EFFECTS OF MOBILE PHONE RADIATION ON SOME BEHAVIORAL RESPONSES OF THE DESERT LOCUST, *SCHISTOCERCA GREGARIA* FORSKAL (ORTHOPTERA, ACRIDIDAE).

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INTRODUCTION

Although the existence of non-thermal biological responses to radiofrequency radiation (RFR) is now generally accepted, there is no conclusive evidence that mobile phones caused health problems (Hossmann & Hermann, 2003). Many gaps in our scientific knowledge have to be filled as soon as possible so that we can provide people with the evidence they need to make an informed choice about using their mobile phones (Hamblin & Wood, 2002).

Studies on the effects of mobile phone radiation on insects and other less costive organisms are needed. Several early teratologic studies were performed in which pupae of *Tenebrio molitor* (darkling beetle) were exposed to RFEMF at various levels for varying durations (Carpenter and Livstone, 1971; Green *et al.*, 1979; Lindauer *et al.*, 1974; Olsen, 1982 & Pickard and Olsen, 1979). Others suggested that mobile genetic elements (transposable elements or mobile genes) play an important role in the forming of genetic effects in response to low doses of radiation (Zainullin *et al.*, 2000) as well as in conditions of chronic gamma irradiation (Ivashchenko *et al.*, 1990; Shaposhnikov & Zainullin, 2000 and Zainullin & Moskalev, 2000). Weisbrot *et al.* (2003) studied the effect of mobile phone radiation on the number of offspring, heat shock protein, serum response element (SRE) and phosphorylation of ELK-1.

According to the EMC World Cellular Database, out of two billion worldwide mobile phone users, nine millions are Egypians. These increasing numbers of mobile phone users made it necessary to look at the effects of mobile phone radiation on behaviour, blood pressure, hearing and cancer. This piece of work may provide information that could show that it is important to search for mobile phone safety guidelines.

MATERIAL AND METHODS

Insects

A laboratory colony of the desert locust, *Schistocerca gregaria*, was maintained in the insectary of department of entomology, faculty of science, Cairo University under highly controlled conditions. This colony was kept at 28-30°C, 65-70% R.H. and natural photoperiod. These insects were used in all experiments.

Mobile phone irradiation

One hundred and fifty insects were subjected to a single (acute) discontinuous radio frequency (RF) signal produced by a GSM multiband Ericson mobile phone (about 900/ 1900 MHz and power approximately 0.03 m W/cm^2) for 2 hours. Two mobile phones were hanged in the middle of a fiber cage (20x 20x 20 cm) containing the insects. Three to five hours post-exposure, behavioral response of the irradiated insects was tested.

Experimental design: The apparatus used in measuring behavioral response of the desert locust, *Schistocerca gregaria*, is composed of 2 separate cages connected to each other by a tube (3 m length and 20 cm diameter). All parts of the apparatus are supported with stands to be kept at the same horizontal level. An opening in the middle (1.5 m distant from each cage) of the tube was done for insect release.

Tropism is defined as an involuntary orienting response; positive or negative reaction to a stimulus source (e.g., food, light, humidity, and gravity). Locusts are known to be positive trophotropic, phototropic and hydrotropic but negative geotropic insects (Uvarov, 1928).

Trophotropism (the orienting response to food): Both control and irradiated insects were starved 24 h prior to the experiment. Both cages were kept at 28-30°C, 65-70% R.H. and natural photoperiod. Only one of the two cages was supplied with food. Starved insects were released from the opening, half the distance from the two cages. Insects were given about 12 h as a chance to find their food. The numbers of positively and negatively responded as well as non-responded insects were counted. The experiment was repeated thrice for both control and irradiated insects. The mean percentge of positively and negatively responded as well as non-responded insects were calculated then compared to that of control.

Phototropism (the orienting response to light): The same above mentioned apparatus was used. Both cages were covered with a black cloth and kept in a dark room at 28-30°C, 65-70% R.H and supplied with food. Only one of the two cages was supplied with a light source. Insects were released from the opening, half the distance from the two cages. Insects were given about 12 h as a chance to respond to light. The numbers of positively and negatively responded as well as non-responded insects were counted. The experiment was repeated thrice for both control and irradiated insects. The mean percentage of positively and negatively responded as well as non-responded insects were calculated then compared to that of control.

Hydrotropism (the orienting response to humidity): The same above mentioned apparatus was used. Both cages were kept at 28-30°C, natural photoperiod and supplied with food.

One of the two cages was supplied with a solution to adjust 65-70% R.H and the other was adjusted to approximate drought condition. Insects were released from the opening, half the distance from the two cages. Insects were given about 12 h as a chance to respond to humidity. The numbers of positively and negatively responded as well as non-responded insects were counted. The experiment was repeated thrice for both control and irradiated insects. The mean percentge of positively and negatively responded as well as non-responded insects were calculated then compared to that of control.

Geotropism (the orienting response to gravity): The same above mentioned apparatus was used. Both cages were kept at 28-30°C, 65-70% R.H, natural photoperiod and supplied with food. Insects were released from the opening, half the distance from the two cages. Insects were given about 12 h as a chance to respond to gravity. The numbers of positively and negatively responded insects were counted. The experiment was repeated thrice for both control and irradiated insects. The mean percentge of positively and negatively responded as well as non-responded insects were calculated then compared to that of control.

Statistical analyses

Statistical analyses of the data were carried out using the computer program SPSS for Windows (Version 10.0). ANOVA and subsequent multiple comparison tests (Scheffé) were done to calculate the significance level between means.

RESULTS AND DISCUSSION

Studying the effects of mobile phone radiation on insect behavior and biology is an essential part for understanding its expected effects on animal as well as human health. The present work is an important step for further studies on other mobile phone effects. Interestingly, a single dose irradiation caused visible changes in the response of both adult and 5th nymphal instar of the desert locust, *Schistocerca gregaria*, to food, light, relative humidity and gravity.

Table (1) shows the effects of mobile phone radiation on some behavioral responses of adult desert locust, *Schistocerca gregaria*. It was observed that the positive trophotropism of adult locust (previously starved for 24 h) was significantly (P<0.01) decreased by about 20% after irradiation with mobile phone. The percentage of negative trophotropic insects was non-significantly (P>0.05) reduced by about 5%. Worthly mentioned that the mobile phone radiation significantly (P>0.01) increased the percentage of non-responded insects by about 25% (Table 1).

Additionally, the positive phototropism of the adult locust was significantly inhibited (P<0.01) by 12% after mobile phone irradiation. The percentage of insects that were negatively responded to light was reduced (P>0.05) by about 6%. Repeatedly the inhibitions in both positive and negative phototropism were found to be shifted (P<0.001) to the favor of non-responded insects by about 18% (Table 1).

About 30% and 10% reductions in the percentage of insects that were positively-responded (P<0.001) and negatively responded (P>0.05) to the optimum relative humidity, respectively. The percentage of non-responded insects was significantly increased (P<0.001) by about 40% after mobile phone irradiation (Table 1).

Furthermore, negative geotropism of the adult locust was significantly decreased (P<0.01) by about 12% to the favor of positive geotropism which was significantly increased (P<0.01) by the same percentage (Table 1).

When the same dose of radiation was applied to the 5th nymphal instar of the desert locust, Schistocerca gregaria, it was found that the percentage of positive trophotropic nymphs (previously starved for 24 h) decreased non-significantly (P>0.05) by about 8% after mobile phone radiations (Table 2). Statistical analysis revealed that the percentage of negative trophotropic nymphs was significantly reduced by 15% (P<0.001). The reductions in both cases were reflected in a significant (P<0.001) increase (23%) in the percentage of non-responded insects (Table 2).

It was observed that the positive phototropic nymphs significantly decreased (P<0.01) by about 10% after irradiation with mobile phone (Table 2). Also the percentage of negative phototropic insects was significantly (P<0.001) reduced by 24% after exposure to radiation. Worthly mentioned that the percentage of non-responded insects was approximately doubled (P<0.001) after mobile phone irradiation (Table 2).

TABLE (I)

Effect of the mobile phone radiation on some behavioral aspects of adult *Shistocerca gregaria*.

Response	Trophotropism Mean % ± S.E. (Min – Max)*			Phototropism Mean % ± S.E. (Min – Max)			Hydrotropism Mean % ± S.E. (Min – Max)			Geotropism Mean % ± S.E. (Min – Max)	
	+ve	-ve	±**	+ve	-ve	±	+ve	-ve	±	-ve	+ve
Before irradiation	72.8±3.3 (65.3-82.9)	24.4±3.0 (15.1-30.6)	2.8±0.4 (2.0-4.1)	80.4±1.3 (76.2-82.5)	12.2±1.5 (8.0-16.2)	7.4±0.8 (5.1-9.5)	70.3±1.1 (67.0-72.2)	28.1±1.1 (26.1-31.5)	1.6±0.2 (1.2-2.1)	89.3±1.9 (79.5-95.6)	10.7±1.9 (4.4-20.5)
After irradiation	53.3±3.3 (45.5-63.1)	19.7±4.9 (4.3-9.5)	27.0±1.8 (23.3-32.6)	68.3±2.1 (61.5-72.2)	6.2±1.2 (2.6-8.3)	25.5±3.3 (19.4-35.9)	39.4±5.3 (25.5-54.5)	20.0±2.9 (10.9-25.5)	40.6±5.9 (21.8-50.9)	77.1±2.5 (65.1-89.7	22.9±2.5 (10.3-34.9)

* Numbers between brackets refer to the range (min-max).

** ± refers to the % of insects that did not respond positively or negatively.

TABLE (II)

Effect of the mobile phone radiation on some behavioral aspects of *Shistocerca gregaria*, 5th nymphal instar.

Response	Trophotropism Mean % ± S.D. (Min – Max)*			Phototropism Mean % ± S.D. (Min – Max)			Hydrotropism Mean %± S.D. (Min – Max)			Geotropism Mean %± S.D. (Min – Max)	
	+ve	-ve	±**	+ve	-ve	±	+ve	-ve	±	-ve	+ve
Before irradiation	48.3±3.3 (39.0-56.8)	21.2±2.6 (14.4-28.4)	30.5±0.7 (28.8-32.6)	35.6±1.0 (32.4-37.6)	28.9±0.1 (28.7-29.4)	35.5±0.9 (33.7-38.2)	71.2±2.4 (66.2-78.6)	7.9±1.3 (4.3-11.3)	20.9±1.2 (17.1-23.0)	87.7±1.2 (82.8-92.9)	12.3±1.2 (7.1-17.2)
After irradiation	40.3±0.9 (38.5-43.2)	6.0±0.7 (3.8-7.7)	53.7±1.2 (50.3-57.1)	25.6±2.2 (21.0-32.4)	4.8±0.9 (3.7-5.5)	69.6±2.4 (62.3-75.3)	37.6±3.9 (27.9-49.0)	7.9±0.9 (5.4-10.8)	54.5±3.5 (45.6-64.6)	60.0±2.4 (52.3-70.1)	40.0±2.4 (29.9-47.7)

* Numbers between brackets refer to the range (min-max).

** ± refers to the % of insects that did not respond positively or negatively.

Statistical analysis revealed that the percentage of positively hydrotropic nymphs was significantly decreased ($P<0.001$) by 34% after irradiation. Meanwhile, the percentage of negative hydrotropic insects was not changed ($P>0.05$). On the other side the percentage of non-responded insects was significantly increased ($P<0.001$) by 34% after irradiation (Table 2).

Furthermore, the percentage of normal negative geototropic nymphs was significantly decreased ($P<0.001$) by about 28% to the favor of positive geotropic one that was significantly increased ($P<0.001$) by the same percentage (Table 2).

Moreover, it was observed that the ability of adult locust to fly was lost after mobile phone irradiation. They jumped and settled down then the wing beats began when they were standing on the ground or the walls (no coordination between the wing beat and jumping in the beginning of flying) so, they failed to fly. Generally the insects seemed as they were dizzy, lazy and unbalanced after exposure to mobile phone radiation. Five days post-exposure to mobile phone radiation, insects began to restore their ability to fly and seemed to be normal.

In general, it was observed that the reductions in the percentage of responded insects (whatever positive or negative response) in all cases were translated into increases in the non-responded insects by the same percentage. It is note worthy that more reductions were observed in normally responded adults and abnormally responded nymphs after radiation. As expected, it can be observed that nymphs were generally more affected than adults when exposed to mobile phone radiation.

The present results could be interpreted as the radiation caused the insects to be in a status of dizziness and unbalance. The dizzy and unbalanced insects could not respond to any influence, became hesitated and finally paused. Possibly this status could be attributed to muscle stress or muscle tonus. Moreover, the non-response status may be due to affected or blocked receptors, due to changes in some centers in the brain, nervous system or both.

To my knowledge, this is the first report that described the effect of mobile phone radiation on insect behavior in Egypt. Very few publications have reported some effects of mobile phone radiation on insects. Carpenter and Livstone (1971), Green *et al.* (1979), Lindauer et al. (1974), Olsen (1982), Pickard and Olsen (1979) conducted several teratologic studies in which pupae of *Tenebrio molitor* (darkling beetle) were exposed to radiofrequency electromagnetic field (RFEMF) at various levels for varying durations. They concluded that teratogenic effects in *Tenebrio* were thermally induced and not non-thermal in etiology. Others suggested that mobile genetic elements (transposable elements) play an important role in the forming of genetic effects in response to low dose of radiation (Zainullin *et al.*, 2000) as well as in conditions of chronic gamma irradiation (Ivashchenko *et al.*, 1990; Shaposhnikov & Zainullin, 2000 and Zainullin & Moskalev, 2000). Recently, Weisbrot *et al.* (2003) reported that the non-thermal radiation from the GSM mobile phone increased the numbers of offspring, elevated heat shock protein (hsp70) levels, increased serum response element (SRE) DNA-binding and induced the phosphorylation of the nuclear transcription factor, ELK-1 in *Drosophila melanogaster*. Genetic effects of low dose irradiation on *Drosophila melanogaster* were suggested to be due to induction of mobile genetic elements (Zainullin *et al.*, 2000). In addition, Zainullin and Moskalev (2000) presented that chronic gamma irradiation may cause life span variation, genomic destabilisation with an induction of mobile genetic elements in *Drosophila melanogaster*. Shaposhnikov and Zainullin (2000) demonstrated that chronic exposure of *Drosophila melanogaster* to gamma radiation leads to substantial changes in the genetic structure of a population and an enhanced level of dysgenic sterility. Their results indicated that genetic instability and adaptation to the effect of chronic gamma-radiation are associated with the radiation-induced mobilization of mobile genetic elements. Furthermore, Ivashchenko *et al.* (1990) suggested that gamma-irradiation may interact with P transposon to induce processes at the level of DNA repair in *Drosophila melanogaster*

In conclusion, the present work threw the light on the adverse effects of acute dose mobile phone radiation on insect behavior. It is expected that the accumulated dose (chronic exposure) may cause behavioral, physiological or genetic effects which could be recoverable or not. This piece of work ensured the adverse effects of mobile phone radiation on insects and raised questions about its risks on human, children,...etc. Moreover, this study opened the horizon toward studying physiological as well as genetic effects of mobile radiation in insects.

SUMMARY

Experiments were designed to examine the effects of a discontinuous radio frequency (RF) signal produced by a GSM multiband mobile phone (about 900/1900 MHz and power approximately 0.03 m W/ cm^2) on the orienting response of adult as well as 5^{th} nymphal instar desert locust, *Schistocerca gregaria*, to food, light, humidity and gravity. The positive trophotropism of the previously starved adults

and nymphs was decreased by about 20% and 8%, respectively, after irradiation with mobile phone. The percentage of negative trophotropic insects was also reduced by about 5% and 15% in case of adult and nymph, respectively. The percentage of non-responding insects was increased by about 25% and 23% in case of adult and nymph, respectively. The percentage of positive phototropic adults and nymphs was inhibited by 12% and 10%, respectively, after mobile phone irradiation. Negative phototropic insects were reduced by about 6% and 24% in case of adult and nymph, respectively. The inhibitions in both positive and negative phototropism were found to be shifted to the favor of non-responding insects by about 18% and 34% in case of adult and nymph, respectively. About 30% and 10% reductions were recorded in the percentage of positive and negative hydrotropic adults, respectively. The percentage of non-responding adults was increased by about 40% after mobile phone irradiation. The 34% reduction in the positive hydrotropic nymphs was mirrored as 34% increase in the non-responding nymphs after irradiation. Both negative geotropic adults and nymphs were decreased by about 12% and 28% to the favor of positive geotropic ones which were increased by the same percentages. Moreover, it was observed that the ability of adult locust to fly was lost for five days post-exposure to mobile phone radiation. This study opened the horizon toward studying physiological as well as genetic effects of mobile radiation on insects.

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