EFFECT OF SMARTPHONE USE ON COGNITIVE FUNCTIONS IN ADOLESCENTS: A CROSS SECTIONAL STUDY

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Abstract

Background: Smartphones have become an essential part of daily life. Smartphones and related mobile technologies have the potential to affect a wide range of cognitive domains. This reduces an individual's social implication in the real world and, as a consequence, his or her psychological well-being. **Purposes**: This study aimed to evaluate the cognitive functions including attention, memory, logical reasoning and visual processing in adolescents who use smartphones and to determine the difference between no-risk and high-risk smartphone users in cognitive functions. **Methods:** Two hundred ninety two normal adolescents from both sexes participated in this study, Their age ranged from 12-16 years. They were divided into two groups according to the score of smartphone addiction scale. Group A included no-risk smartphone users and group B included high-risk smartphone users. Assessment of cognitive functions was conducted by assessed by Rehacom computerized software and Youth-Pediatric Symptom Checklist (Y-PSC) for evaluating their behavioral and emotional functions. **Results:** The results of the present study showed statistically significant differences between both groups regarding to (Y-PSC) score ($p = 0.003$). There was no significant difference in alertness with and without warning sound between both groups ($p = 0.85$, 0.89) respectively while there was a significant decrease in selective attention regarding reaction speed and reaction control of group B compared with that of group A ($p = 0.04$, 0.03) respectively. There was no significant difference in divided attention regarding auditory and visual modality between both groups ($p = 0.42$, 0.82) respectively. Regarding spatial number search, there was no significant difference in attention and neglect/ hemianopsia between both groups while there was a significant decrease in working speed of group B compared with that of group A ($p = 0.36$, 0.45, 0.01) respectively. No significant difference was found between both groups in working memory while there was significant decrease in memory for words of group B compared with that of group A ($p = 0.79$, 0.01). Significant decrease was found in logical reasoning of group B compared with that of group A ($p = 0.03$). There was a significant decrease in number of correct solutions of group B compared with that of group A ($p = 0.03$). Regarding visual field sub-domains (visual scanning and visual field deficits), no significant difference was found between both groups ($p = 0.29$, 0.11, 0.5). **Conclusion**: Prolonged smartphone usage was significantly associated with decreased cognitive functions. Specifically, the high risk smartphone users demonstrated a significant decrease in selective attention, working speed, memory for words, and logical reasoning.

Keywords: Smartphone, Cognitive functions, Smartphone addiction scale, Youth-Pediatric Symptom Checklist, Adolescents.

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INTRODUCTION

Cognition is the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses. It encompasses various aspects of high-level intellectual functions and processes such as attention, memory, knowledge, decision-making, planning, reasoning, judgement, perception comprehension, language, and visuospatial function, among others. Cognitive processes use existing knowledge and generate new knowledge [1].

Cognition can be divided into different domains of ability, which can be tested separately; the most important of these are attention and concentration, memory and learning, language, visuospatial function and executive functions [2].

Computerized cognitive assessment is one of the advances in computer technology have produced a vast amount of software for use in cognitive assessment. The use of computerized cognitive assessment devices is receiving increasing attention in clinical practice, research, and clinical trials [3]. Rehacom is a comprehensive and sophisticated system of procedures for computer assisted cognitive assessment. According to Schuhfried [4] and HASOMED [5] there is a number of screening modules available for use, and these are improving and expanding on each release.

According to the American Psychological Association (APA) [6], it identified six major benefits of computerized assessment including: (1) automated data collection and storage, (2) greater efficiency of use, (3) release of the clinician from test administration to focus on treatment, (4) greater sense of mastery and control for the client, (5) reduced negative self-evaluation among clients that experience difficulty on the computer and (6) greater ability to measure aspects of performance not possible through traditional means, such as latency, strength and variability in response patterns.

The use of smartphones facilitates access to disparate social media opportunities, messaging capabilities, internet access, as well as other purposes. However, excessive smartphone use may have negative effects on adolescents, especially since adolescence is a sensitive period characterized by the occurrence of many changes physiologically, psychologically and socially. This suggests that this age group can be particularly vulnerable to the negative effects of cell-phone use due to risks of childhood onset mental disorders characterized by a disturbance in impulse control and cognitive flexibility [7].

Some studies have indicated that the excessive use of smartphones has negative effects on human psychology [8]. This reduces an individual's social implication in the real world and, as a consequence, his or her psychological well-being because it produces the kind of isolation, loneliness, and depression the individual seeks to ease by connecting to the internet [9].

MATERIALS AND METHODS

- **Participants**

Two hundred and ninety two normal adolescents from both sexes were selected from governmental preparatory and secondary schools in Qalyub city according to sample size calculation using G-power test (effect size = 0.65, power = 0.95, $\alpha = 0.05$). Their age ranged from 12-16 years, they were smartphone users according to the score of smartphone addiction scale ranged from 10-60 points to indicate no-risk and high- risk smartphone users. The cut-off value for males was 31 and 33 for females. Those who scored higher than the cut-off values are considered as high-risk for smartphone addiction [10]. All adolescents were at a score of 27 or below according to the score of youth pediatric symptom checklist [11,12]. They were able to follow instructions during the assessment procedures. Children with visual or auditory disabilities, neurological or musculoskeletal disorders, perceptual disorders and epilepsy or autistic features were excluded from the study.

- **Study Design**

This cross-section study was approved by Research Ethical Committee of the Faculty of Physical Therapy, Cairo University (P.T.REC/012/003288). The purpose and the protocol of this study were explained to all children and their parents before conducting the study. Informed consent was obtained from all the participant's caregivers.

- **Outcome measures**

All adolescents completed the following assessments including; smartphone addiction scale to determine no-risk and high- risk smartphone users and Youth-Pediatric Symptom Checklist to assess their behavioral and emotional functions. Rehacom computerized software used for assessment of cognitive functions.

PROCEDURES FOR SELECTION

- **Assessment of the severity of smartphone addiction**

Each adolescent was examined in a separate, quiet and comfortable room in the school facilities during the regular school schedule. The smartphone addiction scale is a well-validated specific questionnaire used to identify the level of the smartphone addiction risk. Smartphone Addiction Scale-Short Version (SAS-SV) is a revised version of the Smartphone Addiction Scale (SAS). It examines smartphone addiction and yields a total score that is indicative of the severity of smartphone addiction; higher scores indicate more severe addictions. It consists of 6 factors (daily-life-disturbance, positive-anticipation, withdrawal, overuse, tolerance, and cyberspace-oriented relationship) which are accessed through 10 items, based on self-reporting six-point Likert scale (1: "strongly disagree", 2: "disagree", 3: "weakly disagree", 4: "weakly agree", 5: "agree", and 6: "strongly agree"). The scores are to total up to be measured. The cut-off value for males was 31 and 33 for females. Those who scored higher than the cut-off values are considered as high-risk for smartphone addiction**.**

- **Assessment of behavioral and emotional functions**

Youth-Pediatric Symptom Checklist (Y-PSC) is one version of the Pediatric Symptom Checklist which is a psychosocial screen designed to evaluate emotional, behavioral and cognitive problems. The youth self-report (Y-PSC). The Y-PSC was designed to screen adolescents for psychosocial problems in school settings. As a self-report measure, it is useful for identifying symptoms of internalizing disorders, such as anxiety or depression, which are often missed by parents. The Y-PSC can be administered to adolescents ages 11 and up. The PSC consists of 35 items that are rated as "Never," "Sometimes," or "Often" present and scored 0, 1, and 2, respectively. The total score is calculated by adding together the score for each of the 35 items. The cutoff score for the Y-PSC is 30 or higher. Items that are left blank are simply ignored (i.e., score equals 0). If four or more items are left blank, the questionnaire is considered invalid.

PROCEDURES FOR EVALUATION

- **Assessment of cognitive functions**

Rehacom computerized software was used in this study to assess cognitive functions in adolescents. The areas of cognitive domains that were assessed were attention, logical reasoning, memory and visual processing. There were 9 screening modules divided into: four attention sub-domains (alertness- selective attention- divided attention- spatial numbers search), two memory sub-domains (working memory- memory for words), one logical reasoning sub-domain and two visual field sub-domains (visual scanning - visual field).

STATISTICAL ANALYSIS

The statistical analysis was done by using statistical package of social studies sciences (SPSS) version 25 for windows. Descriptive statistics as the mean and standard deviation were calculated for demographic characteristics including age, weight, height, BMI and also for all measured variables. Inferential statistics as independent t-test was used for between group comparisons. The statistical significance level was set at 0.05.

RESULTS

Comparing the general characteristics of the subjects of both groups revealed that there were no significant differences between groups in the mean values of age, weight, height and BMI (P >0.05) **(Table 1).**

Comparing the mean values of smartphone addiction scale score revealed that there was a statistically significant increase in SAS of the group B compared with that of the group A (p = 0.001) **(Table 2).** Comparing the mean values of Y-PSC score revealed that there was a significant increase in Y-PSC of the group B compared with that of the group A (p = 0.003) **(Table 3).**

Comparing the mean values of attention sub-domains revealed that there was no significant difference in alertness with and without warning sound between group A and B (p = 0.85, 0.89) respectively, while there was a significant decrease in reaction speed and reaction control of group B compared with that of group A (p = 0.04, 0.03) respectively, There was no significant difference in auditory modality and visual modality between both groups (p = 0.42, 0.82) respectively. Regarding spatial number search, there was no significant difference in attention and neglect/ hemianopsia between both groups while there was a significant decrease in working speed of group B compared with that of group A (p = 0.36, 0.45, 0.01) respectively. **(Table 4).**

Comparing the mean values of memory sub-domains revealed that there was no significant difference in working memory between both groups (p = 0.79), while there was significant decrease in memory for words of group B compared with that of group A (p = 0.01) (Table 5). Comparing the mean values of logical reasoning sub-domains revealed that there was a significant decrease in number of correct solutions of group B compared with that of group A (p = 0.03) Regarding visual field sub-domains (visual scanning and visual field deficits), no significant difference was found between both groups (p = 0.29, 0.11, 0.5) **(Table 6).**

Table 1. Comparison of the mean values of demographic characteristics between both groups

	Group A	Group B	p-values
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	
Age (years)	14.09 ± 1.28	14.34 ± 1.39	0.11
Weight (kg)	51.23 ± 8.21	52.29 ± 10.24	0.32
Height (cm)	157.32 ± 8.66	158.9 ± 9.02	0.12
BMI (kg/m²)	20.74 ± 2.64	20.29 ± 3.02	0.17

$\bar{x}$: Mean; **SD:** Standard deviation; **p values:** Probability values

Table 2. Comparison of the mean values of SAS score between both groups

	Group A	group B	p-values
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	
SAS	24.03 ± 6.15	37.94 ± 5.09	0.001*

$\bar{x}$: Mean; **SD:** Standard deviation; **p values:** Probability values; ***p:** significant

Table 3. Comparison of the mean values of Y-PSC score between both groups

	Group A	group B	p-values
	x̄ ± SD	x̄ ± SD	
Y-PSC	20.38 ± 4.04	21.8 ± 4.11	0.003*

x̄: Mean; **SD:** Standard deviation; **p values:** Probability values; ***p:** significant

Table 4. Comparison of the mean values of attention subdomains between both groups

Attention	Group A	Group B	p-value
	x̄ ± SD	x̄ ± SD	
Alertness			
Without warning sound	-0.34 ± 0.7	-0.35 ± 0.73	0.89
With warning sound	-0.34 ± 0.71	-0.32 ± 0.72	0.85
Selective attention			
Reaction speed	0.43 ± 0.41	0.31 ± 0.55	0.04*
Reaction control	-0.21 ± 0.7	-0.41 ± 0.88	0.03*
Divided attention			
Auditory modality	-0.01 ± 0.69	0.06 ± 0.68	0.42
Visual modality	0.35 ± 0.37	0.34 ± 0.42	0.82
Spatial number search			
Working speed	0.51 ± 0.88	0.22 ± 1.14	0.01*
Attention	-0.32 ± 0.71	-0.39 ± 0.75	0.36
Neglect/ hemianopsia	0.67 ± 0.61	0.62 ± 0.76	0.45

x̄: Mean; **SD:** Standard deviation; **p values:** Probability values; ***p:** significant

Table 5. Comparison of the mean values of memory sub-domains between both groups

Memory	Group A	Group B	p-value
	x̄ ± SD	x̄ ± SD	
working memory	0.22 ± 1.03	0.25 ± 0.97	0.79
memory for words	0.39 ± 0.66	0.17 ± 0.82	0.01*

x̄: Mean; **SD:** Standard deviation; **p values:** Probability values; ***p:** significant

Table 6. Comparison of the mean values of logical reasoning and visual field sub-domains between both groups

	Group A	Group B	p-value
	x̄ ± SD	x̄ ± SD	
Logical reasoning			
Number of correct solutions	0.09 ± 0.63	-0.06 ± 0.66	0.03*
Visual field			
Visual scanning	-0.36 ± 0.43	-0.33 ± 0.43	0.5
Visual field			
Deficit on the right	-0. 11± 0.2	-0. 08± 0.22	0.29
Deficit on the left	-0.18 ± 0.35	-0.12 ± 0.24	0.11

x̄: Mean; **SD:** Standard deviation; **p values:** Probability values; ***p:** significant

DISCUSSION

The purpose of this study was to investigate the effect of smartphone use on cognitive functions in adolescents. Over the last decades, the number of smartphone owners has been constantly increasing to reach 83.72% of the world's population in 2022 (compared to 49.40% in 2016), with the highest percentage of smartphone users being adolescent students (high school graduate or less). Smartphones are practical, and provide easy, convenient access to many services including unrestricted communication with others, academic materials access, and leisure online activities [13]

This study was conducted on 292 normal adolescents, their age ranged between 12 to 16 years. It was reported that teenagers between the ages of 12 to 16 who use mobile phones frequently are more susceptible to cognitive and psychological problems, which highlights the need for further investigation into the potential impact of long-term mobile phone use on adolescent development. This came in agreement with **Girela et al.** [14] and Wacks and Weinstein [15] who mentioned that excessive smartphone use has been linked with impaired cognitive functions and mental health problems among children, adolescents, and young adults.

Some longitudinal studies have found that more frequent mobile phone use among teenagers (11–21 years) predicted a higher incidence of depressive and anxiety symptoms [16,17] as well as higher hyperactivity/inattention and conduct problems [18,19]. Similarly, some cross-sectional studies have shown that greater mobile phone use among children and adolescents (5–19 years) was particularly related to concentration problems, attention problems, hyperactivity symptoms, and conduct problems [14,15].

The results of the present study showed statistically significant increase in (Y-PSC) score of group B compared with that of group A. There was no significant difference in alertness with and without warning sound between both groups respectively while there was a significant decrease in selective attention regarding reaction speed and reaction control of group B compared with that of group A respectively. There was no significant difference in divided attention regarding auditory and visual modality between both groups respectively. Regarding spatial number search, there was no significant difference in attention and neglect/ hemianopsia between both groups while there was a significant decrease in working speed of group B compared with that of group A respectively. No significant difference was found between both groups in working memory while there was significant decrease in memory for words of group B compared with that of group A. Significant decrease was found in logical reasoning of group B compared with that of group A. There was a significant decrease in number of correct solutions of group B compared with that of group A. Regarding visual field sub-domains (visual scanning and visual field deficits), no significant difference was found between both groups.

In accordance with the results of this study, a cross-sectional study in 6- to 16-year-old students found increased attention problems, among other symptoms as headaches, fatigue, and concentration problems [20]

As regard youth-pediatric symptom checklist (Y-PSC), it was found that there was a significant increase in Y-PSC of the group B compared with that of the group A. This was consistent with **Liu et al.** [21] who found that such psychometric evidence is critical for PSC-Y, considering that group similarities and variations in psychosocial problems among youth have attracted much attention from researchers. Mohta and Halder [22] found that there was negative relationship between smartphone addiction and overall psychological health in adolescents.

The results of the present study revealed that there was no significant difference in alertness with or without warning sound between both groups. This disagree with the findings of Ekstrom and Beaven [23] who reported that exposure to smartphone blue light LED at night diminished alertness and cognitive functions the next day.

Regarding selective attention in the present study, it was significantly decreased in smartphone addiction group as there was a significant decrease in reaction speed and reaction control in group B compared to group A. This came in agreement with Liebherr et al. [24] who found that smartphone use has significant impact on attention. Also, Kim et al. [25] studied the relationship between prolonged usage of smartphone and symptoms of depression, anxiety, and attention-deficit/hyperactivity in South Korean adolescents. They reported that there was a significant relationship between smartphone addiction and attention-deficit. Hong et al. [26] found that excessive smartphone use can lead to neurological changes where the brain of the affected individual has been found to have significantly higher levels of gamma-aminobutyric acid (GABA), which results in poorer attention and control as well as being more easily distracted.

The results of the present study regarding memory subdomains revealed that there was no significant difference in working memory between both groups. This come in agreement with Hadar et al. [27] who reported that there was no significant difference between both groups in working memory as well as in inhibition performance.

The results of comparison between both groups revealed that there was a significant decrease in memory for words of group B compared with that of group A. This finding comes in agreement with Mohta and Halder [22] who reported that there was significant difference in working memory between the smartphone addiction group and the non addicted control group. They reported that working memory involves holding information temporarily and processing it. A probable reason for lesser error in case of adolescents without smartphone addiction is that with continuous use of smartphone similar functions are carried out; the individual has the task of continuously responding to a stimulus. A number of applications that are carried out for example in gaming require the use of such mental operations repeatedly. It brings the individual into practice and thereby reduces the number of errors. This would, however, not necessarily translate when having to retrieve information stored for long time in the memory or has not been used recently. Hence, it would not provide a permanent advantage over healthy controls. Also, Wacks and Weinstein [15] found that the excessive use of smartphone can lead to impaired working memory.

On the other hand, this result contradicts with the findings of **Morikawa et al.** [28] who reported that there was significant difference in memory for words in smartphone users. Smartphone users' memory for words was superior compared with both non-users with social isolation and without.

Regarding visual scanning and visual field, the results of the present study revealed that there was no significant difference in deficit on the right, deficit on the left and visual field deficit between both groups. This comes in agreement with **Wang et al.** [29] who found that there were not statistically significant associations between smartphone overuse and myopia, blurred vision, or poor vision. Also, this consistent with the findings of Lanca and Saw [30] who revealed that screen time was not significantly associated with the prevalence and incidence of myopia.

On the other hand, this result disagrees with **Erdem and Efe** [31] who reported that smartphone addiction was associated with visual problems. Also, **Maples et al.** [32] reported that under the experimental condition of responding to questions and carrying on a conversation using a cell phone, the subjects' visual field areas were significantly constricted compared with the control condition of not using a cell phone.

As regard logical reasoning there was a significant decrease in number of correct solutions of group B compared with that of group A. This comes in agreement with **Stothart et al.** [33] and **Kushlev et al.** [34] who revealed that problematic smartphone use would make users' attention more likely to be disturbed by the alerts and notifications of smartphones, and even damage cognitive functions, including logical reasoning ability.

On the other hand, this result is inconsistent with findings of Peña and Enrique [35] who reported that using video games on smartphones can develop logical thinking. Thus, it has been found that use of video games enables students and young people in general to interpret situations more critically and reflectively, strengthening decision making and helping them develop their capacity for teamwork and logical thinking.

CONCLUSION

The findings of the present study indicated that prolonged smartphone usage was significantly associated with decreased cognitive functions. Specifically, the adolescents with smartphone addiction demonstrated a significant decrease in selective attention, working speed, memory for words, and logical reasoning.

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Conflict of interest

Authors report no conflict of interest.

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