Family Medicine & Primary Care Review 2022; 24(1): 92–99, https://doi.org/10.5114/fmpcr.2022.113022

REVIEWS

ISSN 1734-3402, eISSN 2449-8580

Exploring the link between smartphone overuse and cognitive decline: a scoping review

IN-GYU YOO[1, A–G], JI-HYE DO[2, D–F]
ORCID ID: 0000-0003-2884-2253

[1] Department of Occupational Therapy, College of Medical Sciences, Jeonju University, Jeonju, Republic of Korea
[2] Department of Occupational Therapy, The Graduate School, Yonsei University, Seoul, Republic of Korea

A – Study Design, **B** – Data Collection, **C** – Statistical Analysis, **D** – Data Interpretation, **E** – Manuscript Preparation, **F** – Literature Search, **G** – Funds Collection

Summary **Background.** The technological innovation of smartphones and various software has made our lives more convenient. However, the negative effects of our excessive dependence on them cannot be overlooked.
Objectives. The purpose of this scoping review was to understand the relationship between the use of smartphones and our cognitive functions, as well as to present important research directions for the future.
Material and methods. All relevant literature, published as of 1 March 2020, was searched using the following databases: CINAHL, Embase, PubMed, PsycINFO. The framework proposed by Arksey and O'Malley, which has a review process of five stages, was used for the review.
Results. Overuse of smartphones was found to be related to decrease concentration, working memory and cognitive suppression. In particular, the results of concentration and cognitive restraint function could be interpreted as a result of the impulsive behaviour pattern of an individual, and the results of working memory could be explained by the principle of overload due to the limitation of the user's working memory capacity. The association between smartphone usage levels and cognitive functions was compared. The results of this scoping review highlight the need for future research to thoroughly assess the user's impulse and associated cognitive functions for smartphone use.
Conclusions. Furthermore, it will be necessary to consider ways to improve user convenience by developing therapeutic paradigms that can reduce the overuse of smartphones.
Key words: attention, cognition, memory, smartphone.

Yoo IG, Do JH. Exploring the link between smartphone overuse and cognitive decline: a scoping review. *Fam Med Prim Care Rev* 2022; 24(1): 92–99, doi: https://doi.org/10.5114/fmpcr.2022.113022.

Background

The use of smartphones is now a necessity, not a choice. The technological innovation of smartphones and various software has made our lives more convenient. However, the negative effects of our excessive dependence on them cannot be overlooked [1]. According to a recent study, almost half of the American population showed hyper-reliance on smartphones, and more than 90% of young people aged 19–29 reported daily use of smartphones. According to a report in the UK, researchers have explained that this dependence leads to anxiety and fear of cell phone inactivity [2, 3]. Many recent studies have explained the relationship between smartphones and cognitive functions and have argued that the dependence on smartphones may increase user anxiety and negatively affect cognitive functions [4–6].

Research on the relationship between smartphone use and cognitive function has mainly focused on electromagnetic radiation (EMF) exposure. However, researchers have not consistently explained the direct link between EMF exposure and cognition [7–10]. The Amsterdam-born Children's Study (ABCD) and the Australian ExPOSURE cohort study also did not find a connection between cognitive function and smartphone use [11]. In previous studies of smartphones, response time, short-term memory, attention, information processing speed and executive functions were not directly affected by RF exposure [12, 13]. Some studies have demonstrated an association between exposure to EMF and improved spatial perception [14–16]. Another recent study described the characteristics of the users as the main influencing variables for smartphone addiction and explained that the urgency and impulsivity of the users can lead to negative consequences of smartphone addiction [17]. Smartphone use is receiving much attention, mainly in children and adolescents with developing nervous systems, and many studies have demonstrated possible effects on attention and working memory. However, the direction of effectiveness has been inconsistent, and only some studies have been relevant [7, 18]. Despite these studies, consistent results are still lacking. In particular, it will be necessary to confirm whether the use of smartphones itself is a problem, or whether the addictive behavioural characteristics of smartphone use are a problem. In addition, in order to solve these problems, it will be necessary to confirm which therapeutic direction is correct to plan. Studies on the effects of each age group are also insufficient. At present, studies have been conducted on various age groups, such as children and adults, but it was difficult to find a study that clearly explained the difference in influence. Some researchers also describe this discrepancy as a matter of study design and study group characteristics (e.g. duration of exposure and localisation of participants). Accordingly, in this review, we conducted a scoping review of literature in order to analyse the studies conducted so far and to find directions for future research.

Methods

Search strategy

This review is intended to provide answers to specific questions instead of evaluating all literature. We examined the literature, aggregated quantitative data about what has been done and summarised and interpreted literature from a specific research area. Although a connection between smartphone use and cognitive function has been studied in various ways, a systematic review of the two variables has not yet been sufficiently conducted.

Stage 1: Identifying the research question

We searched each database for literature published in the last 10 years up to 1 March 1. The framework proposed by Arksey and O'Malley, which includes a 5-step review process, was used. In the first step, we reviewed the relevant studies and selected three research questions. The initial exploratory research questions were: 1) What topics have been mainly explained about the problems of using smart phones over the past 10 years? 2) What differences can be identified for each study by age group? 3) What is the future research direction of the researcher, and what should be considered when proceeding?

Stage 2: Identifying relevant studies

In the second stage, the following criteria were included: a) journal article types, b) published from 2009 to present, c) written in English, d) research aimed at determining the impact of smartphone use on cognitive function (studies that confirmed the impact of smartphone use during work were defined into double work studies and were excluded from this review). We combined the search terms (smartphone OR mobile phone OR cellular phone OR cell phone OR cellphone OR hand phone) AND (cognition OR cognitive function), with humans and English language as limits. Four electronic databases were used: CINAHL, Embase, PubMed, PsycINFO. The article was exported and managed using the Refworks referencing software program.

Stage 3: Study selection

In the third step, the title and abstract were reviewed and selected. The rest of the study was read in full and evaluated according to the inclusion criteria. We set targets as specific as possible, so this review did not include studies that confirmed the impact of smartphone use during assignments. The reason was to clearly confirm the characteristics of smartphone use itself rather than the influence caused by the double task. Publications published in posters, books, magazines or other languages were excluded.

Stage 4. Charting the data

From the final 14 articles included, data was extracted from five categories that were used to analyse the full-text review, including study design, participants, age, cognitive function and main finding. Data extraction was independently conducted by a reviewer. The process of study selection is shown in the flow diagram. The findings were presented with a narrative description in tables (Figure 1).

Stage 5. Collating, summarizing, and reporting results

In the fifth stage, data was systematically categorised and organised using a data charting form developed using Microsoft Excel (Table 1). In the past decade, major research trends and results have been presented, focusing on the association between smartphones and cognitive functions.

As shown in Figure 1, the electronic database search excluded duplicate articles. A total of 1,976 unique titles were selected, and only two additional articles were identified by searching the reference list. According to the inclusion criteria, a total of fourteen articles were included after a selection based on title, abstract and full text. A total of nine papers had been published in the past 5 years, and a total of five papers had been published in the last 3 years. The studies were conducted in Europe (*n* = 8), Oceania (*n* = 3), Asia (*n* = 2) and the Middle East (*n* = 1). Eight studies included a randomised controlled trial (RCT), and four were longitudinal cohort studies. The rest were various single group pre- and post-clinical trials, as shown in Table 2. Three of the eight RCTs had a smaller group size (less than 20),

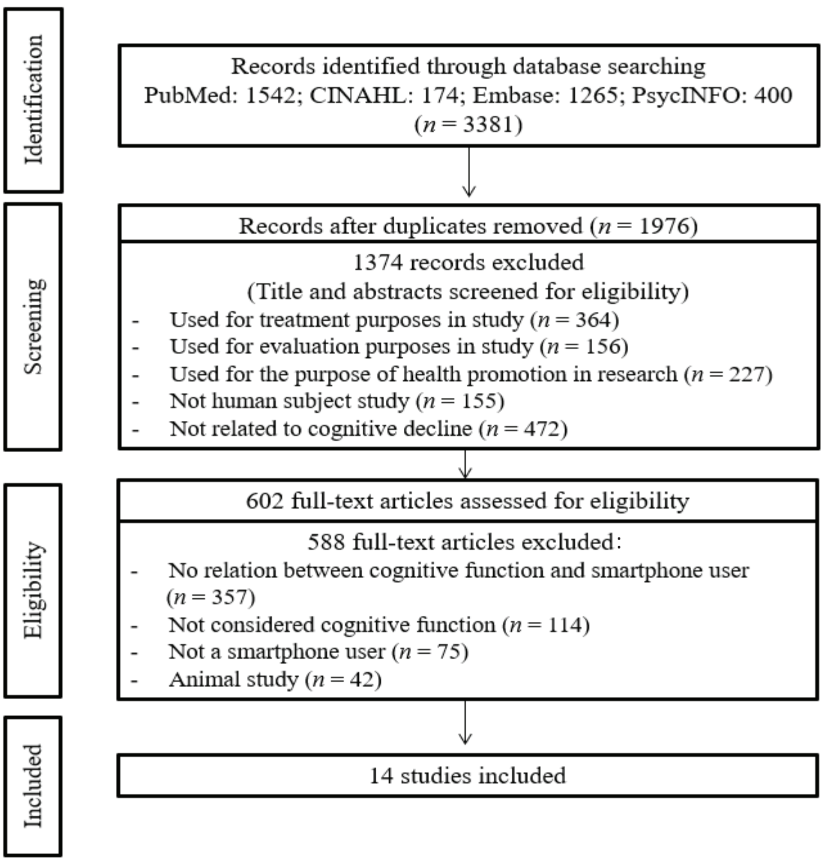

Figure 1. Flowchart illustrating inclusion process

Table 1. Summary of evaluated cognitive functions in 14 studies

Article	Fundamental processes								Intermediate processes			Higher order process		
	Attention	Memory					Processing speed	Inhibition	Learning	Visual motor processes	Cognitive flexibility	Social cognition	Executive
		VF	ST	IL	WK	PP							
Children to adolescent													
Abramson et al. (2009) [7]	x				x				x				
Bhatt et al. (2017) [11]	x				x			x	x				x
Guxens et al. (2016) [8]							x	x		x	x		
Thomas et al. (2010) [24]	x				x				x				x
Schoeni et al. (2015) [9]		x											
Adult													
Canale et al. (2019) [17]					x								
Dumbrava (2016) [19]						x							
Eltiti et al. (2009) [20]					x								
Hadar et al. (2017) [25]	x				x			x				x	
Hadlington (2015) [21]					x								
Hartanto et al. (2016) [26]					x			x				x	x
He et al. (2020) [22]					x								
Kalafatakis et al. (2017) [23]				x									
Wiholm et al. (2009) [13]			x										

VF – Verbal figure, ST – Spatial, IL – Implicit, WK – Working, PP – Prospective.

one had a crossover design, and the other two were pilot-level studies. A total of 4,863 participants from fourteen studies were included in the study and were recruited based on the inclusion criteria shown in Table 2. Most participants were children, adolescents and young adults. In five studies, the children and adolescents were under the age of 18, and nine studies were carried out on adults over 20. Most participants in the studies did not have any special physical or mental disorder, and when grouped, they were classified as heavy smartphone users or the control group. Table 2 details the different characteristics of the participants for each study.

Results

Smartphone use time

The duration of smartphone usage was between 5 minutes to 4.5 hours under experimental conditions, and this usage was reported on a weekly or daily basis. There were differences in cell phone use by age group: children and adolescents under 20 years old reported 2 to 8 calls per week and SNS (Social Network Service). In adults over 20 years of age, the study was conducted by classifying them as heavy users. In the two studies, the user condition was described as an evaluation tool for grasping the level of smartphone use, and subjects with a MPPUS of 108.5 or higher or an SAS score of 32.8 or higher were defined as heavy users. Table 2 details the different exposure levels in each study.

Cognitive functions

Various cognitive functions were used in each study to assess cognitive changes. Eight studies used memory as the main evaluation variable [13, 17, 19–24]. Cognitive processing can be divided into three processes. First, fundamental processes are mainly described as the ability to acquire and store information, and second, intermediate processes are described as the ability to process information. Finally, the higher order process is the ability to execute the processed information, which is described as high-level cognitive function. In a study on adults, various types of memory, such as verbal and figural memory, spatial memory, prospective memory, implicit memory and working memory, were used as measurement variables. Three studies on children and adolescents used attention, work memory and learning abilities as common assessment variables [7, 11, 25]. Among them, one study on children and adolescents considered executive function and inhibition ability together with attention, working memory and learning abilities [11]. The evaluation of cognitive function items applied in each study is described in detail in Table 1.

Impacts of mobile phone overuse

In the fundamental processes, the increase in the use of smartphones was associated with a decrease in participants' attention. In two studies on children and adolescents, Abramson's study reported an increase in the response time of the detection task [7], and Bhatt's study also reported a decrease in accuracy and an increase in response time [11]. In one study on adults, Hadar's study reported a reduction in accuracy in numerical processing tasks [25].

There were partially consistent results regarding working memory in all the studies. In three studies on children and adolescents, Abramson's study reported a decrease in the accuracy of working memory caused by smartphone use [7], and Thomas' study showed statistically significant deterioration in the working memory of heavy smartphone users. However, Schoeni's study had no significant change in working memory was confirmed [9]. In six studies on adults, Canale's study suggested the possibility of decreased visual working memory [17], and Hadlington's study showed statistically significant deteriora-

Table 2. Summary of study characteristics and key results from 14 studies

Article citation	Country	Study design, Participants	Age, Time use	Cognitive function	Main finding
Children to adolescent					
Abramson et al. (2009) [7]	Australia	Cross-sectional clustered study (*n* = 317)	13 years, 8 times/week – Phone call 8 times/week – SMS messages	Attention Working memory Learning	Attention ↓ (response times) Working memory ↓ (accuracy) Learning↑ (response times)
Bhatt et al. (2017) [11]	Australia	Cohort study (ExPOSURE) Baseline (*n* = 619) and follow-up (*n* = 412)	Baseline: 10.0 (0.4) years, 2 times/week – Phone call 0.5 times/week – SMS messages Follow-up: 11.0 (0.5) years, 2.5 times/week – Phone call 2 times/week – SMS messages	Attention Working memory Learning Inhibition Spatial & executive ability	Attention ↓ (accuracy and response times) Inhibition ↓ (response time)
Guxens et al. (2016) [8]	Netherlands	Cohort study (ABCD) (*n* = 2354)	5-6 years, Heavy user: 1–2 times/week (17.6%), 3 times/week (9.4%)	Speed of information processing Inhibitory control Cognitive flexibility Visuomotor coordination	Inhibitory control ↑ Visuomotor coordination ↑
Thomas et al. (2010) [24]	Australia	Longitudinal study (MoRPhEUS) (*n* = 236)	Baseline: 12.9 years, 8 times/week – Phone call 8 times/week – SMS messages Follow-up: 13.8 years, 10 times/week – Phone call 10 times/week – SMS messages	Visual attention Working memory Learning Executive function	Working memory↑
Schoeni et al. (2015) [9]	Switzerland	Longitudinal study (HERMES)(*n* = 439)	14.0 (0.85) years, 16.0 minutes/day – phone call 30.9 times/day – SMS messages	Verbal and figural memory	Figural memory↓
Adult					
Canale et al. (2019) [17]	Italy	RCT study Turned off (*n* = 40), Silent mode (*n* = 41), Calculator (*n* = 39)	22.73 (1.67) years, Experimental condition: 4.5 hours	Visual working memory	VWM/attentional processes ↓ (high availability + positive urgency)
Dumbrava (2016) [19]	Romania	RCT study, User (*n* = 37), Non-user (*n* = 31)	Adults	Prospective memory	Time, event and activity-related memory performances↓
Eltiti et al. (2009) [20]	UK	RCT study (Double-blind provocation study) Sensitive (*n* = 44) and Control (*n* = 44)	Sensitive group: 46.14 (13.2) years Control group: 54.03 (15.4) years, Experimental condition: 50 min	Working memory	Not affected by short-term exposure
Hadar et al. (2017) [25]	Israel	RCT study Heavy smartphone user (*n* = 16) Nonusers (*n* = 35) (second phase: NUsp (*n* = 12), NUco (*n* = 16))	Heavy smartphone user: 24.0 (2.5) years, Nonusers: 24.7 (2.0) years, Heavy user: 1068 (104) times/week	Attention Working memory Inhibition response Social cognition	Attention: accuracy↓ Social cognition↓ (social threat↑) Impulsivity↑
Hadlington (2015) [21]	UK	Single group study (*n* = 210)	23.19 (7.47) years, Heavy user: MPPUS 108.5 ↑	Working memory	Difference between high and low mobile user groups ($p = 0.000$)

Table 2. Summary of study characteristics and key results from 14 studies

Article citation	Country	Study design, Participants	Age, Time use	Cognitive function	Main finding
Hartanto et al. (2016) [26]	Singapore	RCT study, Exp. 1 (*n* = 79) Exp. 2 (separation (*n* = 35), non-separation (*n* = 35))	Exp. 1: 21.6 (2.11) years, SAS = 32.38 Exp. 2: 21.4 (1.87) years, 7.1 hours/day, 71 times/day	Exp 1: Executive function Nonverbal fluid intelligence Exp 2: Working memory Inhibition	Exp 1. Executive function: response time↑ Exp 2. Inhibition: accuracy↓, response time↑
He et al. (2020) [22]	China	RCT study, Intervention (*n* = 19) Control (*n* = 19)	Intervention: 20.95 (2.07) years, 5.47 (1.87) hours/day, 1.47 (1.08) hours/day (bedtime) Control: 21.37 (2.63) years, 5.82 (3.31) hours/day, 1.39 (0.68) hours/day (bedtime)	Working memory	Working memory: accuracy↑, response times↑
Kalafatakis et al. (2017) [23]	Greece	RCT study EG (*n* = 64) MCI (*n* = 20) CG (*n* = 36)	Adults, Experimental condition: 5 minutes	Implicit memory	Memory performance↓
Wiholm et al. (2009) [13]	Sweden	RCT study (Double-blind cross-over design) Symptomatic group (*n* = 23)/Non-symptomatic group (*n* = 19)	SG: 28.8 (7.0) years Non-SG: 29.4 (6.0) years, Experimental condition: 2.5 hours	Spatial memory	No significant interaction of task trials

CG – Control group, EG – Experimental group, SG – Symptomatic group, MCI – Mild cognitive impairment, Non-SG – Non-symptomatic group, NUco – Non-user control, NUsp – Non-user given smartphone, RF-EMF – Radiofrequency electromagnetic fields, VWM – Visual working memory.

tion in the working memory of heavy smartphone users [21]. In He's study, an intervention was applied that could lead to an improvement in working memory [22]. However, in three studies, a statistical significance, based on the changes in the level of smartphone use and working memory capability, was not reached [20, 25, 26].

Four studies identified a potential for changes in memory with different characteristics. Dumbrava's study confirmed the ability to perform time-, event- and activity-related memory and suggested the possibility of changes in prospective memory functions [19]. A study by Kalafatakis suggested the possibility of functional changes in implicit memory over short exposure times [23]. The study by Schoeni and Wiholm study identified visual-centric memory, confirming the link between smartphone use and degraded figural memory [9, 13].

In the intermediate processes, learning was used as an evaluation item in three studies on children and adolescents, and two of the three studies did not find a statistically significant association [7, 11, 24]. Problems with the inhibition process were identified in two studies on children and adolescents and two studies on adults [11, 25, 27]. In Bhatt's study on children and adolescents, the use of smartphones led to an increase in response time, and in Hartanto's study on adults, a decrease in accuracy and an increased response time were seen.

In the higher order process, executive functions were identified in two studies on children and adolescents and in one study on adult [11, 24, 26]. In one study, the effects of smartphone overuse on executive function ware described [26]. Guxen's and Hartanto's research confirmed changes in cognitive flexibility according to smartphone use, although the study did not confirm a difference [26, 27]. In Guxen's research on children and adolescents, the use of smartphones suggested the possibility of increased visuomotor coordination [27]. In Hadar's study on adults, social cognitive function was also considered, and it was argued that smartphone overuse could increase social anxiety and impulsivity [25].

Discussion

The goal of this scoping review was to identify the relationship between excessive smartphone use and changes in cognitive function. A total of fourteen articles met the inclusion criteria. The reason for conducting this review was to define cognitive problems associated with excessive smartphone use and to find ways to address these cognitive problems in children, adolescents and adults. Specific questions were targeted as part of the review, and we provided a discussion covering each question raised at the beginning of this review, as well as answers based on the selected articles reviewed.

Of the fourteen studies included in the scoping review, twelve confirmed a partially meaningful relationship between smartphone overuse and cognitive functions (excepted two papers of studies on adult). Areas for further work are proposed, considering recommendations for future research on the reviewed papers and on the basis of the current state of knowledge revealed by the synthesis in the literature. One of striking difference is that most cognitive assessment tasks used task-oriented evaluation tools. The lack of research on brain based mechanisms is lacking. Our review compared the studies of different age groups, from children and adolescents to adults. However, the change of task-based cognitive ability had limited in comparing the results in age. In some studies, an EEG was used to confirm the participants' brain activity, and these results strongly supported the change in cognitive functions of users [25]. Further application of these biological tools might help one understand the characteristics of the user's cognitive tasks. In particular, it would be interesting to look at studies that measured objective physiological parameters, such as cognitive task performance level, brain blood flow change, heart rate and skin conductance [20]. Although one study could not confirm an association with skin conductance, changes in brain electrical activity or changes in brain blood flow, the interpretation should be considered limited in terms of short-term exposure to the experimental condition. Recently, the use of biological equipment has been greatly diversified, and quality of life has improved. They are widely used in the business and healthcare community and have enabled communication, monitoring, consulting and other health care services across geographical, cost and time barriers [28]. In health care, mobile health (mHealth) components include monitoring, alerting, data collection, detection and prevention systems. The development of various technologies for modifying the behaviour of smartphones and users will further help one understand the status of the users and improve their psychological and behavioural status [29].

Attention, work memory and cognitive inhibition processing could also be affected by smartphone overuse. Based on this literature review, smartphone overuse had a clear influence on attention, working memory and inhibition processes, which are fundamental in cognition. Regarding attention, changes in accuracy and response time have been suggested; however, this might be related to an impulsive response style rather than the reaction of a specific cognitive function [30–32]. Impulsive response style refers to the tendency to respond before cognitive thinking is completed. This is due to an impulsive nature that favours a quick but inaccurate solution [33].

However, it was found that the issue of concentration and impulsive literacy was not sufficiently discussed in literature. Of the fourteen studies in total, only two studies cited impulsivity. The authors often claimed low levels of concentration among children and adolescent users but did not primarily explain the link with impulsivity. In particular, in order to help children and adolescent users understand the potential impact of intervention, future research will need to clarify the link between concentration and impulsivity and build preventive training for this. As recommended in Hadar's study [25], the researcher should consider the problems of social cognitive ability that may be caused by increased impulsivity [30]. In addition, it is necessary to provide education to expand the knowledge of health care providers and behavioural scientists to solve these problems.

As a result of this review, little attention has been paid to the wide range of cognitive problems arising from its long-term effects. In studies on children and adolescents, long-term observation was attempted due to the characteristics of cognitive development, but long-term observational studies were not found in young adult users. Even considering cognitive development in adulthood, behavioural problems caused by long-term overuse should be clearly identified, and the scope of research should not be limited to interpretation based on short-term changes. The purpose of the study should be to continuously monitor users' cognitive and behavioural characteristics and provide stable services for problems. In future studies, research should be conducted to observe the characteristics of long-term use and cognitive change, focusing on young adult users who are most likely to be exposed to mobile phones, and through this, technology development for various behavioural interventions should be conducted.

In addition, reduction of work memory and cognitive inhibition were identified as major problems. This can be explained by the change in the working memory process that can occur due to the habitual use of smartphones to compensate the working memory. This could be causing the resulting errors and confusion in encoding task-related information [33, 34]. Decreased cognitive suppression ability also develops addictive behaviours and symptoms and can enhance certain behaviours. Conditional learning, such as stabilisation and reinforcement, may strengthen behavioural mechanisms when this ability to inhibit is trained [35, 36]. The cognitive inhibition process is highly correlated with the attention results described. This finding could affect prevention and treatment programmes. Attention and impulsivity can be highly related to the frequency of smartphone use and symptoms of addictive behaviour. Considering the findings of this review, strengthening of executive functions through various behavioural enhancement techniques can be a therapeutic mechanism to prevent behavioral problems due to attention and impulsivity [35–38]. In the context of clinical treatment, the interaction between impulse, inhibitory control and executive function should also be considered. Neuropsychological training can support the connection system and each cognitive resource in suppressing impulsive responses. Future research will also need to address stress reduction techniques and enhancements in executive function to improve people's ability to control social network use.

There are several findings in this review. The opinion that smartphone overuse may affect concentration, working memory and cognitive restraint processing among cognitive functions needs further research to confirm an association with higher cognitive functions that focus on extensive evaluation and executive functions. Besides this, future research will need to standardise diagnostic methods to determine whether an individual has a related disability caused by smartphone overuse. Many of the current studies relied on questionnaire-based assessments to determine the addictive nature of smartphone use. Interviews with experts and a more scientific diagnosis based on biologic parameters may be ideal for future research. In addition, standardisation of cognitive function evaluation items and their analyses and reporting of behavioural characteristics of task performance are important future areas of research. Lastly, in developing therapeutic attempts and methods to prevent the increased addictive behaviour of smartphone users, it is necessary to help users maintain a healthier lifestyle by reducing the negative factors that users can experience with smartphone use. The strength of this review lies in the fact that it is the first review that maps evidence of an association between the level of smartphone use and cognitive functions. Comprehensive searches were performed across multiple databases. Articles were also screened based on inclusion and exclusion criteria. However, some limitations remain. In this review, we did not focus on the exposure to RF-EMF because, in the past, a review on the impact of RF-EMF failed to confirm consistency. Recently, many studies have also focused on the emotional and behavioural characteristics of users.

Lastly, it is necessary to critically discuss the level of user satisfaction and the level of usage cantered on various applications. Recently, in the field of medical health technology, a monitoring intervention method has been proposed by applying various technologies for the purpose of preventing mental health problems. However, a decrease in user fidelity and satisfaction may lead to results different from the purpose of development. Rather than an individualistic approach, a small group form of management may be effective at the socio-cultural level. In addition, individual counseling services may be a more effective method for improving personal and social problems related to low self-esteem that increase mobile addiction than monitoring methods. Future studies will require further consideration of the socio-cultural and psycho-social aspects. We should also pay attention to a variety of mental health-related studies that help cell phone users take advantage of healthier and improved mobile phone technology.

This scoping review had searched extensively through various key keywords, but it is possible that other related publications were not included. We did not evaluate the quality of the existing literature as this is not expected in the scope of evaluation. However, as the amount of future research increases, evaluation of the quality of research on evaluation tools and intervention methods will become an important research method.

Conclusions

This article reviewed and defined the scope of a study comparing the association between smartphone usage levels and cognitive function. The results of this scoping review highlighted the need for future research to thoroughly assess the impulsivity of smartphone users. It also proposed various paradigms to judge the level of smartphone addiction associated with disabilities and mediate cognitive function and user impulses discussed in future behavioural intervention studies to address work memory and cognitive deterrence problems. This is clinically important for psychosocial health factors in children, adolescents and young adults who are prone to various mental problems.

Source of funding: This work was funded from the authors' own resources.
Conflicts of interest: The authors declare no conflicts of interest.

References

1. Lepp A, Barkley JE, Karpinski AC. The relationship between cell phone use, academic performance, anxiety, and satisfaction with life in college students. *Comput Hum Behav* 2014; 31: 343–350.
2. Hadlington LJ. Cognitive failures in daily life: Exploring the link with Internet addiction and problematic mobile phone use. *Comput Hum Behav* 2015; 51: 75–81.
3. Harwood J, Dooley JJ, Scott AJ, et al. Constantly connected – the effects of smart-devices on mental health. *Comput Hum Behav* 2014; 34: 267–272.
4. Anderson M. Technology device ownership: 2015. Pew Research Center; 2015. Available from URL: https://www.pewresearch.org/internet/2015/10/29/technology-device-ownership-2015/.
5. Lee SY. Examining the factors that influence early adopters' smartphone adoption: the case of college students. *Telematics Inf* 2014; 31(2): 308–318.
6. Deursen AJ van, Bolle CL, Hegner SM, et al. Modeling habitual and addictive smartphone behavior: the role of smartphone usage types, emotional intelligence, social stress, self-regulation, age, and gender. *Comput Hum Behav* 2015; 45: 411–420.
7. Abramson MJ, Benke GP, Dimitriadis C, et al. Mobile telephone use is associated with changes in cognitive function in young adolescents. *Bioelectromagnetics* 2009; 30(8): 678–686.
8. Guxens M, Vermeulen R, Eijsden M van, et al. Outdoor and indoor sources of residential radiofrequency electromagnetic fields, personal cell phone and cordless phone use, and cognitive function in 5–6 years old children. *Environ Res* 2016; 150: 364–374.
9. Schoeni A, Roser K, Röösli M. Memory performance, wireless communication and exposure to radiofrequency electromagnetic fields: a prospective cohort study in adolescents. *Environ Int* 2015; 85: 343–351.
10. Sudan M, Olsen J, Arah OA, et al. Prospective cohort analysis of cellphone use and emotional and behavioural difficulties in children. *J Epidemiol Community Health* 2016; 70(12): 1207–1213.
11. Bhatt CR, Benke G, Smith CL, et al. Use of mobile and cordless phones and change in cognitive function: a prospective cohort analysis of Australian primary school children. *Environ Health* 2017; 16(1): 62.
12. Haarala C, Takio F, Rintee T. Pulsed and continuous wave mobile phone exposure over left versus right hemisphere: effects on human cognitive function. *Bioelectromagnetics* 2007; 28(4): 289–295.
13. Wiholm C, Lowden A, Kuster N, et al. Mobile phone exposure and spatial memory. *Bioelectromagnetics* 2009; 30(1): 59–65.
14. Besset A, Espa F, Dauvilliers Y, et al. No effect on cognitive function from daily mobile phone use. *Bioelectromagnetics* 2005; 26(2): 102–108.
15. Rast P, Zimprich D, Boxtel M van, et al. Factor structure and measurement invariance of the cognitive failures questionnaire across the adult life span. *Assessment* 2009; 16(2): 145–158.
16. Smythe JW, Costall B. Mobile phone use facilitates memory in male, but not female, subjects. *Neuroreport* 2003; 14(2): 243–246.
17. Canale N, Vieno A, Doro M, et al. Emotion-related impulsivity moderates the cognitive interference effect of smartphone availability on working memory. *Scientific Reports* 2019; 9(1): 1–10.
18. Barth A, Winker R, Ponocny-Seliger E, et al. A meta-analysis for neurobehavioural effects due to electromagnetic field exposure emitted by GSM mobile phones. *Occup Environ Med* 2008; 65(5): 342–346.
19. Dumbravă A. Prospective memory deficits in portable telephone users. *Cognition Brain Behavior* 2016; 20(5): 367–372.
20. Eltiti S, Wallace D, Ridgewell A, et al. Short-term exposure to mobile phone base station signals does not affect cognitive functioning or physiological measures in individuals who report sensitivity to electromagnetic fields and controls. *Bioelectromagnetics* 2009; 30(7): 556–563.
21. Hadlington LJ. Cognitive failures in daily life: Exploring the link with Internet addiction and problematic mobile phone use. *Comput Hum Behav* 2015; 51: 75–81.
22. He J, Tu Z, Xiao L, et al. Effect of restricting bedtime mobile phone use on sleep, arousal, mood, and working memory: a randomized pilot trial. *PLoS ONE* 2020; 15(2): e0228756.
23. Kalafatakis F, Bekiaridis-Moschou D, Gkioka E, et al. Mobile phone use for 5 minutes can cause significant memory impairment in humans. *Hell J Nucl Med* 2017; 20(Suppl.): 146–154.
24. Thomas S, Benke G, Dimitriadis C, et al. Use of mobile phones and changes in cognitive function in adolescents. *Occup Environ Med* 2010; 67(12): 861–866.
25. Hadar A, Hadas I, Lazarovits A, et al. Answering the missed call: Initial exploration of cognitive and electrophysiological changes associated with smartphone use and abuse. *PLoS ONE* 2017; 12(7): e0180094.
26. Hartanto A, Yang H. Is the smartphone a smart choice? The effect of smartphone separation on executive functions. *Comput Hum Behav* 2016; 64: 329–336.
27. Guxens M, Vermeulen R, Eijsden M van, et al. Outdoor and indoor sources of residential radiofrequency electromagnetic fields, personal cell phone and cordless phone use, and cognitive function in 5–6 years old children. *Environ Res* 2016; 150: 364–374.
28. Silva BM, Rodrigues JJ, Torre Díez I de la, et al. Mobile-health: a review of current state in 2015. *J Biomed Inform* 2015; 56: 265–272.
29. Hilty DM, Chan S, Torous J, et al. A Telehealth framework for mobile health, smartphones, and apps: competencies, training, and faculty development. *Journal of Technology in Behavioral Science* 2019; 4(2): 106–123.
30. Wolniewicz CA, Tiamiyu MF, Weeks JW, et al. Problematic smartphone use and relations with negative affect, fear of missing out, and fear of negative and positive evaluation. *Psychiatry Res* 2018; 262: 618–623.
31. Owens MM, Amlung MT, Stojek M, et al. Negative urgency moderates reactivity to laboratory stress inductions. *J Abnorm Psychol* 2018; 127(4): 385.
32. Canale N, Rubaltelli E, Vieno A, et al. Impulsivity influences betting under stress in laboratory gambling. *Sci Rep* 2017; 7(1): 1–12.
33. Chester DS, Lynam DR, Milich R, et al. How do negative emotions impair self-control? A neural model of negative urgency. *Neuroimage* 2016; 132: 43–50.

34. Klink PC, Jeurissen D, Theeuwes J, et al. Working memory accuracy for multiple targets is driven by reward expectation and stimulus contrast with different time-courses. *Sci Rep* 2017; 7(1): 1–13.
35. Wegmann E, Muller SM, Turel O, et al. Interactions of impulsivity, general executive functions, and specific inhibitory control explain symptoms of social-networks-use disorder: an experimental study. *Sci Rep* 2020; 10(1): 3866.
36. Du J, Kerkhof P, Koningsbruggen GM van. Predictors of Social Media Self-Control Failure: Immediate Gratifications, Habitual Checking, Ubiquity, and Notifications. *Cyberpsychol Behav Soc Netw* 2019; 22(7): 477–485.
37. Gao Q, Jia G, Zhao J, et al. Inhibitory Control in Excessive Social Networking Users: Evidence from an Event-Related Potential-Based Go-Nogo Task. *Front Psychol* 2019; 10: 1810.
38. Jaroslawska AJ, Gathercole SE, Allen RJ, et al. Following instructions from working memory: why does action at encoding and recall help? *Mem Cognit* 2016; 44(8): 1183–1191.

Tables: 2
Figures: 1
References: 38

Received: 06.08.2021
Reviewed: 18.08.2021
Accepted: 04.09.2021

Address for correspondence:
Prof. Ingyu Yoo
Department of Occupational Therapy
College of Medical Sciences
Jeonju University
Hyoja-dong 3-ga
Wansan-gu, Jeonju-si
Jeollabuk-do, 560-759
Republic of Korea
Tel.: +82 63-220-2299
E-mail: otyoo@jj.ac.kr