Effects of Information and 50 Hz Magnetic Fields on Cognitive Performance and Reported Symptoms

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The aim of this study was to explore the role of expectancies and beliefs about the potential effects of electromagnetic fields (EMFs) (what the subject thought the effect was going to be) and the effects of 50 Hz magnetic fields (400 μT_{rms}) acute exposure on cognitive performance, the reporting of physical symptoms and some psychological and physiological parameters. Seventy-four healthy male volunteers aged between 40 and 60 years of age were randomly assigned to one of five groups, which differed in (1) the type of information they were given concerning the expected magnetic field effect on performance in cognitive tests (positive = enhancement of the performance; negative = impairment of the performance; neutral) and (2) the type of exposure (real or sham). Three groups were sham exposed with positive (group+), negative (group−) and neutral information (group+/−); one group was really exposed with neutral information (group expo) and one group was not exposed, though they wore the helmet, and did not receive any field-related information (control group). All the volunteers, except the control group, were led to believe that they would be exposed to a magnetic field of 400 μT_{rms}. The experimental design respected a double blind procedure and the experimental session involved three steps (pre-testing, exposure, and post-testing). Various measurements were taken, including cognitive performance, psychological parameters such as mood, vigilance, and reporting of symptoms. Physiological parameters such as blood pressure and pulse rate were also recorded. The information given did not significantly modify beliefs. No significant difference was found among the five groups depending on the type of information and the type of exposure in cognitive performance, psychological and physiological parameters. In the context of the study, with our population, the type of information given failed to induce expected changes in parameters measured. Our results do not support the hypothesis that an acute exposure to extremely low frequency magnetic fields (50 Hz, 400 μT_{rms}) affects the parameters measured. Bioelectromagnetics 28:53–63, 2007. © 2006 Wiley-Liss, Inc.

Key words: electromagnetic fields; cognitive function; beliefs; symptoms; electromagnetic hypersensitivity

INTRODUCTION

There is a growing concern for some of controversial syndromes displaying medically unexplained symptoms, known as ‘‘Electromagnetic Hypersensitivity’’ (EHS). It is a self-defined syndrome which characterizes people who attribute their adverse health symptoms to environmental electromagnetic field (EMF) exposure, even if involved levels are below the international recommendations. Complaints consist of a variety of unspecific, low intensity symptoms, for example, fatigue, headache, difficulties concentrating, facial prickling, rashes, without any objective measurement [Bergqvist and Vogel, 1997].

However, no clear relationship has been currently established between EMF exposure (50–60 Hz) and EHS [see Rubin et al., 2005 for a review]. People suffering from EHS are not able to detect electric or magnetic fields at exposure levels to which they claim they usually react. The findings of scientific studies do suggest that electric or magnetic fields are not sufficient or necessary factors to explain these symptoms [Bergqvist et al., 2000; Hillert, 2001].

Without excluding a potential role of EMFs in the explanation of EHS, there are some indications of a multifactorial origin. In fact, other factors besides

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electric phenomena have been evoked in EHS, such as social environment and individual characteristics [Hillert et al., 1999]. Certain studies [Sandström et al., 1997; Lyskov et al., 2001] have emphasized that EHS subjects differed from control subjects in baseline values of heart rate and electrodermal activity and make the hypothesis of a rather distinctive physiological predisposition to sensitivity to physical and psychosocial environmental stress factors.

As Bergqvist and Vogel [1997] have observed, we think of another factor which can play a role, if not in the genesis of EHS, at least in the maintenance or aggravation of certain symptoms: a matter of the perception of risks. McMahan and Meyer [1995] indicated that EMF-related health problems may depend on individual levels of worry about overhead transmission lines rather than on proximity to them.

People suffering from EHS did report more symptoms when they knew or believed that they were exposed rather than when they are really exposed [Andersson et al., 1996; Lonne-Rahm et al., 2000]. Risk perception, in addition to the risk itself, determines somatic changes and symptom reports [MacGregor and Fleming, 1996] and may lead to subjective distress [Frick et al., 2002].

Health-related beliefs influence how people attend to and interpret bodily sensations and could partly explain how severe this syndrome can become. As discussed by MacGregor and Fleming [1996], the importance of psychological processes in symptom perception is well illustrated by the effects of placebo studies, medical students' diseases and mass psychogenic illnesses. In fact, hearing and learning information about illnesses and health risks focus attention on one's own bodily sensations, and these sensations may be given more importance and be misinterpreted as symptoms of illness. According to the same authors, people may experience somatic changes in association with a substance, partly because they expect to experience them, and they can unconsciously amplify vague sensations in accordance with their expectations.

As for Bock and Birbaumer [1997], they speak of the "nocebo" effect to designate the negative placebo effect and define it as the belief of being affected in an adverse manner by a chemical substance. A nocebo would be something quite harmless in itself but which can cause symptoms of an illness and the nocebo effect might be provoked by the suggestion or belief that something may be harmful. Authors thus infer by analogy to the placebo effect, that strong expectations are at the root of the nocebo effect. Anxious and suggestible people can present a strong tendency for nocebo effects.

Indeed expectancies about the specific effects of a substance may trigger many physiological and psychological reactions [Kirsch, 1997]. Research on caffeine and alcohol indicated that expectancies about the nature of a given substance have a strong influence on task performance [Kirsch and Weixel, 1988; Fillmore et al., 1998] and expectancy manipulations can affect cognitive and motor task performance [Fillmore and Vogel-Sprott, 1992; Finnigan et al., 1995]. In addition, expectancies about specific effects of a substance can lead to physiological reactions like changes in blood pressure and pulse rate [Kirsch and Weixel, 1988] and also changes in subjective mood and vigilance [Kirsch and Weixel, 1988; Fillmore and Vogel-Sprott, 1992].

Expectations can also induce symptoms in healthy volunteers [Barsky et al., 2002]. For example, more than two thirds of the healthy volunteers involved in a study of Schweiger and Parducci [1981] reported a headache when told that an electric current that induces headache would be passed through their heads, although no electricity was used. Furthermore, "reading a message inducing beliefs about potential harm of chemical substances in our environment facilitated learning of symptoms in response to odorous chemicals" [Winters et al., 2003].

In the context of lack of scientific evidence about EMF effects on health, we can hypothesize that media warnings about EMF pollution may lead to a variety of beliefs, including beliefs that extremely low frequency EMFs have severe effects on health.

Therefore, the objectives of this research were to study the importance of risk perception as a pathogenic factor of EHS and more specifically the role of information on expectancies and beliefs about the potential effects of EMFs we investigated:

(1) whether information given can modify expectancies and beliefs of subjects about the potential effects of magnetic fields on cognitive performance;
(2) whether information about the effects of 50 Hz magnetic fields leads to changes in cognitive performance, reported physical symptoms, physiological measures and mood;
(3) the effects of magnetic fields (50 Hz, 400 μT_{rms}) on cognitive, psychological, and physiological parameters.

We hypothesized that beliefs concerning the effects of 50 Hz magnetic fields lead to changes in cognitive performance, reported physical symptoms, physiological measures and mood. More precisely, for example, we hypothesized that subjects receiving negative information about EMF effects on cognitive performance demonstrate poorer performance to tests, but likewise that they report more symptoms, present mood changes and modifications of their physiological parameters and that subjects receiving positive information show improvement of their performances and so on.

MATERIALS AND METHODS

Subjects

Seventy-four male volunteers (no women to avoid interference of the hormonal fluctuations of the menstrual cycle) aged between 40 and 60 years (mean age of 48.5 ± 6.2 years) (higher prevalence of EHS people and people with environmental sensitivities in this age group) [Hillert and Kolmodin-Hedman, 1997; Joffres et al., 2001] in good physical and mental health (minimum score 24 in Mini Mental State, MMSE) were included in the study. Criteria for exclusion were checked by biological examination and a health questionnaire and were the following: poor health, neurological or psychiatric diagnosis, chronic illnesses, central nervous disorders, epilepsy, claustrophobia, daily intake of medication (such as antidepressant, benzodiazepine, hypotensive), alcohol intake higher than four glasses per day, drug intake, smoking over 20 cigarettes per day, having previously taken part in studies involving magnetic field exposure or in pharmacological studies 2 months previously, having a pacemaker, a cerebral metallic implant, intracerebral prothesis, auditory apparatus, and a Body Mass Index higher than 30.

The participants were recruited through advertisements at the University of Liège and in the region of Liège. The ethics committee of the University of Liège Medical School approved the protocol and all volunteers provided informed consent. Subjects were paid for their participation (50 euros).

Experimental Design

Subjects participated in a 2 h session of testing between 8.30 and 10.30 A.M. or 10.30 and 12.30 A.M. The session consisted of three steps (pre-testing, exposure, and post-testing) and various measurements were taken (Table 1). The experimental design respected a double blind procedure. First, all subjects (except the control group) were led to believe that they would be exposed for 30 min to a magnetic field of 400 μT_{rms} but just one group was really exposed and secondly, the main experimenter was unaware of the type of exposure (real or sham) and of the type of information (cf. appendix) and thus, group assignment. In fact, a second experimenter read some information to the subjects and therefore manipulated the type of effect (impairment, enhancement or neutral) that magnetic field exposure was expected to have on the performance of the subject on cognitive tests. The volunteers were randomly assigned to one of the five groups according to the type of information and the type of exposure (real or sham) (Table 2).

Pre-testing. Psychological questionnaires and physiological parameters were measured in the pre-exposure period (Table 1). Subjects also performed cognitive tests (baseline performance) and filled out the general risk perception questionnaire. The four groups of subjects who expected to be exposed to magnetic field (group+, group−, group+/−, and group expo) indicated their expectancies about the effects of EMFs on their cognitive performance (pre-testing expectancies).

TABLE 1. The Three Steps of the Experimental Session and Measurements Taken

Steps	
Pre-testing	Psychological (trait anxiety, depression, sensibility to anxiety, positive and negative affectivity)
	Physiological (systolic and diastolic blood pressure, pulse rate)
	Cognitive tests (baseline performance)
	General risk perception
	Expectancies concerning the effects of magnetic fields on cognitive performance
	information (positive, negative or "neutral")
Exposure	Cognitive tests
Post-testing	Mood
	Vigilance
	Physiological (systolic and diastolic blood pressure, pulse rate)
	Report of symptoms
	Expectancies concerning the effects of magnetic fields on cognitive performance
	Field detection + stress and comfort under the helmet

TABLE 2. Experimental Paradigm

Subjects ($N = 74$)	Real exposure	Expected exposure	Information (type of effect)
Group− ($n = 15$)	Sham	MF = 400 μT_{rms}	Negative: impairment of the performance
Group+ ($n = 15$)	Sham	MF = 400 μT_{rms}	Positive: enhancement of the performance
Group+/− ($n = 14$)	Sham	MF = 400 μT_{rms}	Neutral information
Group control ($n = 15$)	No exposure	Ambient MF	No information
Group expo ($n = 15$)	MF = 400 μT_{rms}	MF = 400 μT_{rms}	Neutral information

MF, Magnetic fields.

Information. Before exposure, standardized information, according to group assignment, was given to each subject in order to induce specific expectancies (cf. appendix). Positive information involved telling the subjects that studies show that magnetic fields enhance the cognitive performance (group ''+'') and negative information that magnetic fields impair cognitive performance (group ''−''). Neutral information meant saying that studies show either positive effects, negative effects or no effect on cognitive performance (group ''+/−''; group ''expo''). Subjects in the control group did not expect to be exposed, were not exposed and received no information. All volunteers, except the control group ($n = 15$), were led to believe that they would be exposed to a magnetic field of 400 μT_{rms} but just one group (group ''expo'') would be exposed.

Exposure. Subjects were either exposed or not exposed to a magnetic field, depending on their group assignment and simultaneously underwent cognitive tests. The real exposure consisted of exposure for 30 min to a magnetic field of 400 μT_{rms} and sham exposure was identical but with the fields switched off. Exposure started and finished with the subject alone in the room doing nothing for 5 min to leave time for him to pay attention to his body because body monitoring increases the probability of reporting physical symptoms [Mechanic, 1980].

Post-testing. Subjective mood, vigilance, physiological parameters, report of symptoms, and expectancies of the subjects concerning the effects of EMFs on their cognitive performance (post-testing expectancies) were assessed.

At the end of the session, the credibility of sham exposure and the detection of magnetic field in the helmet were evaluated. Subjects noted whether they thought that the fields were on or off during the exposure session and evaluated the comfort and the stress under the helmet.

Exposure Apparatus

The exposure apparatus was a ''magnetic helmet'' designed by the Department of Applied Electricity (University of Liège) to expose the human head (subjects sat in a chair) to a maximally reduced electric field and homogeneous 50 Hz magnetic fields. The helmet is a cubic structure formed by six Helmholtz coils distributed in three orthogonal directions. This magnetic helmet neither produced perceptible warming or noise under experimental conditions [Crasson et al., 1993]. The characteristics of the helmet were published by Crasson et al. [1999]. The ambient field was 0.04 μT when the helmet was switched off. Local geomagnetic field was 38 μT_{max}. The subjects were seated in the apparatus facing magnetic north. For the exposed group (group ''expo'') a vertical 50 Hz magnetic field of 400 μT_{rms} was induced continuously for 30 min.

Measurements

Measurement of expectancies. Expectancies concerning the effects of magnetic fields on cognitive performance were measured twice, once before the information (in pre-testing) and once after the information and exposure (in post-testing).

The subjects were first asked to predict how magnetic fields would affect their performance on the cognitive tests, and when the test was over they were asked if this actually occurred. This assessment was done using a 13-point Likert-type scale ranging from −30 ''largely impaired'' to 30 ''largely enhanced'' and 0 indicating no effect, using a 5-point interval scale.

The subject's general risk perception was assessed using a six-point Likert-type scale ranging from 1 ''nonexistent'' to 5 ''serious'' and 0 indicating no response (unknown risk) to describe 15 potential risks that extend over several fields, such as air pollution, radon, tobacco, and mobile phones. The total score was computed as a function of the number of risks of which the subject was aware and constituted an assessment of his perception of risks in general.

Cognitive performance. Four procedures of the Test for Attentional Performance [TAP, Zimmermann and Fimm, 1994] were used twice to evaluate subject's cognitive performances, once out of the helmet and once under the helmet. Most of the cognitive tasks were selected on the basis of existing data in EMF studies [Cook et al., 1992, 2002; Keetley et al., 2001; Kurokawa et al., 2003] and to reproduce data from our laboratory [Crasson et al., 1999; Delhez et al., 2004].

The Flexibility Task assesses the ability to shift attention by alternating between two sets of targets. In the verbal version the sets of targets are letters and numbers. They are simultaneously and randomly presented on the left or the right side of a fixation point. Letters and numbers are alternatively the target. The subject has to quickly press the right or left key according to the side of the target. One hundred stimuli were presented.

The Divided Attention Task consists of dual tasks that assesses the capacity to simultaneously perform two tasks. The subject is simultaneously submitted to an auditory task (detection of irregularities in the sequence of high and low beeps tones) and a visual task (identification of a square shaped by four crosses on the screen). One hundred visual stimuli and 200 auditory stimuli were presented.

The Working Memory Task assesses the capacity to simultaneously store and update information and thus involves short-term memory. The subject has to compare numbers presented on the screen with previous numbers and detect whether they are identical. One hundred stimuli were presented with 15 targets.

The Crossmodal Integration Task assesses the ability of integrating information from different modality channels. The task consists of presentation of sounds (high or low) and arrows (directed up or down). The subject has to press the response key when concordance of pitch and direction (high sound with arrow directed up and low sound with arrow directed low). Forty stimuli were presented.

Time reaction and the number of correct responses were analyzed for the four tasks.

Psychological parameters. At the beginning of the session, certain psychological characteristics of the subjects were evaluated to observe the potential differences in reactivity with experimentation: two components of anxiety (State anxiety and Trait anxiety) were measured by the State-Trait Anxiety Inventory [STAI, Spielberger, 1993], depression by the Carroll rating scale for depression [Carroll et al., 1981; French version: Charles et al., 1986], positive and negative affectivity by the "Positive and Negative Affect Schedule" [PANAS, Watson et al., 1988], and sensitivity to anxiety by the Anxiety Sensitivity Index Revised [ASI-R, Taylor and Cox, 1998; French version: Bouvard et al., 2003].

Before and after exposure (real or sham), subjective vigilance feelings were assessed with a Visual Analogue Scale [VAS, Norris, 1971] and only after exposure (real or sham), mood was assessed by the Profile of Mood States [POMS, McNair et al., 1971]. The report on physical symptoms was assessed by a symptomatic scale, especially designed in accordance with EHS literature in our laboratory. This later evaluation was proposed only after the exposure session in order to avoid direct induction of symptoms. The scale includes 24 physical symptoms classified in four types: "nose-throat-ear" (prickling in the throat, whistling noises in the ears...), central nervous system (headache, fatigue, difficulties in concentrating...), skin (itching, prickling sensation in the face...), and unclassified (musculo-skeletal, cardiovascular and abdominal phenomena: palpitations, muscular tensions...). The subject was invited to reply to the following question, "During exposure, what were the symptoms you experienced?" on a range from "not at all" to "extreme."

The credibility of sham exposure, the detection of magnetic field in the helmet, and the comfort and the stress under the helmet were assessed by the Field Status Questionnaire [FSQ, Cook et al., 1992].

Physiological parameters. Blood pressure and pulse rate were recorded before and after administration of the cognitive measurements.

Statistical Analyses

The 74 participants were randomly assigned to one of the five groups (Table 1).

The χ^2 Pearson test (Chi-square) was used to analyze data on field detection (FSQ data).

Univariate analysis of variance (ANOVA) and/or multivariate analysis of variance (MANOVA) simple and with repeated measurements were used to compare the five groups with regard to their cognitive performance but also their report of symptoms, their psychological and physiological parameters. We used this method of combining variables (MANOVA) to substantially reduce the number of hypotheses being tested and increase statistical power. The Newman–Keuls post hoc was used when statistical significance was obtained with ANOVA and MANOVA. The F Welch Approximation is an alternative approach of simple univariate analysis of variance (ANOVA) and was used for variables with heterogeneity of variance.

Stepwise multiple regression analysis with backward inclusion of variables was carried out, in an exploratory way, to analyze the relationship between psychological variables and the report of symptoms.

An alpha level of 0.05 was used for all statistical tests.

RESULTS

Preliminary analyses revealed that the five groups were similar with regard to age and psychological characteristics (trait-anxiety, depression, sensibility to anxiety, and positive and negative affectivity) (Table 3). However, although differences are not significantly different, for reasons which we cannot explain, subjects who are going to find themselves by chance in a group of subjects who are really going to undergo exposure present scores that are higher than the other groups.

Data of the FSQ questionnaire indicated that the subjects were unable to perceive the magnetic field under the helmet (χ^2 Pearson = 1.10, dl = 3, P = .77). In fact the ratio of subjects that has responded, "yes, there is a field," was independent of the real state of the field (switched on or off). These data indicated also the level of credibility of sham exposure: 81% of volunteers (n = 48/59) believed that they were exposed to magnetic fields (really exposed: 13/15 and non-exposed: 35/44). These results indicated that sham exposure was credible for 81% of the volunteers.

Expectancies

In a first step, testing the role of information given on the expectancies and beliefs of the subjects about the effects of magnetic fields on cognitive performance (objective 1), we found that pre-test expectancies were significantly more negative than the post-test expectancies for all groups ($F(1,55) = 31.26$, $P < .001$). The group "expo" (really exposed and neutral information) presented expectancies significantly more negative in pre-test and in post-test than the other groups ($F(3,55) = 6.28$, $P < .001$). However, changes in expectancies were not significantly different between the groups ($F(3,55) = 0.59$, $P = .62$) (Fig. 1). The information given did not significantly modify beliefs.

In a second step, we analyzed the effects of this information on cognitive performance, the report of symptoms and physiological and psychological parameters (objective 2) and analyzed the effects of exposure to magnetic fields on the various parameters (objective 3).

Cognitive Performance

We analyzed cognitive performance according to the type of exposure and information in pre-testing and post-testing (Table 4). A significant difference was found on reaction times between pre-testing and post-testing for all groups (Lambda Wilk = 0.43, $F(4,65) = 21.17$, $P < .001$) and post hoc analysis indicated an enhancement of their performance in the post-testing (reaction times were faster) in two of the cognitive tasks: the Flexibility Task and the Working Memory Task.

Psychological Parameters

No significant difference between the five groups was found on the report of symptoms (Symptomatic Scale) (Lambda Wilk = 0.86, $F(16,202,27) = 0.65$, P = .84). The report on symptoms was low and principally associated with the central nervous system (headache, fatigue, difficulties concentrating...) (Table 4).

No significant difference between the five groups was found on mood levels (POMS: Lambda Wilk = 0.67, $F(28,228,57) = 0.95$, $P = .53$; STAI-E: $F(4,69) = 0.67$, $P = .61$) and vigilance (VAS: Lambda Wilk = 0.85, $F(12, 177,56) = 0.92$, $P = .52$) (Table 4).

TABLE 3. Age and Psychological Variables (Trait Anxiety, Depression, Sensibility to Anxiety With Details About the Two Components, "Physical and Cognition," and the Positive and Negative Affectivity) for Each Group: Simple ANOVA or MANOVA

Group	Gr. "−"	Gr. "+"	Gr."+/−"	Gr."control"	Gr. "Expo"	Lambda Wilk or F	P
Age	48.0 (6.0)[a]	48.7 (5.8)	47.8 (6.3)	48.9 (6.8)	48.9 (6.9)	$F(4,69) = 0.08$	.98
Trait anxiety (STAIT)	32.1 (8.1)	33.6 (7.1)	32.9 (4.8)	33.6 (7.1)	37.3 (6.8)	$F(4,69) = 1.26$	.29
Depression (CARROLL)	4.2 (3.6)	4.1 (4.7)	3.5 (2.8)	3.3 (2.8)	4.6 (4.4)	$F(4,69) = 0.28$	.88
Sensibility to anxiety (ASI-R)							
Total	19.0 (13.2)	20.4 (17.6)	19.1 (18.5)	18.9 (14.3)	26.6 (12.1)	Lambda Wilk = 0.93, $F(8,130) = 0.58$	.78
Physical	8.8 (6.9)	9.5 (9.3)	9.0 (10.3)	8.5 (9.3)	11.6 (8.5)		
Cognition	10.1 (7.3)	10.9 (8.8)	10.1 (8.5)	10.3 (6.7)	15.0 (6.4)		
PANAS							
Positive affectivity	33.9 (5.4)	33.3 (6.1)	33.3 (6.3)	33.9 (5.3)	36.0 (6.0)	Lambda Wilk = 0.94, $F(8,136) = 0.49$	.86
Negative affectivity	12.9 (2.8)	12.3 (3.2)	12.6 (5.4)	12.7 (3.2)	14.1 (3.3)		

[a]Mean (standard deviation).

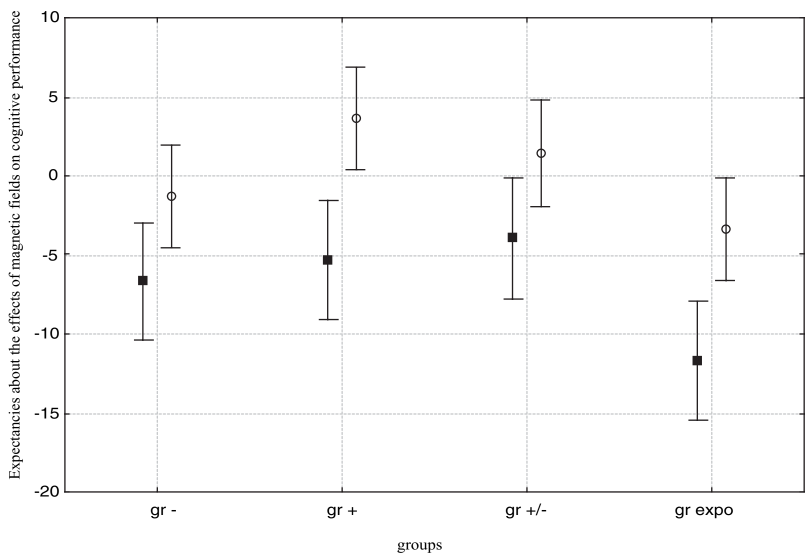

Fig. 1. Modification of the expectancies depending on the time involved (pre- and post-test). ■ Pre-test expectancies were the expectancies of the subjects (concerning the effects that they think that magnetic fields will have on their cognitive performances) before information and exposure. ○ Post-test expectancies were the expectancies of the subjects after information and exposure. Respond 0 = no effect of magnetic fields, respond positively = magnetic fields enhance cognitive performances, and respond negatively = magnetic fields impair cognitive performances.

Physiological Parameters

The analysis of physiological parameters (blood pressure and pulse rate) in pre-testing and post-testing indicated a significant difference in systolic blood pressure and pulse rate between pre-testing and post-testing for all groups (Lambda Wilk = 0.65, $F(3,66) = 11.65$, $P < .001$), with a reduction of the value of these parameters in post-testing (Table 4).

In an exploratory way and because the report on symptoms was not induced by experimental manipulations, we decided to perform a stepwise multiple regression with backward inclusion of variables to explore which psychological or individual variables (sensibility to anxiety, positive and negative affectivity, trait and state anxiety, depression, the three components of vigilance (VAS), level of comfort and stress under the helmet and risk perception) were able to predict the report on symptoms. The model selected four variables (state-anxiety, the variable "satisfaction" of the VAS, positive affectivity and comfort under the helmet) and explained more than 30% of the report on symptoms (R^2 adjusted = 0.32, $F(4,66) = 9.37$, $P < .001$).

As indicated by the data, 81% of the volunteers thought they were exposed to EMF, instead of 100%. We have thus carried out analyses without the remaining 19%. The data on expectancies indicated the same pattern of results except that group "+" and "−" were significantly different, group "+" had significantly more positive expectancies than group "−." The data indicated the same pattern of results between the five groups for the cognitive performance, physiological and psychological parameters.

DISCUSSION

The purpose of this study was to explore the role of information on expectancies related to MF exposure and the effects of acute exposure to 50 Hz magnetic fields (400 μT_{rms}) on cognitive performance, some psychological and physiological parameters and the report on symptoms. The data indicated that the information given to the subjects did not significantly modify (and in the expected sense) their beliefs about the effects of magnetic fields on cognitive performance (objective 1).

Several parameters might have reduced the effectiveness of experimental manipulation. Among these, we can note the characteristics of the message, prior expectations of the subjects about effects to magnetic fields and risk perception, experience of magnetic fields exposure and expectancies re-evaluation and the credibility of sham exposure.

First, about the characteristics of the message, we gave either positive, negative or neutral calm message. Therefore, we manipulated the valence of the message (positive, negative or neutral) in controlling the arousal of the message (calm vs. excited), but we did not modify the arousal of the message, just giving calm messages, not alarming. Virtually all studies have shown that

TABLE 4. Mean and Standard Deviations of Cognitive Performance, Psychological and Physiological Parameters for Each Group

	Gr. "−"	Gr. "+"	Gr. "+/−"	Gr. control	Gr. "expo"
Cognitive performance[a]					
Flexibility					
RT(B-A)[b] (ms)	−100.3 (113.7)	−128.5 (110.1)	−138.6 (210.6)	−95.74 (95.9)	−177.1 (113.9)
Nb CR (B-A)	0.7 (4.6)	1.3 (5.2)	0.0 (6.6)	0.93 (4.8)	2.7 (7.7)
Divided attention					
RT(B-A) (ms)	−1.3 (42.2)	4.1 (33.5)	29.8 (72.7)	0.3 (37.5)	10.0 (56.8)
Nb CR(B-A)	0.4 (1.9)	0.1 (2.4)	0.7 (3.1)	0.1 (1.8)	0.1 (2.3)
Working memory					
RT(B-A) (ms)	−62.1 (134.8)	−81.4 (121.4)	−42.6 (145.6)	−44.5 (165.0)	−77.9 (243.8)
Nb CR(B-A)	−0.4 (1.2)	0.5 (1.1)	0.8 (1.4)	0.4 (1.8)	0.5 (2.5)
Crossmodal integration					
RT(B-A) (ms)	7.4 (78.3)	3.07 (89.8)	−24.1 (64.0)	16.0 (52.5)	−10.7 (58.8)
Nb CR(B-A)	1.5 (4.4)	−0.80 (3.7)	−0.2 (0.9)	0.1 (0.6)	0.2 (0.9)
Psychological parameters[c]					
VAS					
Vigilance	210.9 (150.5)	249.2 (153.8)	104.8 (99.6)	264.3 (180.8)	196.2 (162.3)
Satisfaction	108.2 (94.7)	119.9 (87.4)	62.4 (65.0)	131.9 (99.1)	93.4 (86.3)
Calm	42.7 (33.1)	49.0 (41.7)	34.2 (34.5)	44.3 (38.8)	43.7 (34.7)
Symptoms: total	6.6 (7.3)	5.6 (8.1)	4.1 (5.5)	4.9 (6.2)	10.3 (19.7)
"Nose-throat-ear"	0.4 (1.1)	0.7 (2.5)	0.4 (0.7)	0.3 (1.2)	0.7 (1.5)
CNS	4.1 (4.1)	3.9 (5.8)	2.4 (3.1)	2.9 (3.1)	5 (8.5)
Skin	1.1 (3.8)	0.3 (0.7)	0.3 (0.7)	0.8 (1.6)	3.3 (7.8)
Unclassified	0.9 (1.7)	0.6 (1.3)	1.1 (2.7)	0.8 (1.3)	1.3 (3.8)
STAIE	24.2 (4.1)	23.9(4.1)	24.5 (4.1)	24.5 (4.1)	26.3 (5.1)
POMS	13.5 (16.4)	7.0 (10.2)	3.2 (4.2)	10.1 (13.8)	4.2 (6.7)
Physiological parameters					
Blood pressure (B-A)					
Systolic	−4.8 (9.9)	−2.5 (8.7)	−0.6 (9.1)	−3.1 (8.0)	−6.1 (11.6)
Diastolic	−0.6 (4.7)	0.0 (4.5)	−0.4 (7.1)	0.1 (7.2)	−1.1 (6.1)
Pulse	−4.5 (4.5)	−2.4 (4.6)	−4.9 (5.5)	−3.3 (6.5)	−2.5 (5.1)
Mean (Syst + Diastol × 2)/3	−2 (5.6)	−0.8 (5.0)	−0.5 (5.2)	−1.6 (6)	−2.8 (6.4)

[a]Test for Attentional Performance, TAP, Zimmermann and Fimm [1994].
[b]Differences between A = baseline performance and B = performance during exposure were used for cognitive and physiological parameters. RT, reaction time; ms, millisecond; +Nb, number; CR, correct response.
[c]Psychological parameters, Visual Analogue Scale, VAS, Norris [1971]; the Symptomatic Scale, Crasson not published; State Anxiety Inventory, STAIE, Spielberger [1993]; Profile of Mood States, POMS, McNair et al. [1971].

emotional messages are better remembered than non-emotional messages. When the valence is controlled, stimulating messages are better remembered than calm messages [Lang et al., 1995].

Secondly, as for the subjects' characteristics, they, on average, had weak prior expectancies with respect to the effects of 30 min magnetic field exposure and were not anxious people (see results of the STAIT in Table 3). They did not expect dramatic changes from this exposure on their cognitive performance and one could argue that simple information is too weak as suggestion. We can hypothesis that anxious people should be more suggestible.

Thirdly, unlike caffeine or alcohol, few people have already experienced effects of a magnetic field exposure for 30 min on their cognitive performance. The results indicated an enhancement of the performance after two cognitive tests which can be attributed to a learning effect. We can hypothesize that perception of this improvement could have provided information consistent with the expectation of enhancement performance under magnetic field and discredit the expectation of impairment. Inherent feedback obtained by performing the task may have helped to diminish the expectation of impairment and strengthen the expectation of enhancement of performance.

Last of all, as for the credibility of the sham exposure (that the subjects did believe they were exposed to a magnetic field), the results indicated that 81% of the subjects believed they were exposed to magnetic fields. Nevertheless, we cannot overlook the 19% of subjects who introduced expectations contrary to the experimental assignment and we carried out analyses without this 19% to eliminate this potential bias. The data indicated that in our study, the lack of credibility for 19% of the subjects had an effect on expectancies of the subjects but had no significant effect on the cognitive, physiological, and psychological parameters.

The two other objectives consisted of analyzing the effects of information given on cognitive performance, reporting physical symptoms and some physiological and psychological parameters (objective 2) and analyzing the effects of exposure to magnetic fields on these various parameters (objective 3). Therefore, we were trying to see if there was a potential difference between the group of subjects really exposed to magnetic fields, the groups with sham exposure and the control group.

The data indicate that the information given had no significant effect on the parameters measured: cognitive performance, report on symptoms, and physiological and psychological parameters. To the best of our knowledge, there is, to date, no EMF study that has tested the role of information on these parameters. Therefore, it is difficult to compare our findings with existing literature. Similarly studies were conducted with caffeine [Fillmore and Vogel-Sprott, 1992; Fillmore et al., 1994], which showed that subjects who expected caffeine to enhance performance, performed significantly better than a group led to expect impairment.

Winters et al. [2003] showed that information involving environmental pollution and multiple chemical sensitivity facilitated learning of symptoms. Our experiment did not affect symptom reporting unlike Schweiger and Parducci [1981]. A possible explanation is that the information provided to participants did not mention symptoms. Our findings differ from those of this literature and are more in line with Walach et al. [2002] who showed that information about pharmacological effects of caffeine had no effect on parameters measured (cognitive performance, pulse rate, blood pressure and well-being). The authors argued that simple information written is too weak as a suggestion. They did not succeed in reproducing the effects of a caffeine placebo reported in literature and advanced two main reasons: blind experimenters conducted the experiment and thus all effects of researcher expectancies were blocked and the experimental manipulations aroused weak expectancies.

The results do not support the hypothesis that an acute exposure to extremely low frequency magnetic fields (50 Hz, 400 μT_{rms}) affects the parameters measured, such as cognitive performance, report on symptoms, mood, vigilance, pulse rate, and blood pressure. Our findings are in line with other published data [Cook et al., 1992; Graham et al., 1994; ICNIRP, 2003] and support the previous results obtained in our laboratory [Crasson et al., 1999; Delhez et al., 2004; Crasson and Legros, 2005]. In fact, the results of Delhez et al. [2004] indicated no significant effect from a magnetic field similar to the one used in our protocol (50 Hz, 400 µT rems) of 65 min on the cognitive performance of healthy young men (20–30 years old) and Crasson et al. [1999] did not observe any effect either from the magnetic field (50 Hz, 100 µT) on another task evaluating short term memory (‘‘Auditory Verbal Learning Test,’’ AVLT). Nonetheless, a slowing down reaction time was observed on a visual task.

In this study, the report of symptoms is not associated with the belief of having been exposed to magnetic fields or by real exposure. The regression model that served to better understand what caused this report of symptoms selected four psychological variables (state-anxiety, positive affectivity, the variable ‘‘satisfaction’’ of the VAS and comfort under the helmet) and explained more than 30% of the report of symptoms and reinforced the idea that report of symptoms is largely influenced by the anxiety type of psychological process [Pennebaker, 1994].

This study was undertaken on a healthy population of men who agreed to participate in the study and having no anxiety symptomatology. This could explain why EMF exposure and information about EMF effects have not affected the parameters measured as cognitive performance, blood pressure and pulse rate, psychological parameters and report of symptoms. This research emphasized the importance of individual and situational parameters in such a way that the question that has to be answered is: ‘‘What information in what kind of context is used by what kind of person to experience and express what kind of symptom?’’ [Van den Bergh et al., 2004].

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APPENDIX

Type of Information

Negative information: impairment of the performance (group−). Thanks to numerous scientific studies at present it is now known that exposure to magnetic fields deteriorates, in a transitional manner, performances during tests that measure concentration, attention, memory or reaction time. People tested make more mistakes during the tests, have a slower reaction time and fail to memorize as well. These subjects obtain therefore lower scores when they are exposed to the fields in comparison to those who are not exposed. What interests us in this study is to be able to reproduce these results in our laboratory.

You are going to be exposed to a strong intensity because strong intensities show more changes. However, the exposure corresponds to that which certain workers are exposed to such as blow torch welders and people who work in induction ovens (i.e., a frequency of 50 Hz, the frequency of the network that supplies us in electricity and an intensity of 400 μT), and all studies show that these effects only appear and last during the exposure, they are therefore transitional.

Positive information: enhancement of the performance (group+). Thanks to numerous scientific studies at present it is now known that exposure to magnetic fields improves, in a transitional manner, performances during tests that measure concentration, attention, memory or reaction time. People tested make less mistakes during the tests, have a faster reaction time and memorize as well. These subjects obtain therefore better scores when they are exposed to the fields in comparison to those who are not exposed. What interests us in this study is to be able to reproduce these results in our laboratory.

You are going to be exposed to a strong intensity because strong intensities show more changes. However, the exposure corresponds to that which certain workers are exposed to such as blow torch welders and people who work in induction ovens (i.e., a frequency of 50 Hz, the frequency of the network that supplies us in electricity and an intensity of 400 μT), and all studies show that these effects only appear and last during the exposure, they are therefore transitional.

Neutral information: (group+/− group expo). Studies on the effects of magnetic fields on concentration, attention, memory or reaction time have indicated contradictory results. The absence of effects is noted and when effects are observed, they go either in the direction of an improvement (better results to the tests), or in the direction of a deterioration (lower results to the tests). We would like, in this study, to evaluate if exposure to magnetic fields might influence the results to the various tests.

You are going to be exposed to fields that correspond to those to which certain workers are exposed such as blow torch welders and people working in induction ovens (a frequency of 50 Hz, the frequency of the network that supplies us in electricity and an intensity of 400 μT). When the studies indicate effects of magnetic fields on the results to the tests, they show that these effects only appear and last during the exposure, they are therefore transitional.

No information: (control group). We ask you to carry out some tests to use as a control group in a study that we are handling. We invite you to take these tests as you usually do (in the best manner feasible).