Effect of Electromagnetic Waves of Mobile Phone on Human Brain

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ABSTRACT
Mobile phones (MP) have become one of the most used devices for communication. Historically, enough proofs have ruled out the substantial short-term effect of radiofrequency electromagnetic field (RF-EMF) emitted by MP on the human brain and its cognitive performance. The aim of this mini-review is to examine the different effects of electromagnetic waves emitted by MP on human brain. We base our arguments on analyzing recent neuroimaging and electroencephalography studies that will elaborate the effects of the human brain's exposure to the EMF. Several studies indicated an increase in cortical excitability and/or efficiency related to EMF exposure, while other experiments proved that no changes or variations have been found after EMF exposure. Based on a study done in 2020, the exposure to EMF emitted by MP has no abnormal discharges during the real MPR exposure. In contrast, an increase events number in real exposure has been found.

INTRODUCTION
Mobile phones (MP) have become the most important tool of communication in daily human life due to their countless perks that simplify our lives, even with the possible risks that have been expressed about them. In 2014, there is an estimated 6.9 billion subscriptions globally (1). The MP transmit and receive microwaves radiations at specific frequencies, also they are often used in proximity to the human head, and that makes the human brain exposed to a high-specific absorption rate of radio-frequency electromagnetic fields (RF-EMF) (2). Those waves can be classified into two classes, based on the capability of ionizing atoms and breaking chemical bonds: ionizing and non-ionizing waves (3). MP emit non-ionizing radio-waves with low frequency which vary between 800 and 2200 MHz, and that is too low for breaking bonds or to cause ionization of atoms and molecules. In contrast, for long-term, the exposure to EMF should be taken seriously (3). In 2011, the world health organization’s international agency for research on cancer announced that the usage of MP for 30 minutes or more per day could increase risks of brain tumor caused by EMR.

The biological effect of EMF can be divided into thermal; like microwave mechanism; and non-thermal. Thermal effects are associated to local heat production. Non-thermal effects are caused by energy absorption, which is not associated with temperature change but with some other changes produced in the tissues (4). Radiation emitted by MP could change intracellular signaling pathways by change in Ca$^{2+}$ permeability across cell membranes and level of calcium in cells (4). In addition, the absorption of EMF by tissues increases their temperature and leads to serious risks on human health. Some experimental studies show the thermal effects of EMF such as vascular occlusion and tumors in the brain (5). Headache, blood pressure, heartbeat, other warning signs and an increase body temperature are presumed to be due to EMF exposure (5). The possible physical and biological effects of MP on the human health lead to the analysis of their effects in details (6).

The main objective of this mini-review is to shed light on different effects of EMR emitted by MP on the human brain.
RESEARCH METHODOLOGY
The data used in this mini review were mainly from PubMed and EBSCOhost (from 2010 to March 2020). Research was based on a set of keywords related to (electromagnetic fields, mobile phones, brain, mobile phone radiations, human brain), followed by screening titles and abstracts. The selected articles were grouped into articles related the effect of EMR emitted by MP on the human health, and the effect of electromagnetic waves of MP on the human brain. Articles were selected conforming to eligibility criteria:
- Articles assessed the effect of electromagnetic radiation and written in English;
- Articles studied the impact of EMF on human health;
- Articles evaluated the impact of MP;
- Articles presented clearly information on MP related to the human brain.

RESULTS
Of the 13 studies; two studies used a frequency of 900 MHz electromagnetic waves, five utilized EEG (electroencephalogram) and the rest used other parameters such as temperature, glucose metabolism, ELF (Extremely Low Frequency) ...Etc. Studies essentially analyzed the potential physiological impacts induced by RF-EMFs which were defined based on exposure, intensity, time and frequency. Participants included in studies were adults. The table 1 summarizes outcomes’ studies.

Studies conducted in this area by (Trunk et al. 2013; Zentai and al. 2015; Gupta and al. 2015; Selmaoui and al. 2018; Azmy and al. s. d.) showed that no significant changes had been found after an exposure of EMF emitted by MP. Contrary to results found by (Volkow and al. 2011; Roggeveen, van Os and Lousberg 2015; Adibzadeh and al. 2015; Rogay 2015; Roggeveen and al. 2015; Forouharmajd, Pourabdian, and Ebrahimi 2018; Pattnaik, Dhalwal, and Pattnaik 2019) which exposed an increase in different parameters during the exposure to MP EMFs.

The experiment of modelling and assessment of the electric field strength caused by MP to the human head (Buckus and al. 2016) proves that stronger power, higher SAR and lower frequency of MP are associated with stronger electric forces of MP depending on the effects of the electric power of the device.

DISCUSSION
This current mini-review questions the effect of EMR of MP on the human brain. Electroencephalogram (EEG) is a non-surgical measure of the electrical activity of the brain (16). As a dependent variable, EEG was deliberate because the functioning of brain tissue is based on electrochemical processes (12). Five from 13 studies have examined the exposure effect of EMFs on EEGs of participants. Three studies showed no significant effects or no abnormal discharges during the exposure (Trunk and al. 2013; Zentai and al. 2015; Azmy and al. s. d.); although (Roggeveen and al. 2015) have revealed the effect which was stronger when the MP was placed on the ear and increased the power of several frequency bands (alpha, beta and gamma). Other experiment conducted by (Pattnaik, Dhalwal and Pattnaik 2019) has detected some variations in the power of the brain waves.

The results of (Roggeveen and al. 2015; Pattnaik, Dhalwal, and Pattnaik 2019) proved that the EMR has an effect on the human brain.

First study (Ragy 2015) linked to the exposure to 900 MHz exhibited a significant decrease of an exposed group in total antioxidant capacity levels in brain, liver and kidney tissue. On other hand, (Selmaoui and al. 2018) have demonstrated no changes within the group of volunteers associated with the exposure to GSM radiofrequency. The results of an experiment realized by (Volkow and al. 2011) indicated that an exposure of 50 min was associated with increased brain glucose metabolism in the region closest to the antenna. The finding concords with the study conducted by (Forouharmajd, Pourabdian, and Ebrahimi 2018) which proclaims that the EMFs emitted by MP were increases brain tissue temperature and the effect cumulates on the tissue. The study of the effect of prolonged use of MP on brainstem auditory evoked potentials (Gupta et al.) showed no significant difference in latencies, inter-peak latencies and amplitudes of ABR wave. On other side (Roggeveen, van Os and Lousberg 2015) showed in their experiment that MP radiation induced event related potentials with peak latency 240–500 ms post-stimulus.

Study of (Buckus and al. 2016) exhibits that stronger power, higher SAR and lower frequency of MP is associated with stronger electric force of MP, which means that most of the electric fields are absorbed at the side of the head nearest to the MP. In the same context, an experiment (Adibzadeh and al. 2015) has indicated a variation in the averaged SAR among head regions that could reach inside the brain. Nevertheless, there are apparent inconsistencies between studies that limit conclusive statements in brain areas. This lack of consistency may partly be due to methodological factors, such as differences in signal type, exposure frequency, exposure intensity, age of volunteers, temperature of the brain tissue and exposure duration. Moreover, interference between radio frequencies emitted by MP and EEG signals recorded during exposure, and the history of EMFs earlier to the study, are not always controlled. The Objective of this mini-review was to disclose the effects of MP EMF exposure on the human brain. The presented studies included our review state, in general, that “there is no evidence for any short-term effects of EMFs emitted by MP on human cognitive performance” (17).

CONCLUSION
Whilst several studies propose effects of MP EMF exposure on human brain, there are few confirmations of the harmful nature of these effects, and large understanding is needed of their functional significance. We can justify the effects of MP EMF exposure on the human brain and its function according to the latest study to date (15) which proved that there were no abnormal discharges during the real MPR exposure, but an increase in the number of events in real exposure has been found. The World Health Organization (WHO) has identified the potential health effects of MP EMF exposure on children.
and adolescents as a high priority research area, as they are exposed to a longer period of MP (18). Before further clarifications of the cause and effect relationship for MPs, it is considered safer to reduce MP usage. It has been proposed to reduce the potential damage caused by MPs by restricting the length of the call, or by using hands free devices (19). In order to decrease the potential negative consequences of excessive usage. Further researches are needed to clarify neuro-physiological changes associated with long-term exposure to MP EMF and the effects of different behavioral characteristics of MP use on cognitive functions.

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COMPETING INTERESTS
The authors declare no competing interests with this case.

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REFERENCES
[1] World Health Organization. Electromagnetic fields and public health: mobile phones. 2011; Fact sheet No.193.
[2] Effect of Prolonged Use of Mobile Phone on Brainstem Auditory Evoked Potentials (Gupta et al. 2015).
[3] Effect of electromagnetic waves from mobile phone on immune status of male rats: possible protective role of vitamin D (El-Gohary et Abdel-Azeem Said s. d.).
[4] Effect of exposure and withdrawal of 900-MHz electromagnetic waves on brain, kidney and liver oxidative stress and some biochemical parameters in male rats (Ragy 2015).
[5] Evaluating Temperature Changes of Brain Tissue Due to Induced Heating of Cell Phone Waves (Forouharmajd, Pourabdian, et Ebrahimii 2018).
[6] Impact analysis of mobile phone electromagnetic radiations on human electroencephalogram (Pattnaik, Dhalival, et Pattnaik 2019).
[7] Effects of cell phone radiofrequency signal exposure on brain glucose metabolism (Volkow et al. 2011).
[8] No Effects of a Single 3GUMTS MP Exposure on Spontaneous EEG activity, ERP correlates, and automatic deviance detection (Trunk et al. 2013).
[9] No Effects of Acute Exposure to Wi-Fi Electromagnetic Fields on Spontaneous EEG Activity and Psychomotor Vigilance in Healthy Human Volunteers (Zentai et al. 2015).
[10] Does the Brain Detect 3G MP radiation peaks? an Explorative In-Depth analysis of an experimental study (Roggeveen, van Os, et Lousberg 2015).
[11] Impact of head morphology on local brain specific absorption rate from exposure to MP radiation(Adibzadeh et al. 2015).
[12] EEG changes due to experimentally induced 3G MP Radiation(Roggeveen et al. 2015).
[13] Modelling and assessment of the electric field strength caused by MP to the human head(Buckus et al. 2016).
[14] Effect of acute exposure to RFs emitted by a MP (GSM 900 MHz) on electrodermal responsiveness in healthy human (Selmaoui et al. 2018).
[15] Effects of mobile phones electromagnetic radiation on patients with epilepsy: an EEG study (Azmy et al. s. d. 2020).
[16] The Genetic basis of the normal human electroencephalogram (EEG) (Vogel 1970).
[17] No effects of short-term exposure to mobile phone electromagnetic fields on human cognitive performance: A meta-analysis (Barth et al. 2012).
[18] WHO research agenda for radiofrequency fields (van Deventer, van Rongen, et Saunders 2011).

FAIZ I & KADMIRI N
EMFs Effect of MP on human brain

Health Sci.2020;1:6p 3
### Table 1: Summary of studies analyzed the effect of EM radiation on human brain.

| Year | Study                                           | Main aims                                                                 | Samples                                                                 | Experiment condition (source, frequency, duration, power) or stimuli used                                                                 | Result                                                                 |
|------|------------------------------------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| 2011 | Effects of cell phone radiofrequency signal exposure on brain glucose metabolism (Volkow et al. 2011) (7). | Evaluate if an acute exposure of MP affects brain glucose metabolism.     | ● 47 healthy participants (23 males, 24 females); ● Mean age 31 ±9 years; ● Mean MP use: 1500 min/month. | Samsung model SCH-U310 MP, 0.901 W/Kg is maximum specific absorption with frequency of 837.8 MHz for 30 min. | Compared with no exposure, 50 min MP exposure of participants was associated with increased brain glucose metabolism in the region closest to the antenna. |
| 2013 | No Effects of a Single 3G UMTS MP exposure on spontaneous EEG activity, ERP correlates, and automatic deviance detection. (Trunk et al. 2013) (8). | Investigated the possible acute effects of EMFs on spontaneous brain activity. | ● The first experiment (9 females and 8 males); Mean age: 21.76 ±3.47 years; ● The second experiment (12 females and 14 males), Mean age: 24.08 ±6.68 years. | 3G universal mobile telecommunications system (UMTS); MP (Nokia 6650, Nokia, Espoo, Finland) with frequency of 1947 MHz for 30 min. | In the first experiment, no measurable effect of 30 min exposure of 3G MP in any frequency had found. No significant effect of EMF had found of any event-related potential components. |
| 2015 | No Effects of Acute Exposure to Wi-Fi Electromagnetic Fields on Spontaneous EEG Activity and Psychomotor Vigilance in Healthy Human Volunteers. (Zentai et al.) (9). | Examined the effect of 60 min long 2.4 GHz Wi-Fi exposure on spectral power of EEG. | ● The first experiment, ● 15 females and 10 males, ● Mean age 23.3 years, SEM 0.6 | Wi-Fi exposure produced by MikroTik (Riga, Latvia), peak SAR 10 g level was 99.22 mW/kg at 2.4 GHz for 60 min | No effects of acute exposure to Wi-Fi EMFs on spontaneous EEG activity and sustained attention. |
| 2015 | Does the Brain Detect 3G MP radiation peaks? an Explorative In-Depth analysis of an experimental study (Roggeveen, van Os, et Lousberg) (10). | investigated whether third generation MP radiation peaks result in event related potentials (ERP). | ● 31 females; ● Mean age 26.7(±8.5). | 3G smartphone (brand was not reported), SAR level 0.69 W/kg 15 min, frequency not reported. | MP radiation induced ERP with peak latency 240–500 ms post-stimulus. |
| 2015 | Impact of head morphology on local brain Specific absorption rate from exposure to MP radiation (Adibzadeh et al.) (11). | Investigate the variation in averaged specific absorption rate (SAR) in specific brain-regions. | ● 20 participants (13 males and 7 females) | generic MP with conductivity for 835 MHz is 47.94 and 0.80 (S/m), and for 1900 MHz is 45.44 and 1.27 (S/m). | variation in the averaged SAR among the head could reach up inside the brain. |
| 2015 | Effect of exposure and withdrawal of 900-MHz-electromagnetic waves on brain, kidney and liver oxidative stress and some biochemical parameters in male rats (Ragy) (4). | study the effects of exposure to MP emits 900-MHz EMR on the brain, liver and kidney of male albino rats | ● 30 male adult albino rats (10 rats for each group); ● 16 to 18 weeks old; ● 170 to 200 g. | 3 groups of albino in the experiment; Control group with ordinary rat diet; Exposure group: were exposed to 900-MHz for 1 h/day for 60 days using the experimental phone exposure device; Withdrawal group: were exposed 1 h/day for 60 days to 900-MHz then left for 30 days without exposure. | A significant increase in malondialdehyde levels in exposure group in comparing with the other groups. Significant decrease in exposed group of total antioxidant capacity levels in brain, liver and kidney tissue. |
### 2015

**Effect of prolonged use of MP on brainstem auditory evoked potentials (Gupta et al.) (2).**

| Details | Methodology | Results | Notes |
|---------|-------------|---------|-------|
| Evaluate the effects of long-term MP usage on auditory brainstem evoked responses (ABR). | ● 100 healthy participants (69 females and 31 males);  
● Age: 18 to 30 years;  
● 33 subjects who had never used any MP;  
● 67 subjects who were using MP for more than one year. | For 100 Hz to 3000 Hz; Sweep speed was 1ms/div and sensitivity was 0.5μv/ div. | No significant difference in latencies, interpeak latencies and amplitudes of ABR waves. |

### 2015

**EEG changes due to experimentally induced 3G MP Radiation (Roggeveen et al.) (12).**

| Details | Methodology | Results | Notes |
|---------|-------------|---------|-------|
| Investigated whether a 15 min placement of a 3G dialing MP causes direct changes in EEG activity compared to the placement of a sham phone. | ● 31 females participants;  
● Mean age:  
● 26.7±8.5 years | 3G smartphone (brand was not reported); with SAR level of 0.69 W/kg for 15 min and frequency not reported. | Compared to chest, the effect was stronger when MP was placed on the ear. Increased power of several frequency bands (alpha, beta, and gamma bands). |

### 2016

**Modelling and assessment of the electric field strength caused by MP to the human head (Buckus et al.) (13).**

| Details | Methodology | Results | Notes |
|---------|-------------|---------|-------|
| Create and assess the strength spread by the electric fields of MP around the head. | ● Software “COMSOL Multiphysics” was used to establish the electric field strength created by mobile  
● MP the head; it composed of different thicknesses layers: skin, fat, muscle, skull and brain. | Frequencies of 900 MHz, 1,800 MHz and 2,100 MHz; Radiant power of 2 W, 1 W, 0.8 W, 0.25 W and 0.125 W. | Stronger power, higher SAR and lower frequency of MP is associated with the stronger electric of MP. |

### 2018

**Effect of acute exposure to REFs emitted by a MP (GSM 900 MHz) on electrodermal responsiveness in healthy human (Selmaoui et al.) (14).**

| Details | Methodology | Results | Notes |
|---------|-------------|---------|-------|
| Determine the effect of acute exposure to electromagnetic fields (EMF) emitted by a mobile phone on electrodermal activity (EDA) in response to an auditory stimulus. | ● 28 participants (14 healthy male and 14 healthy females);  
● Mean age: 24±3 years. | Nokia 6650; The real exposure with 900 MHz for 26 min; Total duration is 61 min including 26 min 15 s of real or sham exposure; | Decrease in the number of reposes and their amplitudes because of placement of the MP and whether it was turned ON or OFF; No changes in this group of volunteers associated with the exposure to GSM radiofrequency waves. |

### 2018

**Evaluating temperature changes of brain tissue due to induced heating of cell phone waves (Forouharmajd, Pourabdian, et Ebrahimi 2018) (5).**

| Details | Methodology | Results | Notes |
|---------|-------------|---------|-------|
| Determine the absorption of EMFs and their destructing effects on human health by increasing use of MP. | ● 15 cow brains (due to similarities human brain tissues);  
● Modified model: MT-917 ±0.01 ;900MHz frequency and specific absorption rates of 1.18 W/kg for 15 min. | Thermometer model: MT-917 ±0.01 ;900MHz frequency and specific absorption rates of 1.18 W/kg for 15 min. | EMFs emitted by MP were increasing brain tissue temperature; which has cumulative effect on the tissue. |
| Year | Study Title                                                                 | Investigate the electromagnetic signal from MP operating in Global System for mobile (GSM) and wide band code division multiple access (WCDMA) and analyze their interference impacts on the human electroencephalogram (EEG). | 75 healthy participants (57 males and 18 females); Mean age: 22.2 ±2.27 year; daily usage of MP: 2 to 3 hours | Nokia, Samsung, Panasonic and Motorola MP were using for the experiment with 0.67 to 1.14 W/kg SAR value. | Due to MP usage a variation in the nonlinear parameters and increase in the power of brain wave has found, and a change at the right temporal region has observed. |
|------|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| 2020 | Effects of mobile phones electromagnetic radiation on patients with epilepsy: an EEG study (Azmy et al. s. d.) (15). | Investigate the effect of mobile phone radiation (MPR) on the electroencephalogram (EEG) of adult persons with epilepsy. | 30 patients (15 males and 15 females); | Samsung S3 mini, frequency of 900 MHz and a peak power of 2 W and specific absorption rate of 1.03 W/kg; 15 min of sham exposure; followed by 30 min of real exposure; and final post exposure for extra 15 min. | No abnormal discharges during the real MPR exposure, those who showed an increase in the number of events in real exposure. |

Impact analysis of mobile phone electromagnetic radiations on human electroencephalogram (EEG) (Pattnaik, Dhaliwal, et Pattnaik) (6).