



Research Paper: Do Computer Games Affect Arousal Level in Children With Attention/Deficit Hyperactivity Disorder?



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Running Title Computer Games and Arousal in Children With ADHD

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ABSTRACT

Background: Attention-Deficit Hyperactivity Disorder (ADHD) is a common psychiatric complication in children, which affects about 5-10% of the population. Although ADHD is a multifactorial disorder, one of its causes refers to dysfunction of the arousal.

Objectives: The current study aimed at investigating whether a change in arousal level in children with ADHD differs from the control group.

Materials & Methods: To achieve the research objectives, the mean Skin Conductance Levels (SCLs) as an useful index of measuring arousal levels was used, and then the changes during resting eyes-open condition and after that during playing computer games on 15 male subjects aged 8 to 12 years as the ADHD group and other 15 age-gender matched in the control group were evaluated; then, the recorded data were analyzed with repeated measures analysis of variance. The study was conducted in a child mental health services center in Tabriz, Iran, in 2012.

Results: Across conditions, mean SCL index was lower in the ADHD group than that of controls. Computer games caused a significant increase in SCL index, which was not different between the both groups. The findings showed a similar pattern of changes during testing conditions for both the ADHD and control groups $F(1,28)=85.90; P<0.0001$.

Conclusion: Results confirmed a primary deficit related to autonomic hypoarousal in children with ADHD. The SCL results, in addition to behavioral findings, made the authors to suggest that the dynamic changes of activities in neural system are impaired in children with ADHD.

Keywords: Attention, Attention Deficit Disorder With Hyperactivity, Arousal, Video games

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Highlights

- Autonomic arousal level is low in children with ADHD.
- Skin conductance level is low in children with ADHD.
- High-stimulating computer games increase arousal level in children.

Plain Language Summary

Nowadays computer games are among the most widely used applications in the world and they are the fastest growing form of entertainment among children. Parents are always worried about how computer games affect the learning and quality of life of their children. Several studies have already showed that computer games can have different impacts on learning, anxiety, anger, arousal, and so on in normal children. But what about the children with Attention/Deficit Hyperactivity Disorder (ADHD). Are they affected differently by computer games? In fact yes, they are. In the present study, we tried to find some explanations to describe how computer games affect arousal level in children with ADHD. To conduct our research, we designed a quasi-experimental study and examined 30 boys of the city of Tabriz aged between 8 and 12 years in two groups of children with ADHD and without ADHD as the control group, using Mean Skin Conductance Levels (SCLs) as a useful index of measuring arousal levels. Then, we analyzed the obtained data with repeated measures analysis of variance. The results of our study showed that playing computer games increased arousal in children with ADHD and dynamic changes of activities in neural system are impaired in children with ADHD compared to the control.

Introduction

Attention-deficit Hyperactivity Disorder (ADHD) is a common psychiatric disorder in children, which affects about 5-10% of the population [1]. According to the Diagnostic and Statistical Manual of Mental Disorders-5th edition (DSM-5TM), ADHD is a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development and has symptoms presenting in two or more settings. Several symptoms should be present before age 12 years [2]. These symptoms can cause several dysfunctions in various individual, social, and also family levels. The other general implications of ADHD are costs of treatment, family stress, family breakdown, educational problems, increased risk of drug abuse, etc. [3].

While the causes of ADHD are not entirely known yet, many of psychologists believe that the disorder rises from a dysfunction of the arousal. Over the last two decades, several studies suggested that ADHD is related to a hypoaroused state of brain, which may have impact on gross motor hyperactivity and variable response patterns been observed on sustained attention tasks [4]. One of the first theories, which put forth testable hypotheses, was the optimal stimulation theory [5], which states that ADHD symptoms, such as hyperactivity and restless-

ness, represent a functional set of responses to a chronic state of underarousal.

In this regard, “cortical hypoarousal” model considers ADHD as a result of underarousal in the Central Nervous System (CNS) [6], reflected by an elevation in Electroencephalography (EEG) theta alongside of a decrease in beta activity or increased theta/beta ratio [7]. Several studies proposed increased theta/beta ratio as a sign of underarousal and a fair marker of ADHD [8]. Recently, series of clinical/experimental investigations were performed to examine the physiologic/neural basis of arousal in children with ADHD. In this regard, the theta/beta ratio was calculated and interpreted in several studies in an underarousal framework. Later, such interpretations were confirmed by measuring Skin Conductance Levels (SCL) reduced in ADHD cases [4, 8-11]. SCL was mostly defined as a change in the electrical characteristics of the skin in situations of induced anxiety or stress, which can be measured by recording the electrical resistance of the skin or weak currents generated by the body.

In recent years, there have been a lot of empirical researches on the arousal levels of children with ADHD, which used different stimuli for manipulating and measuring the arousal levels via physiological indices of arousal such as SCL and EEG. One of the first studies

in this field examined the effects of methylphenidate on Autonomic Nervous System (ANS), CNS, and behavioral changes in children with ADHD. They found that SCL was lower in children with ADHD than the controls and this difference was meliorated after medication. Medication with such stimuli increases subjects' arousal to normal level, which may result in the improvement of the behavioral issues [12].

In the other study, Nazari et al. examined the effect of the Continuous Performance Test (CPT) on delta, theta, alpha, and beta frequency bands in 16 children with ADHD [13]. They recorded high-resolution EEG during eyes-open resting and then CPT performance. They reported a significant difference in CPT compared with that of eyes-open in EEG activities in children with ADHD. Specially, switching to CPT induced an increase in alpha power in children with ADHD, while the alpha power decreased in controls, which may reflect a primary deficit associated with cortical hypoarousal in ADHD cases. Another study tested the impact of caffeine on electrodermal levels in children with ADHD, which suggests an anomalous arousal mechanism across conditions; mean SCL was also lower in children with ADHD than that of the controls, which confirms hypoarousal in ADHD cases [14].

Recent studies also emphasized close relationship among electrodermal activity, EEG, and arousal; they encouraged further explanations for suggested linkage. According to such studies, to investigate the arousal levels in children with ADHD, a stimulus to manipulate the arousal level of subjects is required. In the present study, computer games were used as a stimulus to manipulate the arousal levels of children with ADHD. Computer games are the most widely consumed stimuli and it is the fastest growing form of entertainment worldwide [15]. There was lots of interest in the use of computer/video games for learning and behavioral changes with an increasing number of articles Available Online in international conferences, peer-reviewed journals, and research projects devoted to this topic during recent years. Computer games have a considerable range of impacts on behavior changes as well as perceptual, cognitive, and physiological outcomes [16].

A few studies showed that different types of computer games may cause considerable arousal [17]. Schneider et al. showed that arousal (measured by SCL) remains high for a longer time during playing video games compared with the resting state [18]. Most of the computer games lead to arousal that implies the level of activation related to the emotional experience. It ranges from very

excited or energized in high stimulating games, to less exciting at low stimulating one [16]. Bailey and West found some contrasting effects of playing an action video game compared with a non-action video game on both neural activities related to target processing and also the perception of emotion in facial expression [19].

Like the studies mentioned above, in the present study, the importance of research in areas associated with computer games was recognized; the current study mainly aimed at using computer game as a stimulus to investigate changes in arousal levels in children with ADHD. The current study also aimed at comparing the effects of two kinds of computer game, with high and low stimulating rate, on the arousal levels of two matched groups of children with and without ADHD, using SCL as an index of arousal.

Materials and Methods

The present study has a quasi-experimental design. Participants were selected by convenience sampling method. Thirty male subjects, aged 8 to 12 years, participated in the study. Fifteen participants were males without ADHD recruited from local schools. Another 15 male participants diagnosed with ADHD and met DSM-IV criteria for ADHD, were selected from a child mental health services center in Tabriz in 2012; ADHD diagnosis was confirmed in case group by a psychiatrist and a psychologist agreed on their scores on DSM-IV based on parent/child interviews and the Conner parent rating scale-revised Long [20] as an assessment scale.

The sample size of both groups was determined based on minimum sample size proposed for quasi-experimental designs [21]. Inclusion criterions for both groups were male gender, age range 8 to 12 years, IQ range 85-115 based on the Raven IQ Test [22], and the duration of playing the computer games. For this purpose, sampling was limited to male children within the age range of 8 to 12 years who played most of the week days on computer that was assessed by asking a few questions from the subjects.

An exclusion criterion for both groups was an IQ less than 85 based on the Raven IQ test. An exclusion criterion for the control group was ADHD diagnosis, which was assessed using the child symptom inventory-4, parent questionnaire [23]. Children with ADHD signs such as anxiety, depression, or tics disorders were excluded from the study. The comorbidities were controlled via clinical interviews. It should be noted that subjects with ADHD were off-treatment during experiments. Three

participants from the ADHD group were off-treatment for at least 48 hours prior to the testing and 12 subjects were treatment-naïve at the time of the study. All participants were asked to refrain from drinking caffeine two hours before the experiment session.

Each participant was tested individually. An informed consent form was signed by each participant's parents prior to the testing. After an initial greeting to participants, the required explanations were provided for them. Subjects were then sat in front of computer screens and were asked to put their hands on the table. They were asked to stare at a blank page displayed on the monitor screen and relax, since motor activity is expected to elicit increases of SCL.

The experiment was conducted in the following five steps and SCL data were recorded continuously during each condition: 1. In the beginning, the basic arousal states of the participants were assessed for five minutes during a resting eyes-open condition; 2. In this step, arousal levels were manipulated, while the participants played one of the games for five minutes (i.e. "Call of Duty" or "Angry Birds"), while the order counterbalanced across participants; 3. Soon after, the arousal levels of the participants were re-examined in a resting period for five minutes; 4. After a short break, the second part of the experiment began and the participants were asked to play another game for five minutes; and 5. In the final step, the arousal levels were measured again for five minutes in a resting period.

High and low stimulating games

In order to select the computer games as a stimulus, a total of 20 most popular games among children were selected. After an initial review of the games, a total of 30 children were allowed to play them (based on the sample under study), and accordingly, the arousal level of children were measured using the Self-Assessment Manikin (SAM) technique, which is a reliable rating system in-

roduced by Lang and Bradley [24]. The children were asked to score each game in terms of its arousal level using the SAM technique based on a five-point Likert scale (1 represents calm and 5 very excited). The game "Angry Birds" with the mean score of 2 was considered as the low stimulating game and "Call of Duty" with the mean score of 4.5 was identified as the high stimulating game.

Electrodermal activity

SCL is a method to measure the electrodermal activity. SCL is a frequently used technique since it is non-invasive and quickly responds to emotional and psychological stimuli. It records electrodermal activity using a skin conductance sensor (P/N: SA9309M), Procomp Infiniti Encoder (model SA7500, serial no. CA5215), and Biograph Infiniti software version 5.1.3 (Thought Technology Ltd. Canada). The non-adjacent fingers (the index and ring) of the left hand were selected and a conductive electrode was strapped on inside of each finger.

Statistical analysis

After calculating the mean SCL for each condition as the dependent variable, data were entered into a 2×5 Repeated Measures Analysis of Variance (RANOVA), with group (ADHD vs. Non-ADHD) as the inter-group factor, and condition (arousal level during five steps: test 1 vs. the low stimulating game vs. test 2 vs. the high stimulating game vs. test 3) as the intra-group factor. Before applying RANOVA, mean SCL data were natural log-transformed. The normality of SCL data distribution was confirmed by the Shapiro-Wilk Test.

Results

The Mean±SD of age and duration of playing computer games for both the control and ADHD groups are shown in Table 1. Results of t-test indicated that the two groups were matched by age and duration of playing computer games.

Table 1. Mean±SD of age and duration of playing computer game in the study groups using t-test

Factor	Groups		Test Statistic
	ADHD	Control	
N	15	15	
Age (month)	108.84±1.03	112.8±1.05	t=0.87, df=28; P=0.38
Duration of playing computer games (min)	167±1.3	207±1.3	t=0.92, df=28; P=0.36

Table 2. Mean±SD of the natural log transformed SCL score for the study groups

Groups	Condition				
	Test-1	The Low Stimulating Game	Test-2	The High Stimulating Game	Test-3
ADHD	0.725±0.432	0.995±0.480	0.818±0.594	1.187±0.643	1.308±0.516
Control	1.931±0.222	2.170±0.157	2.103±0.189	2.467±0.166	2.482±0.174

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Table 3. Summary results of repeated measures analysis of variance

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Condition	6.919	4	1.729	44.43	0.0001	0.68
Condition×group	0.91	4	0.023	0.58	0.67	0.02
Error	4.36	112	0.039			
Group	56.16	1	56.16	85.901	0.0001	0.75
Error	49.100	28	0.909			

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The Mean±SD of the SCL are shown in [Table 2](#) and [Figure 1](#), and the summary of repeated measures of ANOVA are presented in [Table 3](#). Homogeneity of variance-covariance matrices assumption was tested with Box's M ($P>0.05$); the homogeneity of variance was actually met. Since data did not violated the sphericity assumption, as checked by the Mauchly Test of sphericity ($P>0.05$), adjusting the degree of freedom for the Greenhouse-Geisser correction was not applicable. Results revealed that the main effect of group [$F(1,28)=85.90$, $P<0.0001$, $\eta^2=0.75$] and the main effect of condition [$F(4,112)=44.43$, $P<0.0001$, $\eta^2=0.68$] were significant; however, the interaction effect of group×condition was insignificant [$F(4,112)=0.58$, $P=0.67$, $\eta^2=0.02$].

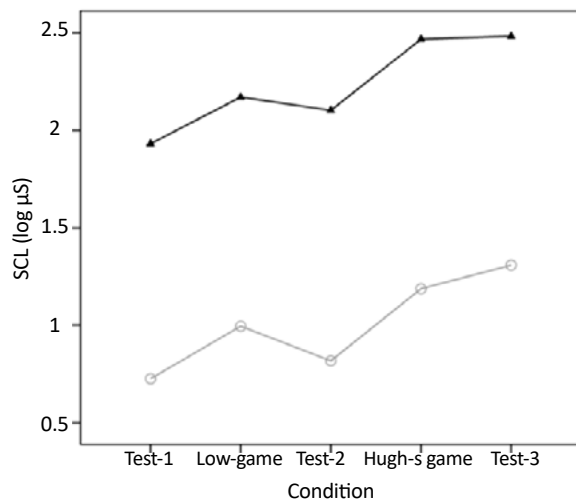
Independent t-test showed that the mean SCL was significantly lower in children with ADHD (Mean±SD=1.006±0.484) compared with that of controls (Mean±SD=2.230±0.162) ($P<0.0001$) ([Figure 1](#)). Pairwise comparisons showed significant differences between all pairs; test-1 (Mean±SD=1.328±0.699), the low stimulating game (Mean±SD=1.582±0.693); test-2 (Mean±SD=1.460±0.784), the high stimulating game (Mean±SD=1.827±0.797); test-3 (Mean±SD=1.895±0.706). As shown in [Figure 1](#), while mean SCL was considerably higher for the control group compared with that of the ADHD group, similar pattern of changes was observed during different conditions for both the study groups.

Discussion

The present study mainly focused on the arousing effect of computer games on children with ADHD in terms of SCL changes. As expected, in the current cross-over study, the mean SCL was significantly lower in the ADHD group than the control group that was in agreement with the ADHD hypoarousal result of some studies [[4](#), [6](#), [7](#), [25-27](#)]. It was also consistent with the result of a recent study, which used anticipatory Electrodermal Response (EDR) as a differentiating arousal index between children with ADHD and the healthy ones and showed that the ADHD group exhibited significantly lower autonomic reactivity to anticipated consequences [[28](#)].

In fact, in the hypoarousal model, ADHD is associated with a hypoaroused state [[6](#)] and ADHD symptoms such as hyperactivity and restlessness represent a set of responses to a chronic state of underarousal [[4](#)]. Also, as expected from the minority of studies, using psychophysiological methods in game research areas [[17](#), [29](#), [30](#), [31](#)] increased SCL, supporting its role as a simple stimulant. The computer-game-induced increase in arousal did not differ between groups. There was an overall increase in arousal level from the baseline to the gaming phase in the both ADHD and control groups.

The SCL increase in the ADHD group supports the generally accepted viewpoint that the common symp-



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Figure 1. Mean SCL (natural log μS) of test-1, the low stimulating game, test-2, the high stimulating game, and test-3

For the ADHD (gray line with circle) and control (black line with triangle) groups

tomatic treatment and stimulant medications elevate arousal levels compared with normal values. This may reduce the need for hyperactive behavior, which can be attributed to self-stimulation and raise of arousal level. In other words, computer games act as a stimulus on elevating children's arousal levels. This finding was consistent with those of the studies using different stimuli to manipulate and increase arousal level in children with ADHD such as caffeine [14], CPT (continuous performance test) [13], and methylphenidate [11]. In these studies, similar to the current study, some stimuli could make changes and elevate arousal level in children with ADHD.

Further analyses in the current study confirmed that despite a significantly greater mean SCL during the gaming phases than the baselines, the computer-game-induced arousal increased in the controls were greater than that of ADHD subjects. Furthermore, the stimulating rate of games was dose-dependent, although it was not apparent in the ADHD group, indicating the failure of stimulant-arousal linkage at the individual level.

The study results showed that the nervous systems of children with ADHD attempt to raise arousal towards normal functional levels by self-stimulation. This extends the anomalous arousal level long-proposed in ADHD to an anomaly in arousal mechanism. ADHD is characterized by difficulties in adjusting physiological arousal [32]. In this frame work, the current study results were in line with those of another study, [14] which evaluated caffeine effects on resting-state electrodermal levels in ADHD cases, and suggested an anomalous arousal

mechanism in ADHD functionally related to impairment in one symptom dimension. Furthermore, the study also aimed at comparing the stimulating effect of two computer games on the arousal levels of both the ADHD and control groups.

Data analysis showed that although both computer games increased SCL than the baseline, the high stimulating game had a more significant impact on increased SCL than that of the low stimulating game. The same results were obtained by both the ADHD and control groups. To explain these findings, the nature of these computer games should be recognized. In the current study, the "Call of Duty" was considered as the high stimulating computer game. The game takes place in a surrealistic battlefield, and has a content of violence and flight. On the other hand, "Angry Birds", used as the low stimulating computer game, is an acclaimed game because of its successful combination of addictive game play, comical style, and low price.

To furthermore explain the efficacy of computer games, psychophysiological responses of these games should be elicited based on their content in order to index their emotional arousal. There was a linear, positive, dose-dependent relationship between the violence obtained from a game and its stimulating effect, which increases SCL [17]. This result suggested reliable differences between the game events in the stimulating responses elicited in terms of arousal effect. It is well established that tasks requiring active coping, like the violent computer games, elicit emotional arousal accompanied by increased SCL, which is mediated by the Sympathetic Nervous System (SNS) [33]. This proposal gives new understanding on the arousal disturbances in ADHD, which suggests that it may be a dysregulation of arousal rather than simply hypoarousal [25].

Conclusion

To summarize, the current study indicated that children with ADHD were in a state of autonomic hypoarousal as indexed by their lower SCL. Computer games increased arousal, confirming their usefulness as a stimulant in behavioral studies on ADHD. The study also revealed clear dose-dependent stimulant effects of computer games in terms of increased SCL, the "gold standard" of arousal measures. The extent of this stimulant effect was similar in the both groups. Furthermore, the mechanism of the stimulant effect appears to differ in the ADHD from the control group; with a linear dependence on the stimulating rate of the games in controls, which did not found in the ADHD group. Moreover, the study showed a signifi-

cant relationship between computer game stimulating effects and arousal levels elicited.

The results of the study should be interpreted in terms of some limitations. Limitations include the specific experimental context in which the stimulation occurred, which made it difficult to assess the influence of fear and excitement of the experimental circumstance on the autonomic measures of participants. One of the other limitations of the study was the selection of a low stimulating computer game among many others, due to the stimulating nature of all computer games. Also, the single-gender nature of the study can be noted as the other limitation. Furthermore, the study findings cannot be generalized to all children with ADHD, due to the small sample size and using only one gender. Further investigations in this field on larger samples including both genders can provide a better understanding of ADHD.

Finally, the present study on autonomic responses measured by SCL using computer games as a stimulus in ADHD confirms that SCL changes, while playing computer games, reflect the impact of stimulants on the arousal.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles were considered in this article. The participants were informed about the purpose of the research and its implementation stages; They were also assured about the confidentiality of their information; Moreover, They were allowed to leave the study whenever they wish, and if desired, the results of the research would be available to them.

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Authors contributions

The authors contributions is as follows: Conceived and designed: Mohammad Ali Nazari and Maryam Taghavi Jelodar; carried out the tests: Maryam Taghavi Jelodar and Hasan Shahrokhi; performed the statistical analysis, analyzed the data and drafted the manuscript: Mohammad Ali Nazari and Hasan Shahrokhi; and All authors read and approved the final manuscript.

Conflict of interest

The authors declared no conflict of interest.

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