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Does exposure to an artificial ULF magnetic field affect blood pressure, heart rate variability and mood?

Gen Mitsutake[a], Kuniaki Otsuka[a,*], Sachiko Oinuma[a], Ian Ferguson[b], Germaine Cornélissen[c], James Wanliss[d], Franz Halberg[c]

[a] *Division of Neurocardiology and Chronoecology, Tokyo Women's Medical University, Daini Hospital, Tokyo, Japan*
[b] *Department of Geological Sciences, University of Manitoba, Winnipeg, MB, Canada*
[c] *Chronobiology Laboratories, University of Minnesota, Minneapolis, MN, USA*
[d] *Department of Physical Science, Embry-Riddle Aeronautical University, Daytona Beach, FL, USA*

Abstract

The aim of this study was to determine whether an artificial magnetic field with an amplitude and frequency equivalent to those of geomagnetic pulsations during geomagnetic storms could affect physiology and psychology. Three healthy volunteers wore an ambulatory BP monitor and an ECG recorder around the clock for 12 consecutive weekends in Winnipeg, Manitoba, Canada. In a room shielded against ELF and VLF waves, they were exposed for 8 hours per week to either a 50 nT 0.0016 Hz or a sham magnetic field at one of six circadian stages. Real exposure randomly alternated with sham exposure. They provided saliva and recorded mood and reaction time every 4 hours while awake. Systolic (S) and diastolic (D) blood pressure (BP), and heart rate (HR) were recorded every 30 minutes. Spectral analysis of HR variability (HRV) was performed using the maximum entropy method and a complex demodulation method. For these variables, daily means were compared between real and sham exposure, using paired *t*-tests. Their circadian MESOR, amplitude, and acrophase were analyzed and summarized using single cosinor and population-mean cosinor. Circadian rhythms were demonstrated for HR, SBP, DBP for sham exposure, salivary flow rate, positive affect, vigor, and subjective alertness ($p<0.001$, ~0.02). One participant showed higher HR, lower LF, HF, and VLF powers, and a steeper power-law slope ($p<0.005$, ~0.0001) in an early night exposure to the real magnetic field, but not in other circadian stages. There was no significant difference between circadian responses to real and sham exposure in any variable at any circadian stage. © 2004 Elsevier SAS. All rights reserved.

Keywords: Circadian rhythm; Geomagnetics; Heart rate variability

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1. Introduction

Studies of some parameters of the blood system of rats exposed to magnetic fields in the frequency band of 0.01 to 100 Hz (with magnitudes of 5, 50, and 5000 nT) revealed that magnetic fields at frequencies of 0.02, 0.5–0.6, 5-6, and 8–11 Hz were the most bio-effective, suggesting that electromagnetic fields at ultra-low frequencies (ULF; 0–10 Hz), including those of geomagnetic pulsations, are more bio-effective than 'the power line' ELF (10–300 Hz) magnetic field [20]. There are some reports on the effects of the geomagnetic field activity on both human physiology and behavior [1–13; 15–20; 22,23]. According to Ptitsyna et al. [20], ULF magnetic fields may produce effects on the nervous system and might be associated with cardiovascular disease, and that living systems including humans may have a special sensitivity to geomagnetic fields because the magnetoreception of neural structures should be evolutionarily adjusted to these fields. Moreover, we (KO) found that enhanced ambient ULF waves during geomagnetic disturbances could reduce heart rate variability (HRV) in humans [16]. Thus, existing literature suggests a link between geomagnetic pulsations and human physiology and behavior. The aim of the current study was to examine whether any effect could be documented by exposure to artificial ULF

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*Corresponding author.
E-mail address: frtotk99@ba2.so-net.ne.jp (K. Otsuka)

waves that approximated geomagnetic pulsations during magnetic storms.

2. Study aim

The aim of the current study was to determine whether an artificially generated weak ULF magnetic field with an amplitude and frequency equivalent to that of naturally occurring geomagnetic pulsations during geomagnetic storms could affect HRV and circadian rhythm of systolic (S) and diastolic (D) blood pressure (BP), heart rate (HR), mood, estimated time intervals of 60 seconds (TE), reaction time (RT), and salivary flow rate (FR) and to examine whether any response to the ULF magnetic field was circadian stage-dependent.

3. Subjects and methods

3.1. Participant recruitment

Three clinically healthy male students (21 to 35 years of age) from Winnipeg, Manitoba, Canada, agreed to participate in the study. The study was approved by the University of Manitoba Research Ethics Board, and the participants were informed of the procedures and signed a consent form which guaranteed their anonymity and freedom to withdraw from the trial at any time.

3.2. Overall procedure

The participants were exposed for 8 hours per week to a 50 nT ULF magnetic field (0.0016 Hz) for 12 consecutive weekends in a magnetically shielded room. Real exposure randomly alternated with sham exposure. The exposure to the ULF magnetic field was carried out at one of six different circadian stages (i.e. from 3:00–11:00 h, 7:00–15:00 h, 11:00–19:00 h, 15:00–23:00 h, 19:00–3:00 h, and 23:00–7:00 h) in the room. The participants estimated their mood and time intervals of 60 seconds, and provided unstimulated whole saliva samples during waking hours for each 24-hour monitoring session. They were asked to avoid drinking coffee or alcoholic beverages during the study.

3.3. Exposure to the ULF magnetic field

During each monitoring session, the participants stayed for 24 hours, except for the time taken for meals, in a wooden bed in a magnetically shielded room (interior dimensions: 3 m width×3 m depth×3 m height) shielded against ELF and VLF waves only. The room temperature was kept at about 23 °C, and all illuminations in the room were turned off during the night (i.e. 23:00–7:00 h). The beds in the room were each located between a pair of custom-built Helmholtz coils 95 cm in radius with 12 turns (N) of enameled copper wire. The coils were connected to a function generator (Stanford Research Systems Model DS345 Function & Arbitrary Waveform Generator, Stanford Research Systems, Sunnyvale, CA) outside the room. Protection was provided to prevent the field from exceeding 50 nT with fuses and a breaker. Two investigators continuously monitored the current in the coils, using a Tektronix Model TDS210 Digital Oscilloscope (Tektronix, Beaverton, OR).

3.4. Measurement of ELF magnetic field exposure

Personal ELF frequency (40–800 Hz) magnetic field exposure for one of the three participants was measured with an EMDEX-II meter (Enertech Consultants, Campbell, CA) during six out of 12 experimental sessions. The mean ELF magnetic field for each of the six experimental sessions ranged from 47 to 56 nT. The percentage of time when the participant was exposed to ELF magnetic fields of 40 nT or greater varied between 97.4% and 99.8%.

3.5. ECG monitoring

HRV was monitored with either a 5-lead Holter monitor (SM-50 ambulatory ECG Recorder; Fukuda Denshi; Tokyo, Japan), or a 3-lead ECG monitor (GMS Model AC-301 Active Tracer, GMS, Tokyo, Japan). Time and frequency domain measures of HRV were later calculated from the ECG data from two out of the three participants. For time domain measures of HRV, the mean cycle length of the normal-normal RR intervals (NN) and its standard deviation (SDNN) were computed and averaged over consecutive 5-minutes intervals to cover each 24-hour ECG recording. The maximum entropy method (MEM) with the MemCalc/CHIRAM program (Suwa Trust Co. Ltd., Tokyo, Japan) and a complex demodulation method (CDM) [14] were used to obtain frequency domain measures of HRV. Five-minute time series of NN intervals were processed consecutively and the spectral powers in the very low frequency (VLF: 0.003–0.04 Hz), low frequency (LF: 0.04–0.15 Hz), and high frequency (HF: 0.15–0.40 Hz) regions of the spectra, as well as the LF/HF ratio, were calculated. The ultra-low frequency (ULF: 0.0001–0.003 Hz) component and the power-law slope (1/f: 0.0001–0.01 Hz) were estimated by processing 180-minute NN interval time series.

3.6. Blood pressure monitoring

Systolic (S) and diastolic (D) blood pressure (BP), and heart rate (HR) were automatically measured every half an hour with a commercially available ambulatory BP recorder (Model 2421, A&D Co. Ltd., Tokyo, Japan) during each monitoring session. Stored BP data were retrieved and downloaded to a personal computer with software (Model TM2430-15) commercially available from A&D Co., Ltd., Tokyo, Japan.

3.7. Time estimation and measurements of mood, reaction time, and salivary flow rate

Time intervals of 60 seconds (TE) were estimated at about 30-minute intervals during waking hours of each session, by silently counting to 60. Mood, reaction time, and unstimulated salivary flow rate were measured at about 7:00, 11:00, 15:00, 19:00, and 23:00 h. Mood was rated on the Positive and Negative Affect Schedule (PANAS) [24], the State-Trait-Cheerfulness-Inventory Short State Form (STCI-S<18>) [21], the Mood and Vigor Scale, and the Stanford Sleepiness Scale (SSS) which is available at http: //www.stanford.edu/~dement/sss.html. RT was measured with free computer software, Reaction Timer, which is available from Silicon Chip Publications at: http://www.siliconchip.com.au/software/reaction.zip. Using the software on a personal notebook computer, the participants responded to a visual stimulus (a 2×3 cm red area on the computer display) by pressing the space bar as quickly as possible with their dominant hand for 10 trials in a row. Each of four-hourly RT was calculated as the mean response time to the visual stimulus. FR was calculated as mean salivary volume per minute.

3.8. Mood scales

PANAS consists of two 10-item mood scales – one for positive affect (PA) and the other for negative affect (NA). The two are reportedly highly internally consistent and largely uncorrelated and stable. The STCI-S<18> is aimed at measuring the construct of cheerfulness as a state. The scale consists of 18 items that measure cheerfulness (CH), seriousness (SE), and bad mood (BM). The Stanford Sleepiness Scale (SSS) is an 8-point scale to assess alertness. The Mood and Vigor Scales consist of two 7-point scales, which measure mood and vigor respectively.

3.9. Analyses

All these variables, except for HRV data, were analyzed by single cosinor at a trial period of 24 hours for each session by each participant. Estimates of MESOR, amplitude, and acrophase were further summarized by population-mean cosinor.

For the HRV data, daily means were compared between spans of real and sham exposure to see if there is any difference in physiological responses to the magnetic field exposure, using paired *t*-tests at a significance level of 0.05. The HRV data were further analyzed by dividing each monitoring session into nine sampling intervals (i.e. a 1-hour interval preceding the exposure, followed by 1-, 2-, 2-, and 3-hour during exposure, 1-, 2-, 6-, and 7-hour of post exposure). The spectral powers of HRV components were each compared between real and sham exposure, by using Student's *t*-test at a significance level of 0.001.

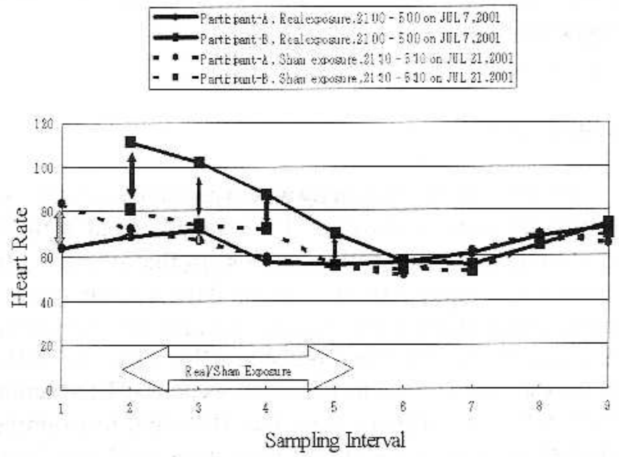

Fig. 1. Changes in heart rate for a monitoring session in which the participants were exposed to the real/sham exposure between 21:00 and 5:00. Sampling intervals 1 to 9 stand for a one-hour interval preceding the exposure, followed by one-, two-, two-, and three-hour intervals during exposure, one-, two-, six-, and seven-hour intervals of post exposure.

4. Results

As shown in Table 1, a circadian rhythm was demonstrated under both real and sham exposure for HR (P<0.001 for both real and sham exposure conditions), SBP (P<0.001 for real exposure; P=0.002 for sham exposure), DBP (P=0.002 for sham exposure), and FR (P=0.001 for real exposure; P=0.02 for sham exposure). As shown in Table 2, a circadian rhythm was also demonstrated for PA (P=0.002 for real exposure; P=0.015 for sham exposure), V (P=0.004 for real exposure; P =0.006 for sham exposure), and SSS (P<0.001 for real exposure; P=0.001 for sham exposure). CH, although non-significant, showed a circadian rhythm with borderline significance of P=0.083 for real exposure and P=0.081 for sham exposure. Neither SE, BM, nor NA showed circadian rhythm.

There was no statistically significant difference between responses to real and sham exposure in any spectral power of HRV components (see Table 3). Likewise, no significant difference was found in any circadian endpoint of either V, SSS, RT, TE, FL, or any circadian mood variables, except for the circadian acrophase of bad mood (t=3.62, df=7, P=0.01; see Table 4).

Further analyses of each participant's HRV data in which each monitoring session was divided into nine sampling intervals also showed mixed results. As shown in Figs 1 to 5, Participant-B showed higher HR, lower VLF (P=0.001~0.026), LF (P<0.001~0.005), HF, and powers, and a steeper power-law slope (P<0.005~0.0001) in an early night exposure (i.e. 21:00–5:00) to the real magnetic field, compared to sham exposure, but not in other circadian stages. There was no significant difference between circadian responses to real and sham exposure in any variable at any

Table 1
Population-mean cosinor summary of blood pressure, heart rate, and salivary flow rate

Variable	PR^{e} (%)	P^{f}	MESOR^{g} ± SE^{h}	Amplitude^{i} (95%	Acrophase^{k} (95% CI^{j})
Real Exposure					
SBP^{a}	23.7	<.001	114.455 ± 3.84	6.57 (4.17, 8.97)	-269 (-254, -286)
DBP^{b}	17.9	.088	72.865 ± 3.44	3.03 (0, 0)	-241 (0, 0)
HR^{c}	22.5	<.001	62.764 ± 2.56	7.06 (5.15, 8.97)	-269 (-255, -283)
FR^{d}	45.1	<.001	0.583 ± 0.48	0.11 (0.03, 0.22)	-215 (-194, -285)
Sham Exposure					
SBP^{a}	22.9	.002	115.714±3.70	7.15 (3.82,	-271 (-253, -290)
DBP^{b}	16.0	.002	71.84±2.99	4.06 (2.16, 5.97)	-257 (-237, -276)
HR^{c}	21.9	<.001	61.071±2.32	6.30 (4.57, 8.02)	-268 (-253, -285)
FR^{d}	48.5	.020	0.295±0.07	0.08 (0.03, 0.14)	-259 (-234, -298)

[a]Systolic blood pressure; [b]diastolic blood pressure; [c]heart rate; [d]salivary flow rate; [e]percentage rhythm, proportion of variance accounted for, on the average, by the fitted model; [f]P-value from zero-amplitude test; [g]Midline-Estimating Statistic Of Rhythm, a rhythm-adjusted mean; [h]standard error; [i]measure of extent of predictable change within a cycle; [j]95% confidence interval; [k]measure of timing of overall high values recurring in each cycle, expressed in (negative) degrees, with 360 equated to period length and 0=0: 00.

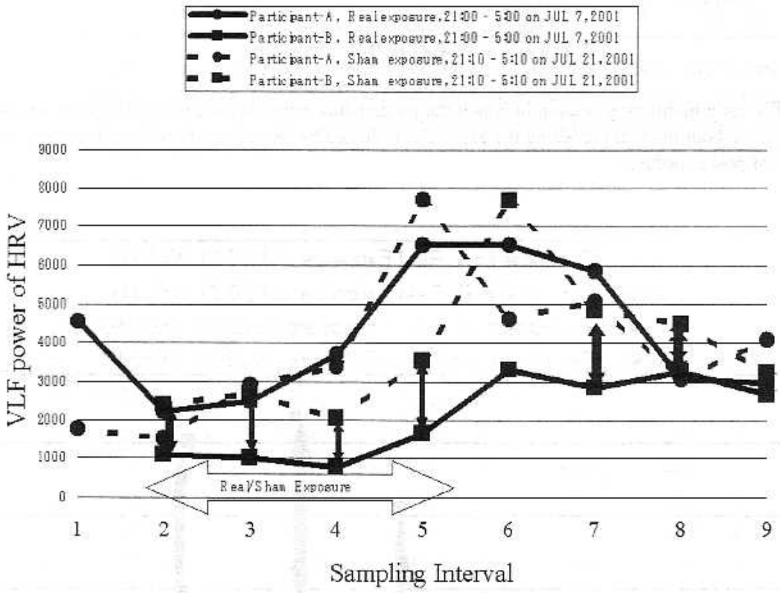

Fig. 2. Changes in VLF power of HRV for a monitoring session in which the participants were exposed to the real/sham exposure between 21:00 and 5:00. Sampling intervals 1 to 9 stand for a one-hour interval preceding the exposure, followed by one-, two-, two-, and three-hour intervals during exposure, one-, two-, six-, and seven-hour intervals of post exposure.

circadian stage. Thus, the results showed inconsistency among participants and/or among circadian stages.

5. Discussion and conclusion

In hindsight, it is clear that the study could have been improved upon. The failure to show an effect of ULF exposure on physiology and psychology might be due partly to the directional properties of the artificial magnetic field used, which may not have replicated sufficiently well the natural magnetic pulsations. The orientation of the artificial magnetic field was horizontal, while the geomagnetic field in the area where the study was conducted was almost vertical to the ground. Another reason could be that the study used alternative current (AC) magnetic field unlike the natural magnetic field, which is in direct current (DC). Although the frequency of the artificial ULF waves was very low (0.0016 Hz) and the magnetic field was almost in DC, this difference might have contributed to the results. Other possible reasons for the negative results are that the intensity (50 nT) and/or the duration (8 hours) of the exposure were

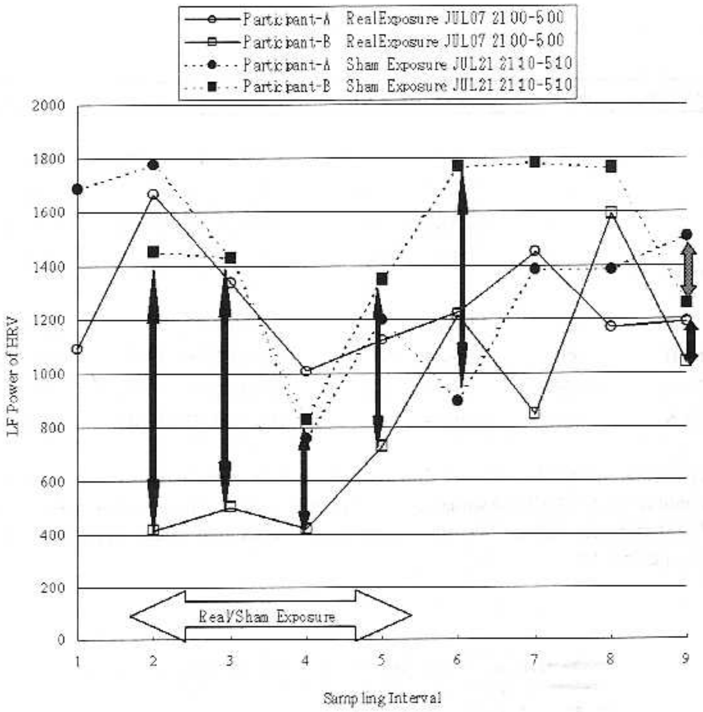

Fig. 3. Changes in LF power of HRV for a monitoring session in which the participants were exposed to the real/sham exposure between 21:00 and 5:00. Sampling intervals 1 to 9 stand for a one-hour interval preceding the exposure, followed by one-, two-, two-, and three-hour intervals during exposure, one, two-, six-, and seven-hour intervals of post exposure.

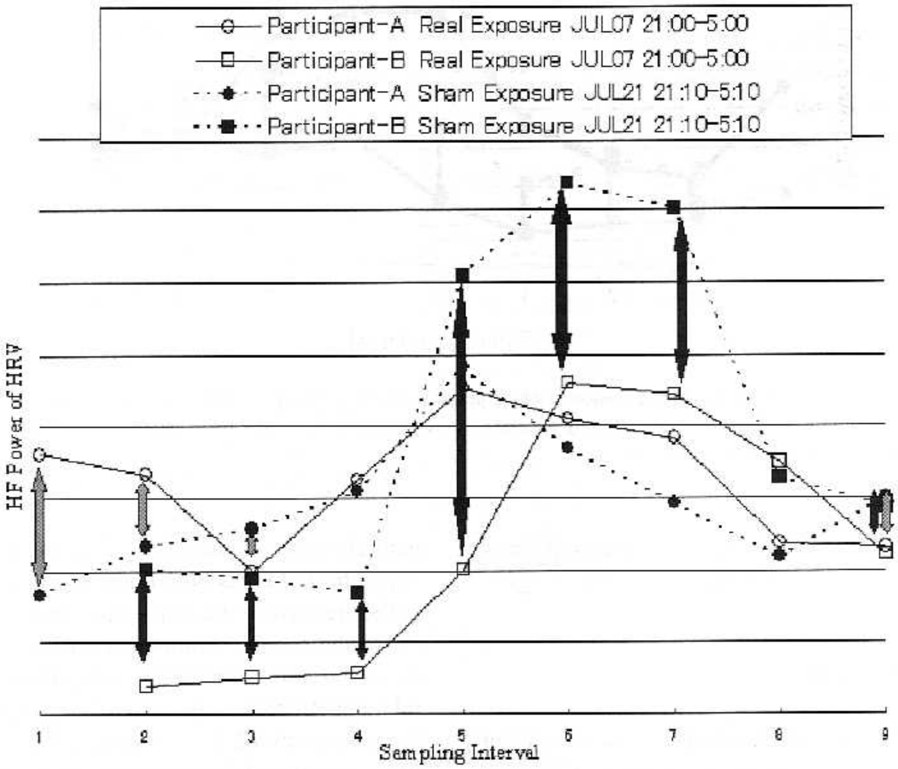

Fig. 4. Changes in HF power of HRV for a monitoring session in which the participants were exposed to the real/sham exposure between 21:00 and 5:00. Sampling intervals 1 to 9 stand for a one-hour interval preceding the exposure, followed by one-, two-, two-, and three-hour during exposure, one-, two-, six-, and seven-hour of post exposure.

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Table 2
Population-mean cosinor summary of mood, vigor, and estimated time intervals

Variable	PR[k] (%)	P[l]	MESOR[m] ± SE[n]	Amplitude[o] (95%	Acrophase[q] (95% CI[p])
Real Exposure					
PA[a]	56.4	0.002	26.95 ± 1.53	2.89 (1.53, 4.25)	-260 (-226, -229)
Na[b]	48.8	0.847	14.92 ± 1.12	0.42 (0, 0)	-23 (0, 0)
CH[c]	50.2	0.083	12.31 ± 0.88	1.26 (0, 0)	-243 (0, 0)
SE[d]	51.3	0.326	14.13 ± 0.96	0.84 (0, 0)	-214 (0, 0)
BM[e]	49.9	0.101	10.46 ± 1.06	0.71 (0, 0)	-93 (0, 0)
M[f]	55.9	0.009	3.783 ± 0.24	0.91 (0.36 1.45)	-248 (-229, -278)
V[g]	53.8	0.004	3.3 ± 0.35	0.91 (0.44, 1.38)	-248 (-223, -277)
SSS[h]	58.1	<0.001	3.294 ± 0.32	0.96 (0.60, 1.33)	-67 (-39, -98)
TE[i]	11.7	0.074	59.213±1.52	1.07 (0, 0)	-104 (0, 0)
RT[j]	50.2	0.359	754.459 ± 15.18	5.47 (0, 0)	-86 (0, 0)
Sham Exposure					
PA[a]	45.0	0.015	26.41 ± 1.86	2.13 (0.70, 3.56)	-298 (-258, -359)
Na[b]	41.9	0.970	13.98 ± 1.27	0.08 (0, 0)	-131 (0, 0)
CH[c]	47.2	0.081	12.48 ± 0.70	0.97 (0, 0)	-268 (0, 0)
SE[d]	38.2	0.071	13.57 ± 0.85	0.92 (0, 0)	-238 (0, 0)
BM[e]	48.5	0.369	10.04 ± 1.44	0.30 (0, 0)	-165 (0, 0)
M[f]	51.0	0.079	3.718±0.42	0.64 (0, 0)	-276 (0, 0)
V[g]	39.5	0.006	3.32±0.50	0.69 (0.21, 1.17)	-284 (-267, -330)
SSS[h]	39.9	0.001	3.275±0.40	0.79 (0.35, 1.23)	-84 (-67, -119)
TE[i]	8.7	0.495	58.289±1.31	0.46 (0, 0)	-210 (0, 0)
RTj	38.2	0.485	755.222±14.91	5.67 (0, 0)	-59 (0, 0)

[a]Positive affect; [b]negative affect; [c]cheerfulness; [d]seriousness; [e]bad mood; [f]mood (on Mood and Vigor Scale); [g]vigor; [h]objective alertness (on Stanford Sleepiness Scale); [i]estimated time intervals of 60 seconds; [j]reaction time; [k]percentage rhythm, proportion of variance accounted for, on the average, by the fitted model; [l]*P*-value from zero-amplitude test; [m]Midline-Estimating Statistic Of Rhythm, a rhythm-adjusted mean; [n]standard error; [o]measure of extent of predictable change within a cycle; [p]95% confidence interval; [q]measure of timing of overall high values recurring in each cycle, expressed in (negative) degrees, with 360 equated to period length and 0=0: 00.

Table 3
Overall mean differences in heart rate variability parameters between real and sham exposure

	Real Exposure			Sham Exposure			t-test		
Variab	Mean	N	SD	Mean	N	SD	t	df	P
HR[a]	69.75	5	3.63	68.07	5	6.54	0.65	4	N.S.
NN[b]	898.97	5	30.99	916.27	5	60.08	-0.6	4	N.S.
SDNN[c]	72.15	5	11.85	76.16	5	10.80	-0.9	4	N.S.
ULF[d]	64.85	5	6.60	72.41	5	7.17	-1.5	4	N.S.
LF[e]	38.62	5	6.14	41.16	5	7.91	-0.9	4	N.S.
HF[f]	28.46	5	6.78	30.72	5	8.12	-1	4	N.S.
LF/HF[g]	1.50	5	0.21	1.49	5	0.22	0.47	4	N.S.

NS: non-significant. [a]Heart rate. [b]NN intervals. [c]Standard deviations of NN intervals. [d]Ultra-low frequency spectral component (msec^2). [e]Low frequency spectral component (msec^2). [f]High frequency spectral component (msec^2). [g]The ratio of LF to HF.

inappropriate. Since the participants were single-blinded to the conditions of the experiments, the possibility that they guessed whether they were exposed to the real or sham magnetic field cannot be excluded. The discrepancy in the results (i.e. HRV, blood pressure, mood, estimated time intervals of 60 seconds, reaction time, and flow rate) between the participants may be due to the difference in the sampling rate. While, for example, heart rate was measured with a sampling rate of 273 Hz for 24 hours per monitoring session, mood was estimated every 4 hours while awake, giving a maximum of only five readings per session, and thus less statistical power to detect any difference between responses to real and sham exposure.

On the positive side, a circadian rhythm with a similar timing was found for positive affect and cheerfulness, which both emphasized ‘good humor’. Also validating earlier results was the failure to demonstrate a circadian variation for negative affect, confirming the findings of Clark, Watson, and Leeka [7]. Dawes' findings of circadian rhythmicity in salivary flow rate [8] were also confirmed. The results of the further analysis of the HRV data suggest a possibility that early night exposure to the ULF magnetic field may

Table 4
Population-mean cosinor summary of mood, vigor, and estimated time intervals

Variable		Real Exposure			Sham Exposure			t-test		
		Mean	N	SD	Mean	N	SD	t	df	P
SBP[a]	MESOR[o]	73.10	12	5.91	72.05	12	5.33	1.02	11	*N.S.*
	Amplitude[p]	4.62	12	2.33	4.15	12	1.80	0.59	11	*N.S.*
	Acrophase[q]	-245.17	12	50.54	-219.50	12	81.94	-0.74	11	*N.S.*
DBP[b]	MESOR	73.10	12	5.91	72.05	12	5.33	1.02	11	*N.S.*
	Amplitude	4.62	12	2.33	4.15	12	1.80	0.59	11	*N.S.*
	Acrophase	-245.17	12	50.54	-219.50	12	81.94	-0.74	11	*N.S.*
HR[c]	MESOR	62.56	12	4.34	60.83	12	4.42	1.26	11	*N.S.*
	Amplitude	7.42	12	2.83	6.34	12	2.93	0.88	11	*N.S.*
	Acrophase	-274.83	12	25.08	-276.83	12	34.16	0.19	11	*N.S.*
PA[d]	MESOR	26.67	11	3.24	27.41	11	3.48	-0.42	10	*N.S.*
	Amplitude	5.32	11	2.10	4.70	11	3.03	0.56	10	*N.S.*
	Acrophase	-241.30	10	79.92	-209.70	10	123.98	-0.60	9	*N.S.*
Na[e]	MESOR	14.74	11	2.16	14.35	11	2.59	0.36	10	*N.S.*
	Amplitude	2.79	11	1.55	1.59	11	0.93	1.97	10	*N.S.*
	Acrophase	-151.30	10	114.84	-219.00	10	108.92	1.66	9	*N.S.*
CH[f]	MESOR	12.24	11	1.95	12.74	11	1.29	-0.73	10	*N.S.*
	Amplitude	2.34	11	1.76	2.64	11	1.73	-0.35	10	*N.S.*
	Acrophase	-245.00	11	66.10	-200.73	11	118.36	-0.96	10	*N.S.*
SE[g]	MESOR	14.15	11	1.98	13.50	11	1.72	0.79	10	*N.S.*
	Amplitude	2.42	11	1.31	1.68	11	0.80	1.37	10	*N.S.*
	Acrophase	-183.73	11	100.23	-234.73	11	71.26	1.39	10	*N.S.*
BM[h]	MESOR	10.38	11	2.19	9.94	11	2.95	0.41	10	*N.S.*
	Amplitude	1.64	11	0.59	1.63	11	0.93	0.01	10	*N.S.*
	Acrophase	-87.91	11	64.67	-164.91	11	78.61	2.11	10	*N.S.*
M[i]	MESOR	10.38	9	0.61	9.94	9	0.95	0.27	8	*N.S.*
	Amplitude	1.04	9	0.79	1.20	9	0.72	-0.71	8	*N.S.*
	Acrophase	-198.67	9	90.73	-216.33	9	95.48	0.67	8	*N.S.*
V[j]	MESOR	3.36	10	0.84	3.45	10	1.02	-0.25	9	*N.S.*
	Amplitude	1.37	10	0.60	1.10	10	0.76	1.20	9	*N.S.*
	Acrophase	-214.50	10	113.90	-251.70	10	91.69	0.67	9	*N.S.*
SSS[k]	MESOR	3.44	10	0.77	3.05	10	0.62	1.14	9	*N.S.*
	Amplitude	1.51	10	0.66	1.15	10	0.57	1.23	9	*N.S.*
	Acrophase	-100.40	10	55.19	-101.90	10	62.35	0.10	9	*N.S.*
RT[l]	MESOR	763.75	10	31.63	685.81	10	242.53	0.96	9	*N.S.*
	Amplitude	18.53	10	13.30	16.53	10	14.65	0.31	9	*N.S.*
	Acrophase	-136.30	10	89.77	-134.90	10	93.66	-0.03	9	*N.S.*
TE[m]	MESOR	58.77	11	3.21	57.69	11	2.61	1.51	10	*N.S.*
	Amplitude	2.14	11	1.20	2.04	11	1.29	0.28	10	*N.S.*
	Acrophase	-153.45	11	71.17	-183.91	11	87.36	0.98	10	*N.S.*
FR[n]	MESOR	0.24	15	0.08	0.29	15	0.09	-1.74	15	*N.S.*
	Amplitude	0.12	15	0.06	0.13	15	0.06	-0.51	15	*N.S.*
	Acrophase	-256.00	15	35.26	-264.13	15	37.91	0.62	15	*N.S.*

NS: non-significant. [a]Systolic blood pressure. [b]Diastolic blood pressure. [c]Heart rate. [d]Positive affect. [e]Negative affect. [f]Cheerfulness. [g]Seriousness. [h]Bad mood. [i]Mood rated on Mood and Vigor Scale. [j]Vigor rated on Mood and Vigor Scale. [k]Objective alertness rated on Stanford Sleepiness Scale. [l]Reaction time. [m]Estimated time intervals of 60 seconds. [n]Salivary flow rate. [o]Midline-Estimating Statistic Of Rhythm, a rhythm-adjusted mean. [p]Measure of extent of predictable change within a cycle. [q]Measure of timing of overall high values recurring in each cycle, expressed in (negative) degrees, with 360 equated to period length and 0 =0: 00.

increase heart rate and reduce heart rate variability of those who are susceptible to it. However, they are inconsistent among subjects and among circadian stages.

Futures studies would need to use more rigorous designs, a larger sample size, artificial magnetic field of appropriate strength and waveform, and a better magnetically shielded