idea that ADHD is a disorder of self-regulation and point out self-regulation as the core aspect of EFs. According to the researches self-regulation include three main components: 1) thought, emotional and behavioral states that result in representation and monitoring, 2) ample motivation to keep going until achieving the desired behavior, and 3) sufficient capacity (Heatherton & Wagner, 2011). As Barkley mention to emotional self-regulation and self-motivation as two important elements in EFs (Barkley, 2011).

## Emotional self-regulation

One of the most acceptable models in emotion regulation (Faraone et al., 2019) introduces two necessary factors of emotional insight (i.e., awareness about emotions and clarity of them) and behavioral responses to emotion (i.e., how individuals modify distressing emotion) as the requirements for emotion regulation. Emotion regulation has an important role in initiating behaviors that need time

control, behavioral-inhibition (Walcott & Landau, 2004), self-management (Zimmerman, 2008), and internalizing psychopathology (Becker & Willcutt, 2019; Olatunji et al., 2013). Emotional dysregulation is a common condition in ADHD people (Beheshti et al., 2020; Ben-Dor Cohen et al., 2021). A study emphasizes the lack of emotional insight in ADHD people (Sibley et al., 2010) while other highlights the behavioral weakness in emotion regulation (Barkley & Fischer, 2010). Such people have difficulties in moderating the intensity of emotions, emotional impulsiveness, controlling negative emotional reactions, and dysfunctional pattern of emotion regulation. A bulk of evidence refers to the dysregulation of emotions in ADHD people (Barkley & Fischer, 2010; Bunford et al., 2015; Faraone et al., 2019; Martel, 2009; Shaw et al., 2014; van Stralen, 2016; Welkie et al., 2021). Emotion dysregulation is also associated with the persistence of ADHD symptom levels over time (Biederman et al., 2011). There is of course a subtle point that the proportion of individuals with ADHD affected by emotion dysregulation increases from 25–45% in childhood to 30–70% in young adulthood (Shaw et al., 2014).

## Self-motivation

Motivation is a process that accounts for an individual's intensity, direction, and persistence of effort towards attaining a goal and intrinsic motivation can be considered as the most important aspect of it (Csikszentmihalyi, 2014; Fishbach & Woolley, 2022). Moreover, intrinsic motivation occurs when one acts without any obvious external rewards and it refers to the reason why one performs certain activities for inherent satisfaction or pleasure (Hennessey, 2010; Zimmerman & Chu, 2013). According to Deci and Ryan (2008) intrinsic motivation comes from self-determination theory and three basic needs (competence, connection, and autonomy). The intrinsic motivation is also viewed as an arousal level (Sergeant, 2005) and delayed aversion pathway (Reeve, 2018; Sonuga-Barke, 2002). Also, intrinsic motivation is usually known as a matter of struggle in ADHD people due to various reasons such as dopamine insufficiency (Fanny & Usman, 2020; Volkow et al., 2011) and lack of persistence in the face of effortful tasks (Morsink et al., 2022). ADHD students have many difficulties in motivating themselves to do important but non-urgent tasks, often until they have been forced to do so by a looming deadline.

## Time-management

Getting organized in deadline and schedule plan is known as time-management (one of the EFs), which is not appropriate in ADHD people (Sibley et al., 2016). The time-management

battlefield in ADHD sufferers is characterized by as procrastination, inadequate time estimates by inconsistent time anticipation (Radonovich & Mostofsky, 2004). ADHD individuals suffer from under-estimation or over-estimation about the time that caused temporal myopia. Making good function around time dilemma is related to working memory and predicting future that results to obtain goal-oriented behavior (Barkley, 2011). Another explanation of time-management deficiency in ADHD individuals is the cognitive energetic approach (Jonkman, 2005), which holds that deficient time processing is a consequence of impaired self-regulation. This deficit can be conceptualized as a mismatch between the individuals' arousal and the stimulation provided by the task as researches confirmed (Wiersema et al., 2005).

## Problem-solving

Problem-solving is another EFs including different steps such as awareness beyond the problem, willingness to deal with the problem and being motivated to reach a solution (Dostál, 2015) which is considered dysfunctional in ADHD people. Emotion regulation and motivation have a fundamental role in progressing appropriate problem-solving. In fact, with proper management of emotions in problematic situations and maintaining a good level of motivation to achieve an acceptable result, problem-solving occurs satisfactorily and these two factors can even be considered as necessary dimensions for solving the dilemma. As Nezu and Nezu (2021) and (Güss et al., 2017) refer to the necessity of emotion regulation and the fundamental role of motivation in problem-solving.

## ADHD and executive functions

Although ADHD has been considered as a dysfunctionality of EFs and Barkley, as one of the pioneers of this scientific field in his new explanation about ADHD, discusses the main role of EFs deficiency in ADHD people (Barkley, 2021), its underlying factors and processes have remained rather understudied. Previously, he had mentioned the key and main role of inhibition in the process of EFs' effect on ADHD (Barkley, 1997). But he has recently changed his attitude about the basic factor and has introduced self-regulation as the fundamental element in the conceptualization of ADHD (Barkley, 2021). Many researchers consider the difficulties of people with ADHD to be due to EFs problems; however, in most practical studies, an equal role has been considered for EFs in the phenomenon of ADHD (Mohamed

et al., 2021; Silverstein et al., 2020; Zhang et al., 2021). Of course, many of these studies have been limited to children and adolescents. Dengsø (2022) has recently pointed out that EFs do not have a continuous relationship with ADHD. This relationship seems to be discrete, and EFs stem from deeper neurocognitive problems. Although Dengsø (2022) has mentioned the issue of considering social and cultural issues as an important correlation in this field but has not put forward an idea regarding the priority of important factors in executive functions.

Here, considering the change in Barkley's attitude on the one hand and the lack of detailed study in this direction, on the other hand, this idea comes to mind whether the dimensions of self-regulation including self-motivation and emotional self-regulation can be mediated by other dimensions of EFs in the development of ADHD. In other words, what kind of relationship exists between the dimensions of EFs and whether self-regulation can be the core of the problems of a person with ADHD, while this main category also affects other dimensions of EFs, in general, they make the situation of a person with ADHD more complicated. Furthermore, this disorder has been considered in the categories of cognitive disorders since many interventions target cognitive training as a sufficient solution to improve ADD symptoms (Cortese et al., 2015). While the underlying factors of observable dysfunctions can be seen more in the basic non-cognitive psychological processes including emotion regulation and intrinsic motivation. These two basic processes seem to predict problems in time-management, problem-solving, and inhibition. The last three variables predict the main symptoms of attention deficit, hyperactivity, impulsivity, and sluggish cognitive tempo.

The main very delicate issue that has not been considered by the researchers in the field of ADHD is: do the EFs in ADHD samples have priority over each other? Or what are the causal relationships between the components of EFs in ADHD sufferers? To put it concisely, in the previous studies a lead role was considered for behavioral-inhibition (Diamond, 2013). It means that emotion regulation and motivation were rooted in inhibitory control. Moreover, it was widely believed that inhibitory control runs people forward, alters, and chooses how to react in a particular condition. While such a view considered human beings to serve the habits and assigned a minimal role to other EFs (Cristofori et al., 2019; Shields et al., 2016). Other studies in the field of EFs almost focus on the aspect of working memory and cognitive inhibitory (Blair, 2017). Even in the meta-analysis study about the impact of stress on EFs, it was observed that stress affected working memory and cognitive flexibility, while it did not have much effect on behavioral inhibition (Shields et al., 2016). From this point of view, it can be concluded that behavioral inhibition is not a core EFs, while treating ADHD signs considering the equivalent role for EFs may have serious consequences and it is very critical to

determine the exact pathway of EFs. Despite a long history of research into these topics (Mohamed et al., 2021; Silverstein et al., 2020; Zhang et al., 2021), much is still unknown about how the elements of EFs affect each other in ADHD sufferers. Thus, the main concern of this analysis remains if another aspect of EFs such as self-regulation is the core of EFs, which is suggested likewise recently (Barkley, 2021). As Barkley (2021) suggested self-regulation is one of the important EFs. Thus, the main concern of our study is to examine the role of emotion-regulation and intrinsic motivation as the core of EFs and time-management, inhibition, and problem-solving as the mediators that affect ADHD. Indeed, finding the most important EF that has an important role in the ADHD subscale can show us the effective pathway for interventions.

Additionally, since the university studentship period is a sensitive stage of entering a professional course in the life of an adult, which can be severely destroyed under the influence of ADHD by lower GPA scores or undertaking fewer study skills strategies thus gaining lower academic success (Henning et al., 2022) due to inattention of ADHD, the structural relationships of ADHD with important variables in the sample of university students with ADHD was considered. To this end, the present study aimed to address the following research question: Does behavioral inhibition, time management and problem solving mediate the relationship between emotion regulation and self-motivation with ADHD? To achieve a particular aim, the following hypothesis was considered:

H1: the model of intrinsic motivation, emotion-regulation, behavioral-inhibition, problem-solving, time-management, and ADHD has fit with the observed data from ADHD students.

## Method

### Design of the study

This study was a part of an extensive review about ADHD in university students. The design of the present study was correlational and retrospective.

### Sampling and sample size

Since there is no specialized clinic for ADHD in Iran, to be sure, before conducting the research, we screened the student sample for ADHD. Using the stratified sampling method, all of the universities of Isfahan city in Iran were classified. Then, in each class, using the multi-stage cluster sampling method, academic departments were randomly selected, and after selecting the departments, several classes were randomly adopted. Finally, all the students of the selected classes (1368 students) participated in the phase of screening ADHD symptoms based on the ADHD questionnaire. The first level of sampling was depicted in Fig. 1.

Among 1368 Isfahan university students who participated in the screening ADHD symptoms procedure, about 310 university students were screened based on the cut-off point of the adult ADHD screening questionnaire. All of them were informed about the continuation of the investigation and from the clinical point of view, they were subjected to a diagnostic interview at the clinical office following the protocols of the Coronavirus. Accordingly, 230 students were diagnosed with ADHD symptoms based on a diagnostic interview and were invited to take part in the present study. Out of them, 211 university students were willing to participate in the present research. It should be noted that the diagnostic interviews were completed by the researchers’ assistants that they all have been trained in the clinical diagnosis scope.

Considering the adequacy of the sample size in SEM which is often recognized based on the number of free parameters there are several controversies over the exact number of participants per parameter. For example, Bentler and Chou (1987) suggested that a ratio as low as five cases per variable is sufficient while Kline (2015) proposed a ratio of 10- 20:1 is suitable. Accordingly, 200 participants as the sample size of the present study are proper to perform SEM analysis.

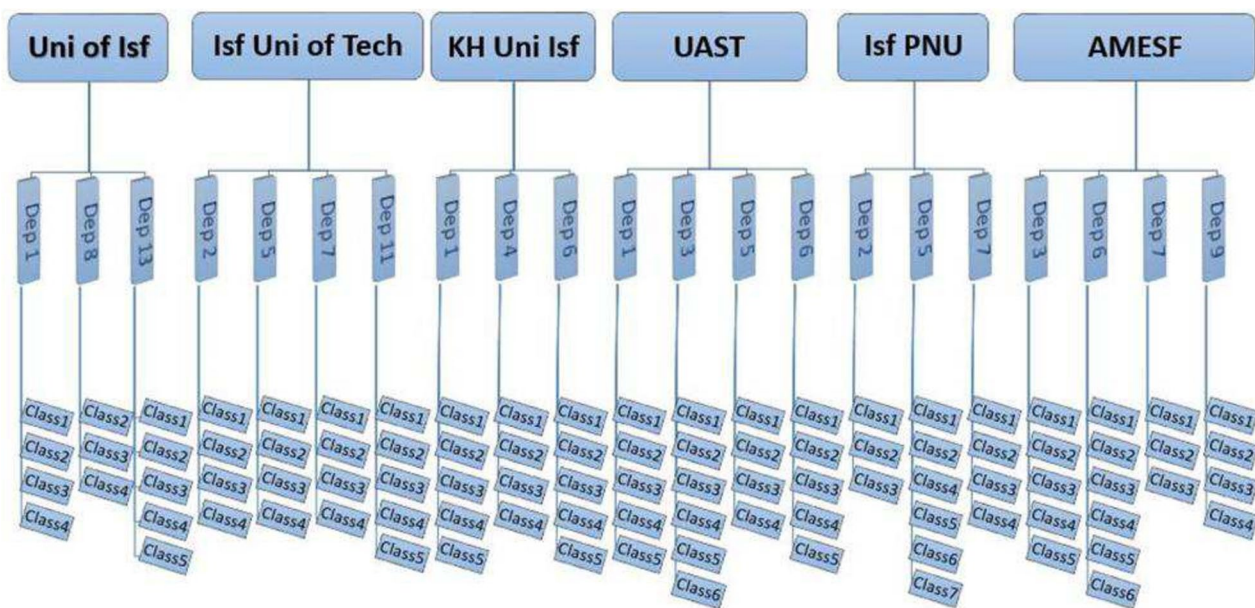
### Data collection

The data of this study, which was obtained using questionnaires, were collected online due to the Covid-19 epidemic. To increase the accuracy of data collection, participants also

were monitored online with cameras. Since the number of questions in this section was very large and it might affect the responses of the participants, the questions were randomly divided into two parts, and each participant answered each part on two consecutive days. To avoid unforeseeable problems regarding answering questions online, a virtual class space was first created, and after a limited number of participants entered the class, the preliminary conversation, and made contact with the camera, the link to the questions was available to them. While answering the questions, the participant’s behavior, whether eager to answer or impatient, as well as the time spent answering each question and how to choose the answers, could be examined by the researchers and assistants. If the participants seemed tired or expressed a desire to take a break, a break was planned for them and informed privately. In the second phase, diagnostic interviews and a detailed review of the entry criteria were conducted face-to-face in compliance with the health protocols of the Covid-19 pandemic. The period of collecting data for the present study was from May 5 to June 13, 2020.

### Participants

After ADHD screening among university students, the clinical sample with the following characteristics was included in the study: 1) diagnosed as ADHD based on DIVA-2 screening interview, 2) getting a score above the cut-off point on the ADHD Barkley screening scale, 3) no comorbidity of bipolar, autism spectrum, and personality disorder (based on diagnostic



**Fig. 1** Sampling procedure of the first level. Uni of Isf: University of Isfahan. Isf Uni of Teck: Isfahan University of Technology. KH Uni Isf: Islamic Azad University of Isfahan(Khorasgan) Branch. UAST:

University of Applied Sciences. Isf PNU: Payam-e Noor University of Isfahan. AMESF: Almahdi Mehr Higher Education Institute of Isfahan

interview), 4) being the university student at the time of study, and 5) having sufficiently fluency in Persian language both in reading and writing skills. The exclusion items were unwillingness to participate in the study and drug addiction during the period of performing the study. At the beginning of the research, the participants were fully informed that the use of drugs can distort the results of the research, and for this reason, if they take drugs, they are requested to inform the researchers.

The population consisted of all university students who were studying in one of the public or private universities in Isfahan, Iran. Considering continuous variables, the sample included 211 university students who were selected based on inclusive characteristics. The sample consisted of 43.1% female, 55.5% male, and 1.4% with no clear choice with a mean age of  $23.18 \pm 1.89$ . Sample characteristics of the study are provided in Table 1. 88.9% sample has an onset age before 12 and 11.1% of the total sample reported the symptoms after the age of 12.

Based on the diagnostic interview of ADHD, 30.3% of the sample (64 participants) was diagnosed as inattention type of ADHD, 27.5% (58 participants) determined as hyperactive/impulsive type, and finally, 42.2% (89 individuals) specified as a combined type of ADHD. More precisely, 13.27% of female students (28 individuals), were determined as inattention type of ADHD, 11.37% (24 individuals) as hyperactivity/impulsive type of ADHD, and 18.48% (39 individuals) as a combined type of ADHD. Of the male students 17.06% (36 individuals) were

diagnosed as inattention type of ADHD, 15.16% (32 individuals) as hyperactivity/impulsive type of ADHD, and 23.22% (49 individuals) as a combined type of ADHD.

## Measures

**DIVA-2** Diagnostic Interview for ADHD in adults (DIVA) by (Kooij & Francken, 2010) was used for screening ADHD university students. The interview comprised of three sections including: 1) The criteria for Attention Deficit (A1), 2) the criteria for Hyperactivity-Impulsivity (A2), and 3) the age of onset and impairment accounted for by ADHD symptoms. In order to simplify the evaluation of each of the 18 symptoms criteria for ADHD, the interview provided a list of concrete and realistic examples, for both current and retrospective (childhood) behavior. The diagnosis of ADHD in university students was decided based on five or more symptoms presence. Due to the high accuracy of this tool and 100% concurrent validity with Conners' Adult ADHD Diagnostic Interview (Ramos-Quiroga et al., 2019), this tool has been used in this study. In the Iranian example, the translated version of this tool has a good diagnostic capability.

**Barkley adult ADHD rating scale—IV (BAARS-IV)** The fourth edition of the ADHD questionnaire of Barkley was used for

**Table 1** Demographic Information of the Sample

				Sex				
				Female	Male	other	Total	
<i>University level</i>	Diploma			4 (1.89%)	4 (1.89%)	0 (0.00%)	8 (3.79%)	
	Undergraduate			84 (39.81%)	107 (50.71%)	3 (1.42%)	194 (91.94)	
	Graduate			2 (0.94%)	5 (2.36%)	0(0.00%)	7 (3.31%)	
	PhD candidate			1 (0.47%)	1 (0.47%)	0(0.00%)	2 (0.94%)	
<i>Economic level of student's family</i>	low			6 (2.84%)	18 (8.53%)	0(0.00%)	24 (11.37%)	
	Relatively moderate			37 (17.53%)	61 (28.90%)	1 (0.74%)	99 (46.91%)	
	Moderate			44 (20.58%)	35 (16.58%)	2 (0.94%)	81 (38.38%)	
<i>Job</i>	Occupied	Personal economic level of students	low	33 (15.63%)	24 (11.37%)	0(0.00%)	57 (27.01%)	
			Relatively moderate	0(0.00%)	8 (3.79%)	0(0.00%)	8 (3.79%)	
			Moderate	0(0.00%)	3 (1.42%)	0(0.00%)	3 (1.42%)	
			High	0(0.00%)	0 (0.00%)	0(0.00%)	0(0.00%)	
	Not occupied			56 (26.54%)	80 (37.91%)	3 (1.42%)	139 (65.87%)	
	Other			2 (0.94%)	2 (0.94%)	0 (0.00%)	4 (1.89%)	
	<i>Marital status</i>	Single			84 (39.81%)	99 (46.91%)	3 (1.42%)	186 (88.15%)
		Married			6 (2.84%)	8 (3.79%)	0 (0.00%)	14 (6.63%)
Divorced				0 (0.00%)	1 (0.47%)	0 (0.00%)	1 (0.47%)	
Widow				0 (0.00%)	2 (0.94%)	0 (0.00%)	2 (0.94%)	
Other				1 (0.47%)	7 (3.31%)	0 (0.00%)	8 (3.79%)	
<i>Smoking</i>	Yes			82 (38.86%)	102 (48.34%)	3 (1.42%)	187 (88.62%)	
	No			9 (4.26%)	15 (7.10%)	0 (0.00%)	24 (11.37%)	

screening ADHD. This scale included 30 items subdivided into four subscales of attention deficiency, hyperactivity, impulsivity and sluggish cognitive tempo with cut-off point about 39. Internal consistency of the total questionnaire reported as 0.91 and that of subscales were 0.9 for attention deficiency, 0.77 for hyperactivity, 0.87 for impulsivity, and 0.86 for sluggish cognitive tempo (Barkley, 2011). The internal consistency of Iranian version was 0.7 to 0.86, respectively (Sadeghi et al., 2017). The internal consistency of BAARS-IV in the present study was 0.97 for inattention, 0.96 for hyperactivity, 0.96 for impulsivity, and 0.96 for sluggish cognitive tempo. Moreover, all of the items have optimal factor loading from 0.63 to 0.81 in second-order confirmatory factor analysis with a suitable model fit index.

**Emotion-regulation skills questionnaire (ERSQ)** The 27-item emotion regulation skills questionnaire by Berking and Znoj (2008) was used. It consisted of nine subscales on awareness, sensation, clarity, understanding, acceptance, tolerance, confrontation, self-support, and modification. Internal consistency of the original scale was reported by producers of the scale and was good (Berking & Znoj, 2008). In the Iranian sample evaluation, the psychometric features of the scale were checked by Moradi Siah Afshadi (2015) and the reliability and validity of the study was approved in the Iranian context. The internal consistency of the ERSQ total score in this study was 0.94 and all of the items remain for computing the total score due to good factor loading with 0.79 to 0.83 in one order confirmatory factor analysis with optimal model fit index.

**Intrinsic motivation inventory (IMI)** The Intrinsic Motivation Inventory (45 items) by Ryan (1982) was used to examine the intrinsic motivation of ADHD students. The instrument assesses participants interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, and perceived choice while performing a given activity, thus yielding six subscale scores. Recently, a seventh subscale has also been added to tap the experiences of relatedness. The inventory consists of 45 items on a 7-point Likert scale which some of them scored negatively. The internal consistency of overall inventory was reported as appropriate both in original study (McAuley et al., 1989) and Iranian sample. In this study, the internal consistency of the total scale was 0.88 and confirmatory validity was approved with optimal model fit index and factor loading of items ranged from 0.73 to 0.82.

**Barkley deficits in executive function scale (BDEFS)** For measuring behavioral inhibition, problem-solving and time-management, Executive functions scale of Barkley (BDEFS) was administered. This scale involved 89 items with five subscales which three of them were used in this study. Items 1 to 21 measured time-management, items 22 to 45 assessed problem-solving and items 46 to 64 measured behavioral inhibition. The validity of the scale in university students

population in English version was approved as appropriate instrument (Kamradt et al., 2021). Internal consistency of all items and each subscale were determined as reliable tool in Farsi versions (Mashhadi et al., 2015). In the present study, the confirmatory factor analysis of the time-management subscale was evaluated as suitable with factor loading ranging from 0.61 to 0.86 and Alpha Cronbach 0.94. The confirmatory factor analysis of the Problem-solving subscale showed appropriate results with factor loadings from 0.70 to 0.79 and Alpha Cronbach 0.92. The internal consistency of behavioral-inhibition was 0.96 and the confirmatory factor analysis revealed good findings with factor loading from 0.74 to 0.85 and a very acceptable model fit index.

## Statistical analysis

After careful consideration of ADHD screening, university students who were informed and included in the study, filled out the questionnaires in online system due to the Covid-19 pandemic and then took part in diagnostic interview. About 0.05% missing data were replaced by mean scores. The statistical analysis of the study was checked through structural equation modeling. Before running SEM analysis, total scores of all variables computed and model was performed with obvious variables. Emotion regulation and intrinsic motivation have been considered as input, time-management, behavioral-inhibition, and problem-solving as mediators, and ADHD subscales of Barkley as output variables of analysis. An estimate approach for the SEM is to minimize residuals which are the difference between the sample covariance,  $S$ , and the model estimated covariance, say  $\Sigma(\theta)$ , where  $\theta$  is the set of model parameters. To do so, it needs to minimize a function of residuals ( $S - \Sigma(\theta)$ ). There are many available fitting functions used for such the estimation purpose; however, The most commonly employed function for SEM is the maximum likelihood (ML) function,  $F_{ML}(\theta)$ , which is

$$F_{ML}(\hat{\theta}) = \ln|\hat{\Sigma}| - \ln|S| + \text{tr}(S\hat{\Sigma}^{-1}) - (p + q),$$

where  $p + q$  is the number of observed variables in the model (Wang & Wang, 2019).

Bootstrapping technique with biased-corrected percentile method two tailed significance (BC) was adopted to evaluate the significance of the direct/indirect effects with 200 bootstrap resamples. The analysis was performed with AMOS 24 and SPSS 24.

## Ethical considerations

This manuscript was part of comprehensive research about ADHD in university students' samples that were approved by the Human Research Ethics committee with the ethical code.

Approval regarding data collection and compliance with all participants' rights, including confidentiality of participants' information and predicting possible harm, and informing participants about possible risks before taking part in the research, as well as approval in the field of authors' participation and informed consent of participants regarding the publication of scientific results, obtained from the ethics committee. To comply with the principle of confidentiality of the information of the participants in the study, the participants were asked to preferably choose a nickname for themselves and mention it in the demographic section (this was just for easier follow-up of their results).

## Results

### Descriptive statistics of variables

Table 2 presents descriptive statistics of the variables among university students with ADHD.

As shown in the Table 2, all of the variables range in normal distribution. The Pearson correlation coefficients among the variables of the study are reported in Table 3.

Based on the results all variables are correlated ( $p < 0.001$ ). As demonstrated from the result of this section, the prerequisites of SEM analysis (correlation among variables included in the model) was approved.

### Structural equation modeling

The structural equation model is displayed in Fig. 1. All coefficients are indicated by the arrows. As in the model, emotion-regulation and intrinsic motivation were considered as input variables, behavioral-inhibition, time-management and problem-solving were the mediating variables and ADHD subscales (attention deficiency, hyperactivity, impulsivity, and sluggish cognitive tempo) considered as the output of analysis (all in obvious mode). The results showed almost

week fit indices:  $\chi^2 = 1018.695$ ,  $df = 10$ ,  $\chi^2/df = 101.869$ ,  $P = 0.001$ ,  $CFI = 0.75$ ,  $GFI = 0.58$ ,  $PCFI = 0.13$ ,  $PGFI = 0.12$ . Based on Hu and Bentler (1999), the fitting indices of the model is not so well. Thus, the modification indices of AMOS software were applied to check the new model. Figure 2 presents the corrected model. The results showed that the model fit the data well:  $\chi^2 = 27.081$ ,  $df = 1$ ,  $\chi^2/df = 27.081$ ,  $P = 0.001$ ,  $CFI = 0.99$ ,  $GFI = 0.97$ ,  $PCFI = 0.02$ ,  $PGFI = 0.02$ .

The possible direct and indirect effects of variables on ADHD subscales as dependent variables are presented in Table 4. The direct effects of intrinsic motivation on hyperactivity and impulsivity were significant ( $p < 0.05$ ) and direct effect of emotion-regulation on SCT was significant ( $p < 0.05$ ). Direct effects of both input variables (intrinsic motivation and emotion-regulation) on all of mediating variables (behavioral-inhibition, problem-solving and time-management) were all significant ( $p < 0.05$ ). Between direct effects of mediating variables on ADHD subscales, solely the direct effects of time-management on attention deficiency, hyperactivity and impulsivity were significant ( $p < 0.05$ ).

Based on the results in Table 4, the hypothesized corrected model fit with the observed data well, therefore, the main idea of this study was approved.

## Discussion

This study examined the links between intrinsic motivation and emotion-regulation and ADHD subscales (attention deficiency, hyperactivity, impulsivity, and sluggish cognitive tempo) through the mediation of (behavioral-inhibition, problem-solving, and time-management). In this study, we postulated that all EFs factors did not have a similar contribution to ADHD problems. Emotion-regulation and intrinsic motivation in ADHD students had much more important effects on other EFs elements such as behavioral-inhibition,

**Table 2** Descriptive Data of Intrinsic Motivation, Emotion-Regulation, Behavioral Inhibition, Problem-Solving, Time-Management, And ADHD Subscales in University Students with ADHD

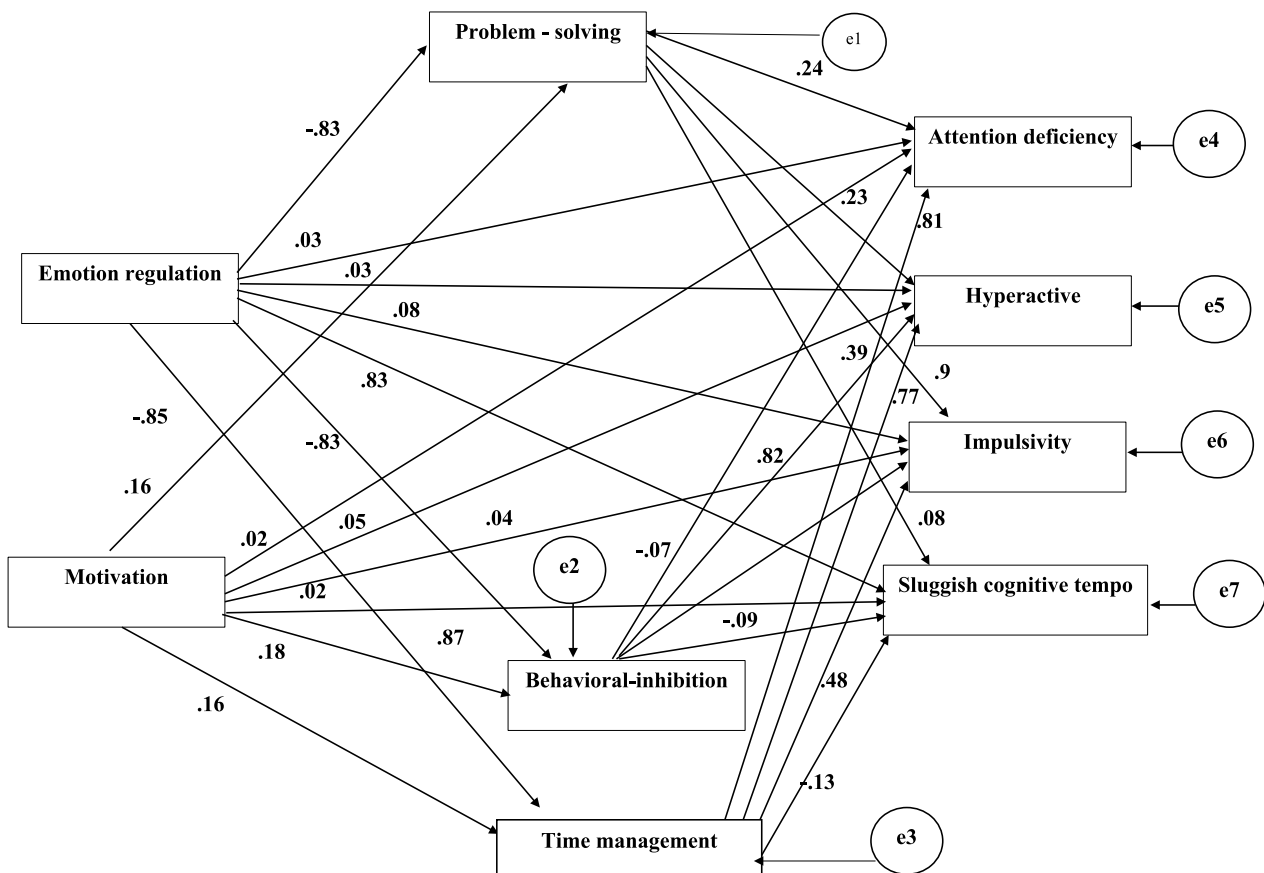
Variable	M	SD	Max	Min	Kurtosis	Std. error	Skewness	Std. error
Intrinsic Motivation	141.40	25.52	224	47.45	1.12	0.33	-1.06	0.16
Emotion- Regulation	81.03	31.74	135	27	-1.10	0.33	-0.33	0.16
Behavioral Inhibition	31.70	18.35	76	19	-0.24	0.33	1.17	0.16
Problem-Solving	40.24	23.11	96	24	-0.06	0.33	1.22	0.16
Time-Management	36.93	21.99	84	24	-0.49	0.33	1.09	0.16
ADHD Attention deficiency	24.18	6.93	36	9	0.35	0.33	1.38	0.16
ADHD Hyperactivity	7.14	3.48	20	5	-0.27	0.33	1.17	0.16
ADHD impulsivity	11.69	5.38	16	4	0.32	0.33	1.35	0.16
ADHD Sluggish Cognitive Tempo	13.46	5.73	45	9	-1.08	0.33	-0.45	0.16
ADHD Total	56.48	18.76	82	37	0.16	0.33	0.59	0.16



**Table 3** Pearson Correlation Coefficients Between Considering Variables for Students With ADHD

	1	2	3	4	5	6	7	8	9
1.Emotion-Regulation	1								
2.Intrinsic Motivation	0.32***	1							
3.Behavioral-Inhibition	-0.85***	-0.41***	1						
4.Time- Management	-0.87***	-0.40***	0.82***	1					
5.Problem- Solving	-0.80***	-0.42***	0.80***	0.79***	1				
6.Attention Deficiency	-0.81***	-0.41***	0.78***	0.84***	0.82***	1			
7.Hyperactivity	-0.80***	-0.47***	0.83***	0.82***	0.81***	0.77***	1		
8.SCT	-0.85***	-0.37***	0.85***	0.77***	0.79***	0.79***	0.78***	1	
9.Impulsivity	-0.79***	-0.42***	0.80***	0.75***	0.87***	0.83***	0.85***	0.79***	1

\*\*\* is significance in 0.001



**Fig. 2** Hypothesized model of EFs and ADHD with emotion regulation and intrinsic-motivation as in put of the model, problem-solving, behavioral-inhibition, and time-management as mediators and ADHD subscales as output of the models

problem-solving, time-management, and also ADHD. To support the idea, we collected data from 211 university students with ADHD and examined the hypothesized model. To evaluate the fit of the model, indices were checked which all were in a good range and the main hypothesis was certified. Concerning the direct and indirect effects of the analysis, the mediating role of behavioral inhibition, problem-solving, and time-management are partial due to significant some direct effects. Thus, it is obvious that motivation and

emotion-regulation have both direct and indirect effects to ADHD subscales (Fig. 3).

Based on the descriptive findings of the subtype of ADHD in a diagnostic interview, the results show a salient point. A previous study in this field which is run right before corona pandemic, determined the rate of inattention subtype to be 18.3%, the hyperactive/impulsive type to be 8.3%, and the mixed type to be 70% (Salvi et al., 2019), while in the present study, the type of inattention has reached 30.3%,

**Table 4** Direct and Indirect Effects of Analysis

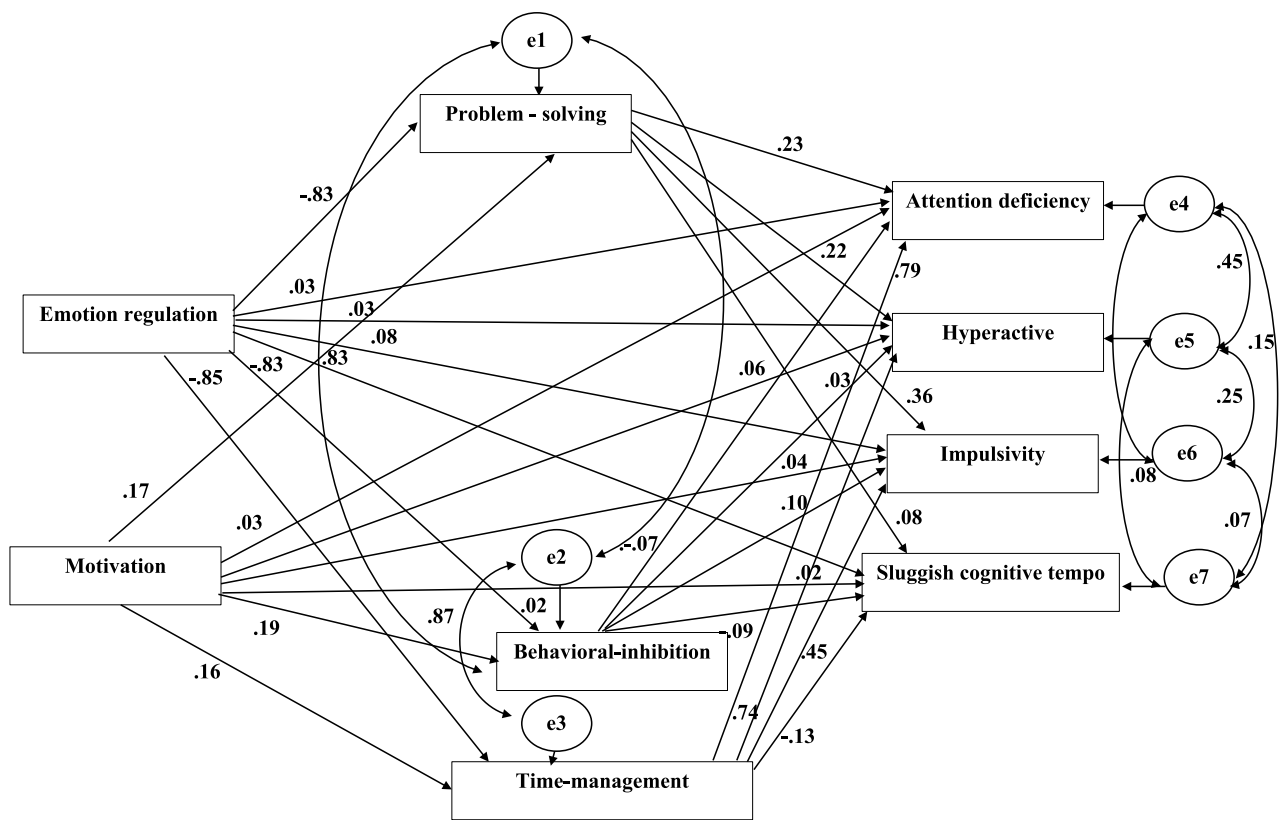
Independent variable	Dependent variable	Effect type	Standard estimate	BC
<i>Intrinsic Motivation</i>	Behavioral-Inhibition	Direct	.15	.028
	Problem-solving	Direct	.13	.021
	Time-management	Direct	.15	.026
	Attention Deficiency	Direct	.03	.106
	Hyperactivity	Direct	.08	.002
	Impulsivity	Direct	.05	.005
	SCT	Direct	.02	.370
<i>Emotion Regulation</i>	Behavioral-Inhibition	Direct	-.80	.028
	Problem-solving	Direct	.81	.023
	Time-management	Direct	.82	.023
	Attention Deficiency	Direct	.02	.715
	Hyperactivity	Direct	.03	.504
	Impulsivity	Direct	-.09	.797
	SCT	Direct	.82	.004
<i>Behavioral Inhibition</i>	Attention Deficiency	Direct	-.82	.628
	Hyperactivity	Direct	.06	.565
	Impulsivity	Direct	.09	.578
	SCT	Direct	-.12	.066
<i>Problem-solving</i>	Attention Deficiency	Direct	.25	.405
	Hyperactivity	Direct	.11	.769
	Impulsivity	Direct	.39	.147
	SCT	Direct	.10	.284
<i>Time Management</i>	Attention Deficiency	Direct	.80	.004
	Hyperactivity	Direct	.80	.005
	Impulsivity	Direct	.46	.003
	SCT	Direct	.14	.087
<i>Intrinsic Motivation</i>	Attention Deficiency	Indirect	.14	.023
	Hyperactivity	Indirect	.14	.026
	Impulsivity	Indirect	.13	.019
	SCT	Indirect	.11	.021
<i>Emotion Regulation</i>	Attention Deficiency	Indirect	-.80	.005
	Hyperactivity	Indirect	-.81	.008
	Impulsivity	Indirect	-.77	.004
	SCT	Indirect	-.13	.028

the hyperactive/impulsive type has reached 27.5%, and the mixed type has reached 42.5%. The change of pattern in subtypes of ADHD compared to previous results could be attributed to the Covid-19 pandemic. The time of data collection for this study was at the same time as the peak of the Covid-19 pandemic. However, the changes that occurred in the pattern of subtypes of the disorder during the corona epidemic can be considered an independent research.

Rigorously, the results of this analysis are consistent with various studies. For example, Morsink et al. (2022) discussed how different views of internal motivation interact with ADHD and introduce a model to better understanding of the intrinsic motivation effect on ADHD. In line with this

study, the direct and indirect effects of internal motivation on the dimensions of ADHD was also evident in this research. Moreover, Reeve (2018) referred to the motivational influence in controlling behavior or behavioral inhibition. As evident from the results of present analysis, the effect of intrinsic motivation on behavioral inhibition was confirmed. Also, Shaw et al. (2014) reported that that emotion regulation had a very important role in ADHD, especially in adulthood. Relatedly, (Sibley et al., 2016) presented tips to improve time-management skills in ADHD people because he believed that that time-management was not satisfactory in ADHD people.

According to Deci and Ryan (2008) in self-determination theory, intrinsic motivation and self-regulation occur as a



**Fig. 3** Hypothesized model of executive functions on ADHD with emotion regulation and intrinsic-motivation as in put of the model, problem-solving, behavioral-inhibition, and time-management as mediators and ADHD subscales as output of the models and modification indices

result of less conflict between the external environment and internal tendencies. In situations where intrinsic motivation is low, one can expect behavior to be driven by every possible tendency. Therefore, behavioral inhibition is greatly reduced in such a state. Implanting the concept of autonomy, through the mobilization of inner motivations, will give a sense of control over the actions. Thus, the direct effect of intrinsic motivation on behavioral inhibition could be explained. On the other side, low intrinsic motivation can result from feelings of low competency, insignificance, and feelings of inadequacy (Deci & Ryan, 2008). These negative attitudes and beliefs lead to distortion in problem-solving, which can explain the direct effect of intrinsic motivation on problem-solving. Based on the self-determination theory, the main function of intrinsic motivation is to perform goals and achieve inner satisfaction. It is obvious that when an individual does not have a good intrinsic motivation, many aspects to appropriate performance such as time-management could be destroyed. A person with low intrinsic motivation shows incomplete and undesirable time management, which causes the goals and internal satisfaction not to be achieved. Also, some researchers refer to the idea that motivation is very important in time-management (Fanny & Usman, 2020). Not having a good perception of time passing or setting schedules without enough knowledge

about dedicating time to plans specifically in the academic period can lead to chaos in almost any aspect of life.

The direct effect of intrinsic motivation on the hyperactivity sub-scale of ADHD could be explained by the difficulty in regulating arousal state in ADHD people (Sergeant, 2005). In Fact, in ADHD people’s lower level of intrinsic motivation causes problems in modifying movements and activity. The direct effect of intrinsic motivation on impulsivity sub-scale of ADHD could be noticed by the delay aversion pathway (Reeve, 2018). Internal motivation could facilitate controlling behavior and wait over time with delay in response. According to (Sonuga-Barke, 2002), ADHD people develop an aversion to delay tendency that is responsible for impulsivity and acting without proper choice and making decisions.

The significant direct effect of emotion-regulation on behavioral-inhibition is greatly due to the effect of self-regulation in effortful control which is the ability to regulate behaviors, emotions, and cognitions. Since ADHD people suffer from a low level of emotion-regulation, behavioral inhibition is very poor and unsuitable. In fact, for having control over behavior and preventing hasty responses, it is necessary to possess appropriate emotion regulation skills. As Walcott and Landau (2004) have noted in their study with the sample of ADHD boys, emotion regulation and

behavioral inhibition are related. The direct effect of emotion-regulation on time-management is consistent with the research of (Zimmerman, 2008). Zimmerman argued that emotion regulation is the key factor in self-management and time-management. The significant direct effect of emotion-regulation on problem-solving could be explained by the role of the emotions regulatory system in modifying cognition and reaching a good level of problem-solving. For example, curiosity, puzzlement, bewilderment, frustration, pleasure, elation, satisfaction, anxiety, and despair are important parts of problem-solving process (DeBellis & Goldin, 2006). Finally, the direct link from emotion-regulation to the sluggish cognitive tempo (SCT) should be noticed. To explain this important direct effect, we should note to internalizing psychopathology, which is rooted in emotional turbulence including rumination (Olatunji et al., 2013), depression, and anxiety (Becker & Willcutt, 2019). When a person gets lost in confusing emotions and is not able to reach a good regulation, some kind of foginess appears that is an account for SCT. This condition is very popular in ADHD people since they could not manage their emotions and concentrate on specific issues. In contrast, they get stuck in mental confusion, slowed behavior and thinking, lethargy and drowsiness, and excessive daydreaming which all are symptoms of SCT.

The indirect effects of analysis which are the indirect effects of intrinsic motivation and emotion-regulation to four ADHD subscales were all significant. Based on the results, it is obvious that time-management has a mediating role in the indirect effects of analysis. Indeed, intrinsic motivation and emotion-regulation influence time-management, and hence time-management alter ADHD subscales. Since the direct effects of the input variables to time-management were also significant, so the indirect effects of this analysis were partial. In explaining the mediating role for time-management and not considering mediating role for behavioral-inhibition and problem-solving, we should refer to the stronger role of time-management in comparison to other mediators such as behavioral inhibition and problem-solving in multi-variables analysis.

The strengths of the present study include a novel idea of hierarchical level standing for EFs instead of same contribution for each domain of EFs in occurring ADHD symptoms. Also, this study examined the model between university students with ADHD without any considerable circumstances for them.

## Limitations

Like all of the other studies, this research also had some limitations. Firstly, lack of statistical control of cognitive capabilities is the most important ones. Future studies could apply more rigorous control variables. Secondly, the participants were not selected from clinical sample who referred to clinics and evaluated by specialists. If possible, future studies can use participants who have referred to specialized

ADHD clinics. Thirdly, the hypothesized model of this study, was not examined in male and female with ADHD separately. Since, the path of the model may be different in male and female samples with ADHD, future studies can consider this point and compare the model in male and female samples. Fourth, this study could be continued with a research in the field of effectiveness considering the results of this study. Future studies can use the findings of this research for the effectiveness of psychological interventions and training of EFs in the treatment of ADHD. Fifth a serious problem in the process of collecting data was the loss of online appointments or face-to-face interviews by the participants, which prolonged the diagnostic procedure to some extent. A large number of questions in the online evaluation phase was another problem, which was partially covered by randomly dividing the questions into two parts on two consecutive days. Participants were also asked to take a short break wherever they felt tired and then continue. However, the large number of questions may have influenced the results, so it is suggested to consider better methods to control this issue in future studies.

## Conclusion

In conclusion, emotion-regulation and intrinsic motivation have fundamental effects on other aspects of EFs in ADHD people and their symptoms. Emotion-regulation and intrinsic motivation had direct significant effects on behavioral-inhibition, time-management, and problem-solving. Also, emotion-regulation had a direct effect to one of the ADHD subscales, SCT, while intrinsic motivation had direct effects to hyperactivity and impulsivity. None of the input variables had a direct effect to attention deficiency. Both of the input variables had indirect effects to all of four ADHD subscales which according to results time-management was mediating the indirect effects. Therefore, it can be concluded that all dimensions of EFs do not have the same and equivalent role in causing ADHD and emotion-regulation and motivation have the fundamental roles.

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**Authors contribution** All authors contributed to the study design. Mahboubeh Moradi Siahafshadi has gathered data and interpret the results and written the first draft of the manuscript. Shole Amiri has conceived the original idea of study, supervised it and edited the final version of the manuscript. Houshang Talebi has contributed to the methodology, data analysis and result sections.

**Data availability** The datasets were analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Competing interest** The authors declare there are no conflicts of interest.

**Consent** Written informed consent was obtained from all individual participants for taking part in the study and publishing the data in the scientific journals.

**Ethical approval** This manuscript was part of comprehensive research about ADHD in university students' samples that were approved by the Human Research Ethics committee with the ethical code of: IR.UI.REC.1399.100. Approval regarding data collection and compliance with all participants' rights, including confidentiality of participants' information and predicting possible harm, and informing participants about possible risks before taking part in the research, as well as approval in the field of authors' participation and informed consent of participants regarding the publication of scientific results, obtained from the ethics committee. To comply with the principle of confidentiality of the information of the participants in the study, the participants were asked to preferably choose a nickname for themselves and mention it in the demographic section (this was just for easier follow-up of their results).

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