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Review Article (Yoga)

Understanding Smartphone addiction and the role of Meditation in its management - A review

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Abstract

With the advancement in science and technology, gadgets have become an essential part of one's life. Smartphones are one such gadget that is indispensable today. Smartphone addiction has become a reality and has several adverse effects on health. There may be detrimental effects in the structure and function of the brain due to smartphone addiction. Meditation and mindfulness techniques also bring about changes in similar areas as those affected by addiction. Databases like PubMed are searched extensively using the keywords "smartphone overuse, smartphone addiction, brain structure, brain function, cognitive function, meditation, mindfulness, effects on brain structure." The result yielded 335 articles. After the screening, thirty-two papers were included in the review. It is observed that smartphone addiction has adverse structural and functional effects on the brain. Meditation and mindfulness enhance the structure and function of the same areas of the brain. Hence, meditation can be an effective tool to reverse smartphone addiction.

Keywords: *Brain, Smartphone addiction, Yoga*

Introduction

In today's world of global connectedness, one cannot avoid exposure to technology. Technology has made every activity of our day-to-day life much more accessible and convenient. However, excessive use of technology is not desirable as it can lead to addictive behaviour. Among research on technological addictions, there is a growing interest in smartphone addiction, as smartphone penetration is increasing globally because of its easier accessibility than other technical gadgets.

Another reason for the growing concern on smartphone addiction is its potential adverse effects, particularly physical and mental aspects of health. There is an increasing body of evidence which have shown that smartphone addiction can be harmful to the structure and function of the brain.

Smartphone addiction is found to bring about detrimental effects on the brain structure, and certain specific structural properties could induce a propensity for such addiction in the individual. Studies have shown that smartphone addiction directly correlates to impulsivity, [1] and this trait is positively correlated to decreased gray matter volume in the prefrontal cortex. Smartphone addiction is found to relate positively to lower Grey Matter Volume (GMV) in the orbito-frontal cortex (OFC), caudate nucleus (CN), cingulate gyrus.[2] There is an inability to abstain from using the substance or object despite a wish to do so often because it is a source of pleasure and related to the brain's reward centre. Psychologically, humans are wired so that inhibitory control exerts an influence on one's action depending on whether it is appropriate or not, even if it were pleasurable. In the case of addiction, the inhibitory centre takes backstage, and indulgence in the activity is to be seen. This implies a fault in the inhibitory control of the brain, and this is duly corroborated by some studies showing lower activity of right anterior cingulate cortex in the brain of smartphone addicts, along with lower grey matter volume of the insula and in the regions of the temporal cortex and left orbito-frontal cortex.[3] The insular region is closely related to other forms of addictions related to stimulus-related salience processing and craving. The same study has shown a change in the activity in the pre-central gyrus, which is similar to findings in internet gaming disorder.[4] The insula and ACC are related to the Default Mode Network and salience function. Similar to the effects of other addictions, smartphone addiction also showed aberrant salience in a study. [5]

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Smartphone addiction is found to influence cognitive functions negatively. Some studies have shown that smartphone use could replace cognitive function because of 'cognitive misers,' that humans tend to be, and smartphones form 'the extended mind'.[5] The same study says that this cognitive miserliness on smartphone users negatively affects certain cognitive functions such as analytical thinking. Studies have shown that smartphone addiction negatively influences cognitive function like attention and elements of social cognition like the social presentation of self, which can be related to social networking services like Facebook, Twitter where social acceptance or otherwise is instantly known.[6] Hadar et al. further stress that increased smartphone usage can causally reduce an individual's capacity (or at least tendency) to postpone gratification in favour of a greater reward in the future. The same is as also proven by Wilmer et al. Smartphone usage is also proven to be harmful to cognitive functions like memory and attention, to be more specific, focused attention and divided attention.[7] Minear et al. showed in their study that there is a positive relationship between excessive use of media and 'self-reported impulsivity'.[8] Another survey on smartphone addiction has shown that the same area of the brain (orbito-frontal cortex, which is a part of the prefrontal cortex) responsible 'for regulatory control over previously re-in forced behaviours' shows reduced grey matter volume. Another study tried to assess the effects of smartphone push notification delivery during a task based on the level of smartphone overuse using Evoked Response Potential (ERP), and they found that smartphone push notifications produced a decline in task performance in the smartphone risk group, exerting a negative influence on cognitive function and concentration. They also observed lower N200 amplitude and longer response latency in the risk group. A higher error rate and longer reaction time were also identified in the risk group during the Go-No-Go task.[9]

Smartphone addiction has profound impacts on the physical and mental health of an individual. Physically, smartphone addiction is a cause of pain in the neck,[10] back, and wrists.[11] Prolonged use can cause severe postural defects[10] with lasting effects, which could be challenging. Smartphone addiction is positively correlated to reduced sleep quality,[12] the severity of insomnia[13] and dry eyes, and lack of relaxation after waking up from sleep. Another study has found a direct correlation between smartphone overuse and reduced physical activity, shown as less walking, reduced burning of calories, reduced muscle mass, and increased fat deposition in the body which could be contributing factors to cardiovascular problems.[14] Another study has confirmed that smartphone addiction could lead to obesity in adolescents as it is associated with emotion dis-regulation, thereby contributing to eating disorders.[15] The mental aspect is also profoundly affected by this addiction. Research has shown that problematic smartphone use can be related to higher levels of anxiety,[16] depression,[17] shyness,[18] loneliness,[19] feeling of being left out,[20] lower self-esteem, confidence, well-being and Quality of life.[21] A study done in Japan shows that female high school students were at a higher risk for depression as their prolonged use of smartphones was for online communication.[22] Guo et al. showed in their study conducted in China that smartphone addiction was associated with anxiety, depression, and lower scores on Happiness Scale and mental well-being.[23] It is also observed that mobile phone addiction was related to poor sleep quality in Chinese college students.[12] Studies have also shown that there are links to personality traits.[24] It is seen that smartphone use disorder is positively correlated with high Neuroticism and low Conscientiousness and low Agreeableness.[1]

Furthermore, according to Peterka et al., smartphone use disorder is positively correlated with social anxiety and impulsivity. In addition, another study found that smartphone addiction harmed the flow of learning and self-regulated learning using a smartphone as university students reported other apps would disturb learning.[1] Finally, another study has shown that smartphone addiction is positively correlated to lower academic performance in students.[16]

Considering the detrimental effects of smartphone addiction on physical and psychological health, interventions to manage such addiction are necessary. Recently interventions related to mind-body medicine such as mindfulness and *Yoga* are gaining popularity because of their beneficial physical and mental well-being. *Yoga* is a conglomerate of several philosophical aspects and practices. It derives from the Sanskrit root word, *'Yuj*,' which means union or yoking the individual soul and universal soul.[25] Therefore, under the umbrella term of *Yoga*, one can include the philosophical teachings of the various sages and the practices like *Asana* (postures), *Pranayama* (breath regulation), *Mudra* (gesture), *Bandha* (body locks), *Shatkriya* (cleansing techniques), *Yama* (codes of conduct), *Niyama* (self-discipline), *Pratyahara* (principles for sense withdrawal), *Dharana* (concentration), *Dhyana* (meditation). Scientific evidence has shown that *Yoga* has beneficial impacts on the physical and mental health of an individual.

Furthermore, several *Yoga* practices, namely pranayama and meditation, have improved brain structure and function. Therefore, it can be speculated that *Yoga* can counter the adverse effects of smartphone addiction on the brain. Hence, in this opinion article, we will explore the evidence for the possible application of *Yoga* on smartphone addicts.

Methodology

Online database PubMed was used as the data source point from where published research data till 2020 related to the present review as mentioned below were screened,

The, selected whole papers were studied for details related to,

i. Brain areas affected due to smartphone addiction,
ii. Functions of the brain affected due to smartphone addiction,
iii. Interventions used,
iv. Design of the study,
v. Type of study,
vi. Number of participants,
vii. Effect of *Yoga* on brain structure and function.

Observations

The PubMed database when searched by using the words "*Yoga*, addiction, brain structure, cingulate cortex, prefrontal cortex, insula, the mesolimbic system" 177 articles were found. Emphasis was given on the structural changes and activation of different areas of the brain during *Yoga* interventions. Forty-one entries like Abstracts sent to conferences, proceedings, and symposia unrelated to our focus area were excluded. Seventy-eight were excluded as the papers dealt with the brain's working about other diseases but bearing no relation in their explanation to addiction. Forty-five entries were excluded as they were reviews. One paper was excluded as it was written in Chinese, and to be included in our review, the paper had to be written in English. Since the interest was in the structural changes in the brain due to smartphone overuse or addiction, only papers that have shown effects on grey matter volume, fMRI (functional Magnetic Resonance Imaging) studies, SPECT (Single Photon Emission Computerised Tomography) studies, and EEG studies were included. After screening, 12 studies were included: experimental studies relating to *Yoga*, addiction, and the brain. There were very few studies that studied *Yoga* for smartphone addiction and explained the effects on brain structure.

The database PubMed when searched using the words "*Yoga*, brain function, cognition, executive function" 159 articles were found. Papers written in any other language apart from English were excluded, and two papers were excluded. Eighty-seven papers dealt with different issues and were found unrelated to the opinion article. Fifty papers were reviews and thus, were excluded from the review. Cognition is observed to be a vital function of the brain. Therefore, papers dealing with *Yoga* and its effects on cognition are included for review. Twenty papers were found to be relevant to the review and hence included here.

Discussion

Mind-body medicine (*Yoga*) and areas of the brain affected due to smartphone addiction:

This opinion article has included studies related to meditation and its effects on brain structure and studies about addiction and structural changes in the brain. In several studies, it was have found that smartphone addiction and other forms of addiction could transform the brain structure and neurological pathways. For example, the brain areas that have reported lower volume of grey matter in addiction are the orbito-frontal cortex, caudate nucleus, cingulate gyrus, and prefrontal cortex.

Different kinds of meditation have been studied, namely, *Vipassana*, Mindfulness-based stress reduction, ecstatic meditation, insight meditation, Zen meditation, *Sahaja Yoga* meditation. Lazar et al. studied the effect of Insight meditation on cortical thickness. They have taken 35 participants and used magnetisation prepared rapid gradient echo (MPRAGE), MRI for the investigation in the case-control study having a duration of 1 week. Twenty meditators were made to undergo one week of Insight meditation. Fifteen controls with their age, sex, race, and education matched with the case group were recruited. Results showed no uniform thickening of the cortex in meditators, but specific cortex areas like the right anterior insula, frontal cortex show thickening. They have suggested that areas important for emotion and cognition could be implicated in neural plasticity.[26] Luders et al., in their study, have taken MRI images along with voxel-based morphometry of 44 subjects. It was found that gray matter volume has increased in specific brain areas, those being the right orbito-frontal cortex, right thalamus, right inferior temporal gyrus, and right hippocampus. These regions have been related with emotion regulation and response control. They have suggested that these changes are irrespective of the meditation style but are a neural correlate of long-term meditation.[27] Deepeshwar et al. have used functional near-infrared spectroscopy (fNIRS) to study the hemodynamic changes in the prefrontal cortex (PFC) during a cognitive task. They have taken 22 male subjects and used meditation and random thinking as the control group for 20 minutes. They found an increase in the oxy-haemoglobin and total haemoglobin in the right PFC of meditators compared to random thinking.[28]

Holzel et al., in 2011 have studied the effect of Mindfulness-Based Stress Reduction (MBSR), a mindfulness technique, on gray matter density. They have taken 16 meditators and 17 controls for a longitudinal study and used MRI with VBM. After the study's eight-week duration, it was found that gray matter density showed an increase in the left hippocampus, posterior cingulate corte. [29]

Holzel, in another study, took *Vipassana* meditation as the intervention and used MRI along with VBM for the investigation. Thirty subjects (Fifteen meditators and fifteen non-meditators) were assessed after 6254 hours of meditation experience. They found activation of the anterior cingulate cortex and dorsal medial prefrontal cortex bilaterally.[30]

In a case study on ecstatic meditation, Hagerty et al. used fMRI and EEG to show that there was activation of nucleus accumbent (NAc), which is believed to help self-stimulate the reward system. There is also activation of the medial orbito-frontal cortex, Wernicke's area, Broca's area. [31]

Taylor et al., in their study, have taken 12 experienced meditators and ten beginners in meditation for a case-control study for observing the effects of mindfulness on neural mechanisms after an emotional stimulus. fMRI is used to take imagery of the brain when exposed to negative, positive, and neutral pictures. For experienced meditators, there is the deactivation of the default mode network (DMN) comprising the medial prefrontal and posterior cingulate cortex.[32]

Dodich et al., in their study, have taken 12 meditation naïve subjects and 30 controls to assess the impacts of a 4-week *Sahaja Yoga* (SY) meditation training on gray matter density and spontaneous resting-state brain activity. MRI and VBM are used to see the gray matter density and visual inspection of the spatial maps, and analysis of spectral profiles for resting-state brain activity. It found SY practice can cause significant changes in the distribution of low–middle frequencies of resting-state activity. Increased GMV in the right inferior frontal gyrus is seen in the meditation group.[33]

Hernandez et al. used VBM to study the effect of *Sahaj Yoga* meditation on gray matter volume. Twenty-three meditators are compared with 23 controls that were age, sex, and education level. Larger Grey matter volume was seen in several predominantly right hemispheric regions: in the insula, ventromedial orbito-frontal cortex, inferior temporal and parietal cortices, and left ventrolateral prefrontal cortex and left insula.[34]

A cross-sectional study assessed the effect of *Hata Yoga* on cortical thickness using MPRAGE. Twenty-one older women with an average of 8 years of *Yoga* experience were matched with 21 *Yoga* naïve and matched with the study group for age, educational qualification, and physical activity. A greater CT in a left prefrontal lobe cluster included portions of the lateral middle frontal gyrus, anterior superior frontal gyrus, and dorsal superior frontal gyrus.[35]

Korponay et al., in their three-armed study involving 105 subjects, have used mindfulness meditation as the main intervention and Barratt Impulsiveness Scale (BIS) and Magnetic Resonance Imaging (MRI) as the investigating tools. The groups of the study were Long term meditators (LTM), meditation naïve participants (MNP), and waitlist control group (WLC). The duration of the study was eight weeks. As a result of the study, there was no reduction in impulsivity on the Go/No-Go task or Barratt Impulsiveness Scale (BIS-11), nor produce changes in neural correlates of impulsivity (i.e., fronto-striatal gray matter, functional connectivity, and dopamine levels) compared to active or waitlist control groups. [36]

Amaro et al., in their RCT, recruited 200 subjects diagnosed with substance use disorder and residing in a rehabilitation centre. They have used MOMENT BY MOMENT IN WOMENS RECOVERY (MMWR), a tailor-made mindfulness technique for women addicts who belonged to lower social strata. It has been hypothesised that this technique will prevent relapse and be an effective method to deal with addiction.[37]

Mind-body medicine (*Yoga*) and brain functions affected due to smartphone addiction:

Chen et al. in their study had taken data from 32 subjects. Smartphone Addiction Inventory was used to screen the subjects for their addiction level. EEG recordings were done during a modified Go/No-Go task, and the results have shown that N2, an ERP component related to inhibitory function, was more negative in heavy smartphone users.[38]

Hartanto et al. have taken 87 students as their subjects. The various tools used for the study were the Colour − word switching task, Smartphone Addiction Scale, State-Trait Anxiety Inventory, Kaufman brief Intelligence Test, International Positive and Negative Affect Schedule. The subjects were randomly allocated to separation or non-separation, and a series of tests were administered. Results showed that smartphone separation disturbed the shifting aspect of executive function, that is, cognitive flexibility. In the second part of the study, 70 participants were made to take the Stroop task and rotation span task to assess the inhibitory control and working memory. Separation anxiety led to bad performance in tasks assessing working memory and inhibitory aspects of cognition.[39]

Enez et al. recruited 367 subjects for their study. They have taken Smartphone Addiction Scale, UCLA-Loneliness Scale, Brief Social Phobia Scale. The results showed that there was a positive correlation between all sub-scales of SAS and BSPS. Also, SAS and UCLA-Loneliness Scale were positively correlated.[40]

Kim et al. have recruited 14 subjects for their study. They have assessed the P300 and N200 components of ERP to measure concentration and cognitive ability during push notifications. The smartphone overuse group showed lower P300 amplitude and longer latencies. They also demonstrated a higher rate of error in the Go nogo task.[9]

Hadar et al., in their study, have recruited 51 subjects, and the study consisted of two phases. The first phase involved recruiting non-users and heavy users and running a battery of tests on the subjects, those being speeded numerical task processing, memory task, stop-signal task, Beck Depression Inventory, conner's Adult ADHD Rating Scale, Concern for Appropriateness Scale. EEG was recorded during the stop-signal task and TMS. In the second phase of the study, smartphone naïve participants were provided with a smartphone and, after three months of smartphone use, were assessed for the same parameters as in the first phase. The study results show that excessive usage of smartphones is associated with deficits in cognitive capacity, social attitude, and rPFC excitability. The second phase results show a decrease in arithmetic accuracy and increased social concern.[6]

Hawi and Samaha, in their study, have taken 381 participants. They have used Smartphone Addiction Scale and Beck Anxiety Inventory. Smartphone addiction and anxiety and family problems were found to be positively correlated. [16]

Ward et al. have recruited 548 subjects and, after the exclusion, we are left with 520 subjects. Participants were supposed to keep their phones in three different locations-desk, pocket/bag, and other room and groups were divided accordingly. The subjects were assessed for Automated Operation Span Task and Raven Standard Progressive Matrices for the available cognitive capacity. Participants had to complete an experimental test for digit ending drop-off. The first experiment results proves that the presence of the smartphone disturbed their performance on tasks requiring available attention. In the second experiment, 275 subjects completed the experiment. Apart from the three groups assigned in the first experiment, two more groups were assigned: they had to keep their phones in on and off mode. One more instruction was to keep the phone in the face-up position for the desk location. The subjects had to undergo Ospan and Go/No-Go task. The results of experiment 2 suggest that cognitive faculty is affected adversely by smartphone presence, and the degree varies with the dependence of the owners on the phone.[41]

Leynes et al., in their study, have taken 38 subjects, and after dropouts, 33 subjects have completed the experiment. There were two experiments conducted during the study. The first experiment (experiment 1a) involved a computer-paced task with distraction. EEG recordings were done, and ERP was assessed. In the second experiment (experiment 1b), the subjects were involved in a self-paced gambling task. EEG recordings were done on the subjects after that. Results have shown that smartphone use distracts and response time was slower, and P300 amplitude was reduced, indicating that smartphone use reduces cognitive faculty. Whereas experiment 2 demonstrates that long-term smartphone use improves visual-spatial skills, improving cognitive function.[42]

Kraus and Hutton have recruited 19 healthy American children for their study. The parents took part in the survey to assess the children's screen time and independent reading time. The children were made to undergo MRI to determine the resting-state brain connectivity between the visual word area (seed area) and other areas. Reading time was associated with better connectivity between the seed area and language and cognitive areas. In contrast, screen time was associated with lower connectivity between the seed area and language and cognitive control areas.[43]

In yet another study, Ithnain et al. have tried to assess the relation between smartphone addiction and anxiety and depression. Three hundred sixty-nine subjects were recruited, and Smartphone Addiction Scale-M, Beck Anxiety Inventory-M, and Beck Depression Inventory-M were administered to the subjects. Smartphone addiction was found to have a significant correlation with anxiety and depression.[44]

Li et al., in their RCT, have taken 63 participants and assessed them for trait mindfulness using five-factor mindfulness questionnaires (FFMQ) and EEG recordings are done. Eriksen Flankers test is also done to assess reaction time and executive attention. The positive relationship between mindfulness and executive attention, higher trait mindful awareness was associated with smaller congruency interference on P3 amplitudes.[45]

Krishna et al., in their cross-sectional study, have taken 1530 subjects. They have used the Smartphone Addiction Proneness scale for assessment of addiction level. Social Interaction Anxiety Scale is also administered to the subjects. They found in their study that smartphone addiction had a close association with social interaction anxiety among dental students.[46]

Hutton et al., in their cross-sectional study, have taken 47 pre-school children and assessed the effect of screen-based media exposure on brain development. They have used Diffusion Tensor Imaging (Fractional anisotropy and radial diffusivity), Get Ready To Read, Comprehensive Test Of Phonological Processing-2, Expressive Vocabulary Test-2 for assessment of brain development. The parents were made to undergo ScreenQ. Higher scores in ScreenQ implied higher exposure to screen-based media. It was found that increased screen-based media exposure related positively to reduced micro-structural integrity of the brain from the lower FA and higher RD assessment, and this meant language, literary development, and executive function are affected.[47]

Gothe et al. recruited 30 female subjects and divided them into two groups, yoga, and aerobic exercise, and made them take the Flanker and Back task. Results showed improvement in inhibition and accuracy in the *Yoga* group.[48]

Ganpat et al., in their study, have recruited 60 female high school students and assessed them for attention and self-esteem using the d2 task and Rosenberg Self Esteem test after five days of Integrated *Yoga* Module.[49]

Rajesh et al. recruited 370 college students and made them undergo a battery of tests comprising Mindfulness Attention Awareness Scale, Barratt Impulsiveness Scale, General Health Questionnaire. Results showed that mindfulness and impulsivity are negatively correlated.[50]

Gupta et al. recruited 175 subjects for their case-control study. The *Yoga* module was given as an intervention for ten days. State-Trait Anxiety Inventory was given to measure the state anxiety and trait anxiety, and results have shown that *Yoga* reduced anxiety significantly.[51]

Conclusion

From the in-depth analysis of the current review it can be concluded that, the brain areas activated during different kinds of meditation techniques are implicated in the reward system, response control, impulsivity, salience, and cognitive function. Also, there is larger grey matter volume of specific areas of the brain. In addiction studies, mainly smartphone addiction, the brain areas involved are the prefrontal cortex, cingulate cortex, nucleus accumbent, orbito-frontal cortex, which are related to the functions mentioned above. Thus, it can be seen that the mind-body medicine can be adopted as an effective tool for the management of smartphone addiction.

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