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SPPCR

SOCIEDADE PORTUGUESA PROTECÇÃO CONTRA RADIAÇÕES

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SOCIEDADE PORTUGUESA DE PROTECÇÃO CONTRA RADIAÇÕES
Instituição de Utilidade Pública
Rua 5 de Outubro Lote 33 1º E 2695-697 S. João da Talha PORTUGAL
Telefone: 351 21 9552062 Telecópia: 351 21 9942077
Email: jgbpcr@mail.telepac.pt
jgdebrito@mail.teleweb.pt;joao.brito@netc.pt
http://paginas.teleweb.pt/~nop03539/

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EDITORIAL

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RADIOPROTECÇÃO

REVIEW OF STUDIES VALIDATING THE PROTECTIVE EFFICACY OF A NEW TECHNOLOGY (*) DESIGNED TO COMPENSATE POTENTIAL ADVERSE BIOEFFECTS CAUSED BY VDU AND GSM CELL PHONE RADIATION

B.J. Youbicier-Simo, R. Messagier, M. Fillion-Robin
Tecnolab Research Center, ZAC de la Thalie, Av. l'Europe, 71100 Chalon Sur Saône, France
(*) Tecno AO: international registered patent and trademark

Summary

A total of 13 studies were initiated and coordinated by Tecnolab Research Center in 6 laboratories from 3 countries (France, UK, Japan). These studies were aimed at:
- 1) investigating potential adverse bio-effects associated with exposure to non-ionizing radiation (NIR) emitted by two types of communications devices, video display units (VDU) and cell phones;
- 2) assessing the efficacy of a compensation magnetic oscillation technology designed to protect from NIR. Five types of biological systems including chicken embryos, young chickens, healthy mice, mice suffering from cancer and humans were used. A set of 10 biological parameters were assessed, including embryonic mortality, hormones, antibodies, haematological parameters, stress, mood, ocular damage, neurogenesis, micronuclei formation and intracellular calcium. Overall endpoints were affected by irradiation, in terms of increased embryonic mortality, immune depression, depletion of hormones crucial for the regulation of the immune system (corticosterone and melatonin), changes in haematological parameters, increased stress, mood alteration, induction of ophthalmologic disorders, inhibition of the neurogenesis in brain areas associated with memory processes, induction of symptoms of cell dysfunction, apoptosis or cancer, and disruption of trans-membrane fluxes of calcium. On the other hand, the compensation magnetic oscillation technology tested allowed significant correction of altered physiological parameters, as well as improvement or disappearance of observed pathological symptoms.

Key words: Bioelectromagnetism - Video display units (VDU) - Cellular mobile telephone - Compensation magnetic oscillation technology-

Introduction

In recent years, there has been an exponential proliferation of electronic devices emitting non-ionizing radiation (NIR), namely communication equipments such as video display units (VDU) or cellular mobile telephones. This anthropogenic radiation induces overloading of the electromagnetic environment of living beings, leading to increased exposure of the general population. Public concern raised by this situation has rekindled the debate about the harmfulness of NIR and h as aroused scientific interest worldwide. In spite of inconsistencies in the results of the studies devoted to the investigation of potential interference of NIR with living matter, a growing body of evidence suggests that NIR is biologically active (Reiter , 1993; Daniells *et al.*, 1998; Mann and Röschke, 1998; Velizarov *et al.*, 1999; Macias *et al.*, 2000; Hyland, 2000), and can adversely affect biology (Arnetz and Berg, 1996; Farrel *et al.*, 1997; Persson *et al.*, 1997; Repacholi *et al.*, 1997; Braune *et al.*, 1998; Frey, 1998; Hocking, 1998; Hardell *et al.*, 1999; Bianchi *et al.*, 2000; Ceconi *et al.*, 2000; Hocking and Westerman, 2000; Huber et al., 2000; Koivisto *et al.*, 2000; Oftedal *et al.*, 2000; Savitz *et al.*, 2000). Among other reasons of conflicting results is the fact that in most studies carried out so far, irradiation was performed with surrogate frequencies different from those allocated to commercial devices. In fact, the frequency spectrum of the emission of some commercial devices has similarities with those of certain physiological activities, and thus can affect them. This is precisely the case with *GSM* mobile telephony, since not only do living organisms have a preconditioned sensitivity to the microwave carriers used by this technology, but the particular pulsing of the signal used in *TDMA* (Time Division Multiple

Access) contains frequency components – specifically at 2 Hz and 8.34 Hz – that lie, respectively, in the range of the δ and α brainwaves of the human electro-encephalogram (EEG). This is also the case with the recently introduced *TETRA* system (Trans European/or Terrestrial Enhanced Trunked Radio Access), whose lower frequency carrier is pulsed at 17.6 Hz. For this frequency lies in the β brainwave band, and is close not only to that at which a flashing light can provoke seizures in people with photo-sensitive epilepsy (Harding and Jeavons, 1994), but also to the frequency which causes the maximum efflux of calcium ions from brain cells (Bawin *et al.*, 1978, Blackman *et al.*, 1980); the significance of the latter is that calcium is an important mediator in vital biochemical functions. In the case of cell phone handsets there is, in addition, the much more penetrating and equally noxious low frequency *magnetic* field that arises as the current from the battery is switched on and off in the manner required to implement *TDMA*. (Linde and Mild, 1997; Pedersen and Andersen, 1999). In this regard, the proliferation of electronic devices might be prejudicial not only to the equilibrium of the ecosystem, but also to human well-being, and therefore poses a real public health issue that should be tackled seriously. Consistent with this rationale, research efforts undertaken in our research center since a decade have been oriented in two directions: 1) investigation of bio-effects elicited by communication devices such as VDU and cell phones; 2) design and validation of the efficacy of a new technology aimed at compensating harmful bio-effects elicited by NIR. This paper is a review of studies committed and coordinated so far by the research team of Tecnolab. A summary of experimental protocols and main results is presented in Tables 6 and 7.

1. Biological effects of VDU radiation

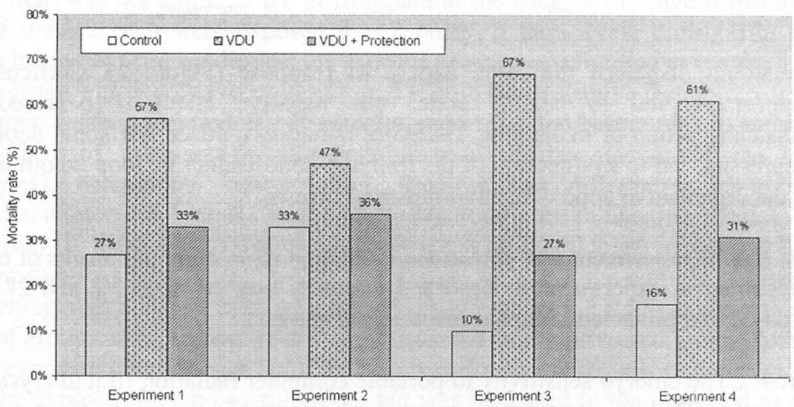
1.1. Animal studies

1.1.1. Mortality and immune-neuroendocrine effects in the chicken

A study was carried out in collaboration with the University of Montpellier (France) in order to investigate the impact of NIR given off by three types of VDU, TV, desk computer and portable computer, on embryonic development, as well as on neuroendocrine and immune parameters in the chicken. The efficacy of a compensation magnetic oscillation technology was tested as well.

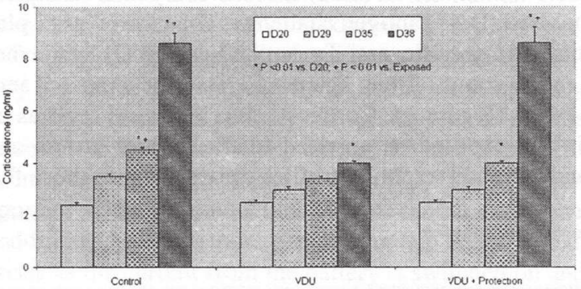
Experiment 1: Fertilized chicken eggs were placed 50-80 cm in front of a TV set of the cathode ray tube (CRT) style. Ambient values of extremely low frequency (ELF) and very low frequency (VLF) fields were 0-12 nT and 2 nT respectively. With the TV set switched on, the field strength at the level of the eggs was 135 –270 nT for the ELF and 2-4 nT for the VLF fields. Three groups of 30 eggs each experienced the following electromagnetic treatment, continuously during 21 days: the control group was not exposed; the exposed (VDU) group was exposed to the TV set switched on; the protected (VDU + protective technology) group was exposed to switched on TV equipped with the protective technology. The eggs were incubated under 38 + 1 °C, 45-50 % relative humidity and permanent darkness during 21 days. Embryonic mortality was assessed by candling the eggs at 2-day intervals from 3 to 13 days of development (ED3-ED13) and on the day of hatching (ED21). After hatching, the brood from each experimental group was submitted to the same electromagnetic treatment experienced during embryonic life. Young chickens were repeatedly immunized by injecting porcine thyroglobulin (Tg) subcutaneously at 21, 30 and 39 days of age. Blood samples were collected the day before immunization (D20) and at weekly intervals after the first (D29), the second (D38) and the third (D 47) antigen challenge. Then the level of plasma corticosterone, as well as serum titres of specific anti-Tg antibodies (Ig G) were measured. Embryonic mortality was 27 % in the control group against 57 % in the exposed, and was reduced to 33 % in the protected group (Figure 1). Corticosterone levels, as well as antibody titres were markedly reduced in the exposed as opposed to the control group, and were restored to normal. Hormonal and antibody response profiles were similar to those featured in Figure 2.

Figure 1: Mortality rate among chicken embryos exposed to VDU radiation and protected by a compensation magnetic oscillation technology



Experiment 2: The radiation source was a desk computer of the CRT type. Three sets of 30 fertilized eggs each (control, exposed, protected) were placed 50-80 cm from the side of the computer. Background values of the ELF and VLF fields were 0-27 nT and 2 nT respectively. With the computer switched on, ELF values were 142-660 nT and VLF values were 2-13 nT. The incubation conditions, the evaluation of embryonic mortality, as well as the handling conditions of the chicks and chickens were exactly the same as in experiment 1. Young chickens were submitted to a slightly modified version of the immunization program used in experiment 1. They were immunized at 21, 30 and 36 days of age by subcutaneous injection of porcine Tg. Blood samples were collected at D20, D29, D35 and D38, and assayed for plasma corticosterone and melatonin, as well as serum titres of specific anti-Tg antibodies (Ig G). The timetable changes employed in the immunization protocol were designed to refine the hormonal profile between D29 and D38. Embryonic mortality was 33 %, 47 % and 36 % in the control, exposed and protected groups respectively (Figure 1). Corticosterone and antibody profiles were similar to those observed in experiment 1 (Figure 2)

Figure 2: Hormonal and antibody responses of young chickens exposed to VDU radiation and protected by a compensation magnetic oscillation technology



Plasma melatonin displayed the same pattern of response (Figure 2). Corticosterone is immunosuppressive and in healthy state, this negative effect is balanced by the immunoenhancing action of melatonin. Therefore radiation-induced hormonal depletion and immune depression led to dysfunction of the immune-neuroendocrine loop whom integrity is crucial for the organism to cope with environmental insults.

Experiment 3: This experiment was performed to attempt replicating the results of embryonic mortality recorded in experiment 2. Recorded mortality was 10 %, 67 % and 27 % in the control, exposed and protected groups respectively (Figure 1).

Experiment 4: , The embryo sensitivity to portable computer radiation (liquid crystal display style) was tested. The exposure set up comprised a portable computer fixed on wooden platform. The latter was made of two plans at right angle in order to simulate the position of somebody using a computer. The keyboard of the portable computer was held horizontally 10 cm above the eggs placed on the horizontal plan and the screen was 30 cm away from the eggs disposed on the vertical plan. Background levels of the ELF and VLF fields were 10-19 nT and 1 nT respectively. With the computer switched on, the magnitude of the ELF and ELF fields over the egg platform was 15-267 nT and 1-26 nT respectively. Fertilized chicken eggs were randomly distributed into three groups of 90 eggs each (control, exposed, protected). The incubation of the eggs and the assessment of embryonic mortality were performed as described in experiment 1. Averaged embryonic mortality rate was 16.55 %, 61.41 % and 31.35 % in the control, exposed and protected groups respectively (Figure 1).

Together, these data suggest that:

1. **VDU radiation was toxic for chicken embryos;**
2. **VDU radiation induced hormonal depletion**
3. **VDU radiation induced immune depression**
4. **the compensation magnetic oscillation technology tested substantially mitigated radiation-elicited adverse effects.**

1.1.2. Stress effects in mice

Two experiments were conducted at the Paul-Brousse University hospital in Paris (France).

The first one was designed to determine whether exposure to TV radiation by a TV set can alter hematologic parameters and if an electro-magneto-protective device can effectively prevent adverse effects induced by TV exposure. Four week-old male Swiss mice were involved in the study. The cages containing the mice were placed 20 cm in front of a TV screen. The geomagnetic field at the site of the study was 572 mG. Ambient electric and magnetic field strength was 3 V/m and below 0.01 μT respectively. With the TV set switched on, the electric field strength in the center of the cage was 30 V/m and the intensity of the magnetic field was 0.8 and 0.23 μT in front and at the back of the cage respectively. Three groups of 9 mice each were exposed 9 ± 2 h/day, 5 days/week, during 106 days under different electromagnetic conditions: the exposed group was submitted to switched on TV; the protected group was exposed to switched on TV with the protective technology installed; the control group was not exposed. Blood samples were collected before (day 0) and after 21, 56 and 106 days of exposure for the determination of the number of red blood cells (erythrocytes), hemoglobin concentration, absolute and differential white blood cell (neutrophils, monocytes, lymphocytes) counts. The results are outlined in Table 1. Before TV exposure (day 0), there was no statistical difference in haematological parameters between the three groups under study. After 3 weeks of exposure (day 21), the number of erythrocytes as well as hemoglobin concentration were significantly higher ($P < 0.05$) in the exposed than in the control group, while normal values were observed in the protected group. After 8 and 15 weeks of exposure (days 56 and 106), the number of neutrophils was statistically lower ($P < 0.05$) in the exposed than in control group, but was increased in the protected as opposed to the exposed group. The same trend was noticed for monocytes. Observed decrements further to TV exposure might be accounted for by reduction in the proliferation rate, mobilization to assist target tissues or necropsy. This leads to weakening of non-specific immunity which is crucial for antibacterial and anti-parasitic defence, as well as protection from exogenous chemical pollution.

In the second experiment, the possibility that TV radiation induces stressful effects in mice was investigated by measuring the levels of blood cortisol. The exposure set up, field characteristics and experimental groups (control, exposed, protected) were exactly the same as described in the first experiment. The results are presented in Table 2. The mice were bled after 21 and 106 days of exposure to measure cortisol levels. No difference was observed between the three groups after 3 weeks of exposure (day 21). After 15 weeks of exposure (106), cortisol level was significantly decreased ($p < 0.05$) in the exposed mice as compared with their control counterparts. On the other hand, normal cortisol level was observed in the protected group.

Together, these findings indicate that :

1. **TV radiation altered haematological parameters;**
2. **TV radiation weakened immune defence;**
3. **TV radiation was stressful;**
4. **the compensation magnetic oscillation technology allowed significant correction of disrupted physiological functions.**

1.2. Human studies

1.2.1. Stress effects

This study was performed at the Cochin Hospital in Paris (France). The authors sought to determine whether electromagnetic fields act as a stress factor to affect work performance (interference stress) and also to evaluate the protective effect of the compensation magnetic oscillation technology. The study was initiated with 119 VDU users from French and Swiss companies and civil services and departments, working at least 2 h/day with a computer. Two experimental sessions were carried out at one month interval. For the first session, subjects were tested at the end of the week after having worked with their computers for all the week. As soon as the first test has been performed, the electromagnetic compensation technology was installed on the computers for a duration of one month. The degree of resistance to stress against interfering distractions (stress of interference) is assessed with a psychometric test, "Test de Stress", derived from the Stroop Color-Work Test (Jensen A.R.,Rohwer W.D. 1966). The test consist of three exercices that estimates 3 variables : speed, alertness, concentration. Complementary, for 35 of the 119 participants, after each Stress psychometric test session, a questionnaire of symptoms was filled out.

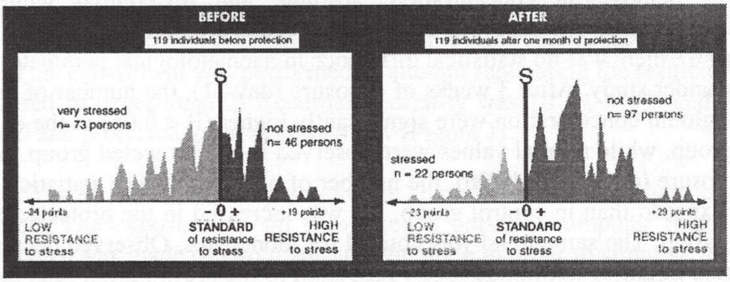


Fig. 3 STRESS TEST

For 119 VDU workers

The results (Figure 3) indicated that in the first experimental session, according to a standard of "normal" resistance to stress : 73 out 119 subjects showed low and very low resistance to stress, while 46 remaining showed a resistance to stress over the standard. Then in the second experimental session, with the compensation device installed on the computers, only 22 fellows out 119 showed low stress resistance and 97 remaining displayed a high resistance to stress. The mean improvement for 119 VDU workers was 14.9%, while for the group initially very stressed, the mean gain was 21.2%. On the other hand, 27 out 35 subjects questioned reported improvement or disappearance of one or several symptoms (headaches, insomnia, conjunctivitis, neck pain, redness of the eyes, tearing, etc.).

Together these findings indicate that:

1. **VDU radiation was stressful;**
2. **resistance to stress was increased by the protective device;**
3. **stress symptoms were improved or neutralize by the protective device.**

1.2.2. Psychological effects

A double blind experiment was undertaken at Luton University (UK) to determine any difference in mood between individuals using VDU equipped with the compensation technology and those without. The participants were 100 undergraduates volunteers of the University of Luton. They were randomly distributed into two groups of 50 fellows each, the control group exposed to VDU and the experimental group exposed to the VDU with the compensation technology installed. The experiment lasted 2 weeks and Mood test was performed by filling out questionnaires. The participants had to mark along a visual analogue scale of 12 parameters from "definitely do not feel" to "definitely feel" how they felt. The variables were combined according to the formula provided by Peveler and Jonhson (1985):

Arousal = alert + energetic + lively - sleepy - sluggish - drowsy

Distress = worried + tense + uneasy - peaceful - relaxed - calm

The results showed that individuals with the compensation technology were significantly more alert and less tense than the control group. Furthermore, the experimental protected group was significantly more aroused and less distressed than the control group. The use of the compensation technology had a positive and immediate effect on the mood of VDU operators.

To conclude :

1. VDU radiation altered mood;

2. the EM compensation device improved it.

1.2.3. Building sickness syndrome effects and electromagnetic stress

A double blind crossover study was conducted at the University of Reading (UK) in order to assess the building sickness symptom scores of office workers using VDUs, and to ascertain the bio-protective effects of a simultaneous exposure to the electromagnetic compensation technology. The study involved 219 office workers from two UK companies. In both companies, the subjects were divided into two equal groups. The building sickness symptom scores were ascertained using a 19 item questionnaire covering general stress environmental and ergonomic factors. First, the subjects answered the questionnaire by interview. Afterwards active and dummy compensation devices with colour codes were installed in two wings or parts of the experimental buildings, one colour code in one wing and the other colour code in the other wing. After a month the subjects answered the questions again, then swapped active for dummy devices and vice versa. Then the findings were analysed after identifying the colour coding for the active-dummy devices. Healthy buildings usually score maximum 4 symptoms per person. The buildings tested had an average score of over 10 symptoms per person. By the use of the EM compensation device on the VDUs, the symptoms of building sickness were reduced by an average between 33 % (t-test analysis) and 36% (raw scores analysis).

While 30% of the staff seemed unaffected by EMF, for 70% of the staff, the reduction of symptoms was over 40%. Significant reductions in respiratory symptoms, headaches and pains in the neck, hands, wrists and fingers between 32% and 47% indicate a major benefit for staff from VDU electromagnetic field protection.

Thus protective technology tested compensated for VDU radiation-induced stressful effects. Up to two third of observed symptoms were due to other factors and at least a third to VDU radiation alone.

These data were reproduced in 8 other UK companies among a total of 567 people.

These data suggest that:

1. VDU radiation induced worsening of building sickness syndrome;

2. the EM compensation device offset this effect protecting from electromagnetic stress.

1.2.4. Ophtalmologic effects

A study was carried out at the University of Kitasato (Japan) in order to assess ocular damage resulting from electromagnetic exposure while performing a VDU task. The latter consisted in performing a video game play continuously during 4 hours. Participants to the study were 10 female laboratory technicians between 20-30 years of age, not occupationally involved in VDU work. The head was 1.2 m in front of the TV screen. At this distance, the electric and magnetic fields strength in the 1-400 KHz band was 9 V/M and 17.5-58 nT respectively. Two experimental sessions were carried out at 1 week interval. In the first experimental session, ocular problems were evaluated prior to and after 4 hours of video game play. The second experimental session took place 1 week later and was similar to the first, except that the VDU was fitted with the compensation technology. Ocular damage was measured prior to and 4 hours after performing the VDU task. Six types of ocular disorders were assessed: injury to corneal epithelium (keratitis); visual acuity and refractivity; near point of accommodation; accommodative response to a step stimulus (refractivity, amplitude, tonic response time, relaxation time, speed); pupillary response to a step stimulus (near response); electro oculogram.

1. When the eye damage in subjects performing identical tasks for 4 hours using television screens either fitted with or without the compensation technology was examined comparatively, the following results were obtained:

2. there was significantly less corneal epitheliopathy in the subjects using the compensation technology than in those without ($p = 0.016$).

3. increase of the distance to the near point was seen with the compensation technology, and when this was considered in conjunction with the relevant literature, it was considered that the compensation technology prevented the occurrence of abnormal tonus accommodation.

4. when the compensation device was fitted, a slowing of the speed of relaxation of accommodation was observed in the step response.

5. there were fewer abnormalities of the pupils in near vision when the compensation device was used than without.

These results suggest that the EM compensation technology tested is efficient for protection of the eyes when work on VDU is carried out.

2. Biological effects of the cell phone radiation

2.1. Animal studies

2.1.1. Embryonic mortality in the chicken

It was the scope of the present study to check the protective efficacy of the compensation technology against the mortality of chicken embryos induced by continuous exposure to GSM cell phone radiation.

The exposure system comprised a 900 MHz GSM cell phone (2 W maximal output) placed horizontally 10 cm above exposed eggs, with or without the protective technology installed. The cell phone operation was monitored by means of a time-switch wired to the electronics inside the cell phone case. EMF intensity measured at the level of the eggs ranged from 6 to 18 V/m for microwaves and from 70 to 90 dBpT for the ELF magnetic field. Four groups of 60 eggs each were submitted to different electromagnetic treatments: the control group was exposed to switched off cell phone; the exposed (cell phone) group was submitted to operating cell phone; the protected (cell phone + protective device) group was exposed to operating cell phone with the compensation device installed; an additional control (protective device) group was exposed to the protective device alone, in the absence of the cell phone. The irradiation schedule consisted in sending 3 min. phone calls continuously during the experimental session. The results are outlined in Figure 4. The incubation of the eggs and the assessment of embryonic mortality were performed as described in paragraph 1.1.1. Embryonic mortality was higher in the exposed than in the control group (60 % vs. 14 %), and dropped to 27 % in the protected group. It was close to baseline value (16 %) when the compensation technology was tested alone in the absence of the cell phone (Figure 4).
The electromagnetic spectrum of GSM cell phones encompasses microwaves as well as ELF fields. We wondered if the cell phone radiation remained biologically active after substantial mitigation of microwaves. To this end microwaves were shielded by means of a fine mesh (350 μ) copper filter. In this instance, the ELF field strength remained unchanged. The mortality rate raised to 76 % and was induced by the ELF field (Figure 4). We also tested the protective efficacy of commercial shield supposed to reduce by 99 % the level of microwaves radiated by the cell phone and absorbed by the head. Recorded mortality rate was 77 % (Figure 4).

These data demonstrated that:

1. **GSM cellphone radiation was harmful for chicken embryos, in compliance with results from different studies showing that ELF fields in the cell range are biologically active;**
2. **This damaging effect was effectively and harmlessly counteracted by the compensation technology tested.**

These data were reproduced in a replication experiment.

2.1.2. Stressful effects in healthy and tumor-bearing mice
This study was performed in collaboration with the University of Montpellier (France).
Experiment 1 was set up to evaluate potential influence of GSM cell phone radiation on the production of stress hormones in healthy mice, and also to test the capacity of the compensation technology to counteract radiation-induced stressogenic effects. The radiation source was a 900 MHz GSM cell phone (2 W maximum output) placed horizontally with the battery downwards, underneath the cage containing the mice. The study was initiated with 4 week-old C57BL mice held under 22 + 2 °C, 12L-12D$_{-19\,h\,-\,07\,h}$, with free access to feed and water. The irradiation schedule consisted in sending 3 min. phone calls 24 h/day, 7days/week during 5 weeks. Five experimental groups of 15 mice each were introduced in the study. The sham-exposed group was exposed to switched off cell phone. The cell phone group was exposed to operating cell phone.

The cell phone + copper filter group was exposed to operating cell phone while being sheltered from microwaves by means of grounded fine mesh (350 μ) copper filter. The cell phone + protective device group was exposed to operating cell phone fitted with the protective device. The cell phone + copper filter + compensation technology was exposed to operating cell phone with the protective device installed, while being sheltered from microwaves by grounded copper filter. Blood samples were collected after 2 and 5 weeks of irradiation for the measurement of the levels of stress hormones (adrenocorticotropic hormone or ACTH and corticosterone). The results are presented in Table 3. The cell phone radiation, either as a whole or after substantially deprived from microwaves, induced significant decrements in plasma ACTH and corticosterone levels, relative to control group ($P< 0.05$). The compensation device allowed partial restoration of corticosterone levels and partial or total restoration of ACTH levels.

In view of aforementioned results, we wonder what would be the influence of the cell phone radiation in mice suffering from cancer and we also tested the protective efficacy of the compensation device. The strain of mice used, handling conditions and irradiation schedule were the same as in experiment 1, except that irradiation lasted 15 weeks. Lewis lung carcinoma 1 cells (LLC1) were injected in the thigh muscle of the right hind led after 12 weeks of irradiation. Six groups of mice ($n = 15$/group) were studied. The sham-irradiated and saline-treated control group was exposed to switched off cell phone and was inoculated with the saline. The tumor group was exposed to switched off cell phone and was inoculated with LLC1 cells. The cell phone + tumor group was exposed to operating cell phone and was inoculated with LLC1 cells. The cell phone + copper filter + tumor group was exposed to operating cell phone while being sheltered from microwaves by means of grounded copper filter and was inoculated with LLC1 cells. The cell phone + protective device + tumor group was exposed to operating cell phone fitted with the protective device and was inoculated with LLC1 cells. The cell phone + copper filter + protective device + tumor group was exposed to operating cell phone fitted with the protective device while being sheltered from microwaves by means of copper filter, and was inoculated with LLC1 cells. Blood samples were collected after 15 weeks of irradiation for the measurement of the levels of stress hormones (ACTH, corticosterone). The results are presented in Table 4. In sham-irradiated mice receiving tumor cells, slightly reduced ACTH and significantly decreased corticosterone levels were observed ($P < 0.05$). This tumor-induced depletion of stress hormones was potentiated by whole or microwave-deprived cell phone radiation. The compensation technology induced restoration of ACTH to levels comparable to those observed in the controls, while only partial restoration of corticosterone levels was observed. With respect to tumor, total compensation was observed for both ACTH and corticosterone. This experiment was replicated with similar results.

Taken together, these findings indicate that:

1. **chronic exposure to GSM cell phone radiation either as a whole or restricted mainly to its ELF component, was stressful for healthy mice;**
2. **chronic irradiation was synergistic with cancer to deplete stress hormones.**
3. **These stressful effects were partly or totally reversed by the compensation technology tested.**

2.1.3. Pilot study on neurogenesis, micronuclei formation and calcium in mice

A pilot study was undertaken in collaboration with the University of Montpellier (France) to determine whether GSM cell phone radiation interferes with the proliferation of progenitor nerve cells in germinative areas of the adult brain, as well as with the formation of micronuclei and intracellular concentration of calcium in peritoneal macrophages of mice, and to prevent induced effects if any. The exposure set up, field characteristics, strain of mice used, handling conditions and irradiation schedule were the same as described in the study above. Three groups of 15 mice each experienced different irradiation conditions during 15 weeks: the control group was exposed to switched off cell phone; the exposed (cell phone) group was submitted to operating cell phone; the protected (cell phone + protective device) group was submitted to operating cell phone with the compensation technology installed. Five mice from each group were injected i.p. with the cell proliferation marker bromodeoxyuridine. With respect to irradiation, quantitative estimation of cell proliferation indicated no inter-group difference in the numerical density of proliferating cells (BrdU-labeled) within the subventricular zone of the lateral ventricle and white matter. On the other hand, a slight but significant decrease (-25%) was observed in the hippocampal dentate gyrus of mice in the exposed group as opposed to controls, whilst mice in the protected group displayed normal nerve cell proliferation rate.

Together, these data indicate that:

1. **prolonged exposure of mice to GSM cell phone radiation moderately but significantly altered hippocampal neurogenesis;**
2. **the compensation technology was effective in restoring normal neurogenesis in this brain area.**

Neurogenesis is active in the adult brain and is linked to changes in blood corticosterone levels (Cameron and Mc Kay, 1999; Gould *et al.,* 1999). The hippocampus is involved in memory processes (Le Maire *et al.,* 2000). Therefore reported alteration of hippocampal neurogenesis under the cell phone radiation was likely associated with variations in plasma corticosterone levels as aforementioned (Tables 3 and 4), and might cause memory problems.

Remaining mice (n = 10/group) were sacrificed and peritoneal macrophages were collected and maintained in culture medium.

The macrophages from 4 mice were fixed and labelled with Hoescht dye, a fluorescent DNA marker. Micronuclei were observed under fluorescent microscope. The results are presented in Table 5 and Figure 5. In the control group, about 5 % of macrophages had more than 2 nuclei and the average number of nuclei for 100 macrophages was 130.75. The percentage of macrophages with more than 2 nuclei was 7 times higher in the exposed than in the control group (31.50 % vs. 4.75 %). Meanwhile the average number of nuclei for 100 macrophages was significantly higher ($P < 0.01$) in the exposed than in the control group (227 vs. 130.75). On the other hand, in the protected group, the percentage of macrophages with more than 2 nuclei was significantly reduced ($P < 0.01$) in comparison with the exposed group (17.25 % vs. 31.50 %). The same trend was observed regarding the average number of nuclei for 100 macrophages (167.75 vs. 227).

These preliminary results indicate that:

1. prolonged in vivo exposure of mice to 900 MHz GSM cell phone radiation induced abnormal levels of micronuclei, which is symptomatic of cell dysfunction, apoptosis or cancer process.;

2. this effect was significantly mitigated by the compensation device.

Further experiments with larger number of mice are underway in order to confirm these data. Remaining macrophages from 6 mice were used to measure intracellular calcium responses to stimulation by PAF (Platelet Activating Factor). Single macrophages were loaded with Fura-2, a calcium-sensitive fluorescent dye, and were stimulated twice during 20 sec. with 200 nM PAF. Intracellular calcium concentration was measured under fluorescent microscope. In the control group, calcium realize increased in response to PAF and two sharp peaks were recorded. In the exposed group, three patterns of response were recorded : weak responses to both stimuli or normal response to only one stimulus or no response at all. Normal responses were observed in the protected group.

To conclude:

1. the cell phone radiation inhibited the stimulation of calcium realize from peritoneal macrophages

2. the compensation technology allowed restoration of normal trans-membrane fluxes of calcium.

2.2. Human studies

2.2.1. Stress symptoms effects from cellular phone

A pilot study was performed in UK to evaluate the impact of the cell phone radiation on chronic stress symptoms. The experimental protocol and questionnaire were the same (Building Sickness Syndrome scores) as described in paragraph 1.2.4. The radiation source was a 900 MHz GSM cell phone with 2 W maximum output. Participants in the study were company managers using their cell phones for up to 4 h every day. The test was carried out over a three-month period with 12 volunteers.

The results were an average improvement in symptom score of 49 % with the EM compensation technology. A large scale test with 1000 subjects is planned to validate these results.

Conclusion

In the scientific community today there is a consensus that recognises the existence of a large number of biological effects linked to exposure to electromagnetic fields. (June 1998 NIEHS, IARC Classifications "ELF possibly carcinogenic(Group 2B)"; May 2000 Report of IEGMP chaired by Sir William Stewart ; January 2001 Report to The General Director of Health Ministry in France from the French expert group appointed by the State Secretary "Mobile phones, their Base Stations and Health")

Nevertheless a controversy remains as to whether there are links between biological effects in animals and human pathologies, as well as the lack of evidence about the deleterious consequences on health from noxious biological effects.

This position principally arises from the demand for a demonstration of a direct link between a stress factor and fatal diseases like cancer, leukaemia, etc. It does not take into account the

chronic biological stress process induced, for instance, by an EM factor that may eventually lead to death, but on a longer and indirect path, and through several steps of disruption of the homeostasis.
Any system able to avoid or diminish the development of biological effects induced by EMF automatically resolves the problem of pathological effects.
The development in biophysics of an advanced technology of simultaneous compensatory emission by autonomous oscillators emitting specific compensation signals designed to correct the biological effects of EM stress is one answer and one solution.
Since the controversy stems from identification of the pathology against which we have to protect human health, the Precautionary Principle should be invoked to protect against any biological effects, be they deleterious or not.
Since studies show that the biological effects of electromagnetic pollution from new technologies can be neutralized and their radiation made biologically compatible, this new EM bioprotective technology and its ability to implement EM biocompatibility should become the main focus of WHO and other health authorities research programmes.

Table 1: Effects of VDU radiation on hematological parameters in mice and correction by a compensation magnetic oscillation technology (*).

	Erythrocytes (10^{12}/l)			Hemoglobin (g/dl)		
	Control	Exposed	Protected	Control	Exposed	Protected
Day 0	6.5 ± 0.9	6.1 ± 6.0	6.5 ± 1.1	13.2 ± 1.2	12.7 ± 6.3	13.3 ± 1.4
Day 21	6.54 ± 0.94	8.13 ± 0.46 (1,2)	6.5 ± 0.57	1.32 ± 1.83	13.66 ± 0.86 (1,2)	10.97 ± 0.96
Day 56	8.11 ±0.7	8.09 ± 0.65	8.37 ± 0.93	14.8 ± 1.3	15.08 ± 08	13.5 ± 0.5
Day 106	8.79 ± 0.4	8.46 ± 0.77	8.5 ± 0.77	14.29 ± 062	13.41 ± 129	13.41 ± 1.29

	Neutrophils (mm^3)			Monocytes (mm^3)		
Day 0	907 ± 329	772 ± 343	888 ± 605	46 ± 28	39 ± 22	55 ± 23
Day 21	863 ± 774	640 ± 272	528 ± 201	37 ± 16	36 ± 29	36 ± 21
Day 56	2247 ± 1314	1095 ± 502 (1)	1438 ± 317	103 ± 76	85 ± 37 (2)	141 ± 48
Day 106	1022 ± 537	468 ± 257 (1)	1471 ± 1503	69 ± 41	30 ± 23 (1,2)	72 ± 46

P < 0.05 : 1- compared with control group; 2- compared with the protected group
(*): Tecno AO: International registered patent and trademark

Table 2 : Effects of VDU radiation on plasma cortisol levels in mice and compensatory effect of a protective equipment (*).

Experimental groups	Day 21	D 106
Control (n = 9)	5.9 ± 3.5	35.5 ± 14.8
Exposed (n = 9)	10.7 ± 5.4	15.4 ± 10.5 (1,2)
Protected (n = 9)	8.9 ± 4.9	31.6 ± 199

P < 0.05 : 1- compared with control group; 2- compared with the protected group
(*): Tecno AO: International registered patent and trademark

Table 3 : Stressogenic effects of 900 MHz GSM cell phone radiation in healthy mice and compensatory effect of a compensation magnetic oscillation technology

	Experimental groups				
	1	2	3	4	5
After 2 weeks of irradiation					
ACTH (pg/ml)	252 ± 32	144 ± 21*	98 ± 14*	138 ± 34*	220 ± 60
Corticosterone (ng/ml)	253 ± 37	146 ± 11*	178 ± 5*	133 ± 29*	103 ± 10*
After 5 weeks of irradiation					
ACTH (pg/ml)	245 ± 18	138 ± 18*	126 ± 27*	150 ± 22*	173 ± 31*
Corticosterone (ng/ml)	228 ± 11	168 ± 16*	149 ± 16*	183 ± 17	189 ± 19

1: Control group; 2: Cell phone group; 3: Cell phone + copper filter group; 4: Cell phone + protective device; 5: Cell phone + copper filter + protective device. * P < 0.05 vs. Control

Table 4: Stressogenic effects of 900 MHz GSM cell phone radiation and compensatory effect of a compensation magnetic oscillation technology in tumor-bearing mice

	Experimental groups					
	1	2	3	4	5	6
Experiment 1:						
ACTH (pg/ml)	244 ± 12	234 ± 15	92 ± 9**b	92 ± 6**b	227 ± 10	217 ± 9
Corticosterone (ng/ml)	282 ± 13	156 ± 9**a	107 ± 7*b	113 ± 9*b	158 ± 10	190 ± 7
Experiment 2:						
ACTH (pg/ml)	236 ± 23	223 ± 11	117 ± 9*b	113 ± 9*b	220 ± 14	213 ± 17
Corticosterone (ng/ml)	234 ± 10	138 ± 9*a	110 ± 10*b	95 ± 10*b	102 ± 8**a	120 ± 11*a

1: Sham-exposed control group; 2: Tumor group; 3: Cell phone + tumor group; 4: Cell phone + copper filter + tumor group; 5: Cell phone + protective device + tumor; 6: Cell phone + copper filter + protective device + tumor.

****P < 0.01; * P < 0.05 a: vs. Control group; b: vs. Tumor group**

Table 5: Formation of micronuclei in peritoneal macrophages after prolonged irradiation of mice by a GSM cell phone fitted with a compensation magnetic oscillation technology (*)

Experimental groups	Mice number	*% of Macrophages with more than 2 nuclei*	Average number of nuclei for 100 macrophages
Control	1	2 %	121
	2	4 %	130
	3	5 %	132
	4	8 %	140
	Mean + SEM	*4.75 ± 1.25 %*	*130.75 ± 3.92*
Cell phone	1	35 %	245
	2	25 %	216
	3	35 %	225
	4	31 %	222
	Mean + SEM	*31.50 ± 2.36 % (a)*	*227 ± 6.28 (a)*
Cell phone + protective device	1	13 %	165
	2	14 %	156
	3	21 %	179
	4	21 %	171
	Mean + SEM	*17.25 ± 2.17 % (a, b)*	*167.75 ± 4.85 (a, b)*

a : P < 0.01 vs. Control ; b : P < 0.01 vs. Cell phone

- *: Tecno AO:International registered patent and trademark*

Table 7. Animal and human studies with GSM cell phones and a compensation magnetic oscillation technology (*)

Biological systems	Exposure conditions	Results	Authors
Chicken embryos (n = 60 /group)	- GSM cell phone (900 MHz, 2W) - 3 min. calls every day during 21 days - Compensation technology	- Increased mortality: 59 % under whole radiation (microwaves (MW) + ELF); 76% after suppression of MW power - Effective compensation by the compensation device: 27% mortality (vs. 15 % for the controls)	- Youbicier-Simo et al., 1998b - Youbicier-Simo et al., 2000a *University of Montpellier (France)*
Healthy mice (n = 15/group)	- GSM cell phone (900 MHz, 2W) - 3 min. calls every day during 5 weeks - Compensation technology	- Drastic decrease in the level of stress hormones (can lead to immune depression) - Correction by the compensation technology	- Youbicier-Simo et al., 2000b *University of Montpellier (France)*
Tumour-bearing mice (lung cancer) (n = 15/group)	- GSM cell phone (900 MHz, 2W) - 3 min. calls every day during 15 weeks - Compensation technology	- Potentiation of tumour-induced depletion of stress hormones (acceleration of cancer process) - Restoration of normal levels of stress hormones by Tecno AO protection	- Youbicier-Simo et al., 2000b *University of Montpellier (France)*
Healthy mice *(pilot study)* (n = 15/group)	- GSM cell phone (900 MHz, 2W) - 3 min. calls every day during 15 weeks - Compensation technology	- 25 % decrease in nerve cell proliferation in the hippocampus (alteration of memory) - Increased formation of micronuclei in peritoneal macrophages (cell dysfunction, death or cancer) - Changes in intracellular calcium concentration in peritoneal macrophages (possibly pathologic) - Effective correction by the protective technology	- Youbicier-Simo et al. 2000 *(study in progress)*
Healthy humans (n = 12)	- GSM cell phone (900 MHz, 2 W) - up to 4 h/day during 3 months	- 49 % average reduction in Building Sickness symptoms score with the compensation technology	- Clements-Croome et al., 2000 *(Study in progress)* *University of Reading (UK)*

(*) Tecno AO: international registered patent and trademark

Table 6. Animal and human studies with VDU and the compensation magnetic oscillation technology (*)

Biological systems	Exposure conditions	Results	Authors
Chicken embryos (n = 30-60/group)	- TV set, Desk computer (CRT), portable computer (LCD) -Continuous irradiation during embryonic life (21 days) and after hatching (38-47 days) - Protective technology	- Increased embryonic mortality - Hormonal depletion: melatonin and corticosterone - Immune depression - Effective compensation by the protective technology	- Youbicier-Simo et al., 1996 - Youbicier-Simo et al., 1997 University of Montpellier (France)
Healthy mice (n = 9/group)	- TV set - 9 h/day, 5 days/week, during 106 days - Protective technology	- Decrease in the number of white blood cells (monocytes and neutrophils : immune depression) - Decrease in plasma corticosterone levels - Significant correction by the protective device	- Bonhomme-Faivre et al., 1999 - Bonhomme-Faivre et al., 2000 ***Paul-Brousse Hospital Paris (France)***
Office workers (n = 119)	- Computer screens - < 2 h/day during 1 month - Protective technology	- 15 % improvement of stress resistance with the compensation device compared with the stress state in the absence of protection	- Fillion-Robin et al., 1996 ***Cochin Hospital Paris (France)***
Undergraduates (n = 100)	- VDU screens - 2 weeks of exposure - Compensation technology	- Increased arousal and decreased distress with the protective device compared with the situation without (psychological test)	- Hayes et al., 1998 ***University of Luton (UK)***
Office workers (n = 212)	- VDUs - 2 months of exposure - Protective technology	- 33 % reduction of the symptoms of building sickness syndrome with the compensation technology (Double-blind and cross over study)	- Clements-Croome et al.,1999 ***University of Reading (UK)***
Healthy women (n = 10)	- TV set (video game) - Continuous exposure during 4 h - Protective technology	- Increase in corneal injury (corneal epitheliopathy) - Ocular fatigue - Correction of these abnormalities and symptoms by the protective technology	- Miyata and Namba, 1999 ***University of Kitasato (Japan)***

(*) Tecno AO: international registered patent and trademark

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