Final Report: Part I

„Provocation Study on Physiological Parameters of the Visual System under the Influence of Radio-Frequency EMF in Humans"

commissioned by

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carried out by

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CONTENT

1. INTRODUCTION

The growth in the use of mobile phones has generated considerable controversy on safety of exposure to electromagnetic fields (EMF) on users. Several studies dealt with the effect of EMF on human brain function in wake [1-6] and sleep [3, 7-10], and different aspects of acoustic [1, 11-13] or visual perception [14-16]. Studies concerning cognitive aspects dealt with attention [6, 14, 17], memory [15, 18], and reaction time [6, 12, 14, 19]. Results of these studies are inconsistent for such reasons as different study protocols and different methods in EMF-parameters, exposure and statistical procedures. To date the 3rd generation of mobile phones captures the market in Europe, and to our knowledge, only a few studies on effects of EMF emitted by Universal Mobile Telecommunications System (UMTS) phones on human performance have been carried out or are ongoing. In the present double-blinded study of EMF exposure of this new signal type for mobile telephony on human visual perception and performance was examined.

2. MATERIALS AND METHODS

2.1 Participants

A total of 58 volunteers (29 female, 29 male), aged from 20 to 40 years (mean 29.1±5.1), participated in our study. They were all screened for medical illnesses and underwent extensive ophthalmologic examinations. All subjects were normal sighted and regular mobile phone users, with an average time of use of 23.8 minutes per day (range: 2-90 minutes according to their statement). Education level of all participants was at least general qualification for university entrance. All subjects gave their written informed consent prior to the experiment. The local ethical committee for research approved the study protocol.

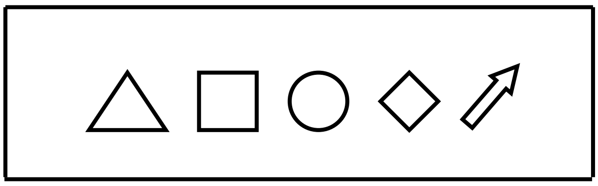
2.2 Tests

Test subjects were sitting inside a laterally shielded exposure cabin. The exposure-head set guaranteed hand free performance. Each subject underwent a sequence of 4 different computer-based tests on visual performance.

Visual discrimination ability and activation of the central nervous system, i.e. arousal, were assessed by **determination of critical flicker and fusion frequency thresholds** (measured in Hz). In ascending mode, the frequency of a red flickering light, presented on a white background in a viewing tube (Dr. Schuhfried Inc., Moedling, Austria), was stepwise increased, starting off with 25 Hz to a maximum of 70 Hz, until it was perceived as a constant light by the subject. Conversely, in descending mode the frequency of high frequency light (70 Hz), perceived by the subject as a constant light at the beginning, was decreased until it was perceived as to flicker. The subjects acknowledged every change in perception by pressing a button, and the critical frequency was then recorded. The duration of the test was approximately 10 minutes.

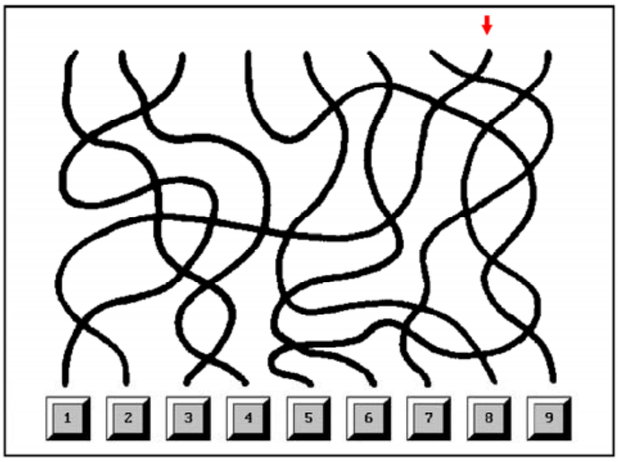
Contrast sensitivity was detected by a special monitor on which 5 different fair grey symbols were presented, appearing gradually from a black background in random order (Rodenstock; see Fig. 1). The distance between the monitor and each subject was 1 m. Each symbol was shown for 9 seconds at the same position in the middle of the monitor. Subjects had to press a corresponding button the time they identified the symbol. The contrast threshold was measured by an individually adjusted ascending and descending mode, with contrast levels ranging from 1 to 20 steps of increasing contrasts between symbols and background. Test duration was approximately 25 minutes.

Fig. 1: Symbols of Contrast Sensitivity



The **Visual Pursuit Test** (Dr. Schuhfried Inc., Moedling, Austria) is a perception test for the registration of concentrated targeted perception and selective attention in the visual area. It is a *line tracking test* and consists of 80 items. Subjects had to follow one out of 9 lines, indicated by a red arrow, with their eyes, find the correct end of the line, and press the corresponding button (see Fig. 2).

Fig. 2: Visual Pursuit Test



The test was scored according to the following variables: number of correct answers, median time for correct answers, and working time. A score was calculated which resulted from speed of working and accuracy of answers. Test duration was approximately 10 minutes.

To assess the **optical perception performance and perceptive speed** the Tachistoscopic Traffic Test Mannheim (Dr. Schuhfried Inc., Moedling, Austria) was conducted. 20 pictures of traffic situations were shown at a presentation time of 1 second per picture. After each picture the subject had to specify whether he or she had seen pedestrians, motor vehicles, cyclists, motorcyclists, traffic signs or traffic lights (see Fig. 3). The number of correct answers and the number of incorrect answers were recorded.

Fig. 3: Tachistoscopic Traffic Test Mannheim

3. PROCEDURES

Each subject was tested on a week day from 3:30 to 7:15 p.m.. The assessment of visual perception consisted of the 4 different tests described in the preceding section. Every subject underwent each test series under 3 different exposure conditions (high, low and sham exposure), which were randomly assigned to each subject. The order of presenting the tests was kept the same for all test subjects. Time table and order of tests are shown in Tab. 1:

Tab. 1: Time table and test order. Testing began at 3:30 p.m. for each subject and ended at about 7:15 p.m..

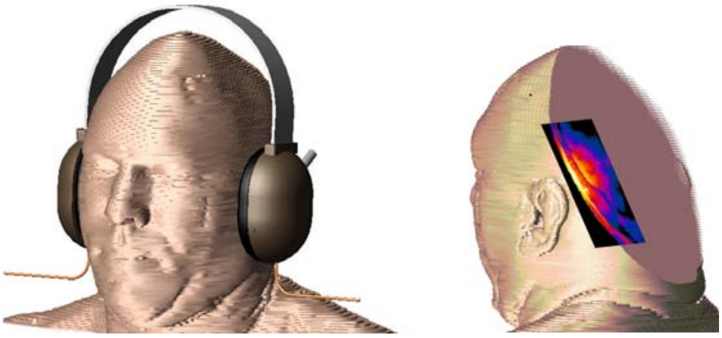
Time of Day	*Test*
3:30	Flicker and Fusion Frequency
3:45	Contrast sensitivity
4:00	Visual Pursuit Test
4:15	Tachistoscopic Traffic Test Mannheim
4:30	Flicker and Fusion Frequency
4:45	Contrast sensitivity
5:00	Visual Pursuit Test
5:15	Tachistoscopic Traffic Test Mannheim
5:30	Flicker and Fusion Frequency
5:45	Contrast sensitivity
6:00	Visual Pursuit Test
6:15	Tachistoscopic Traffic Test Mannheim
	Positive Control (Flickering light)
6:30	Contrast sensitivity
6:45	Visual Pursuit Test
7:00	Tachistoscopic Traffic Test Mannheim

During the tests subjects were sitting inside a laterally shielded exposure cabin. The inner surface of the cabin was covered with radio frequency absorbing material (pyramidal absorbers Eccosorb VHP-12-NRL, Emerson Cuming, Westerlo, Belgium) to prevent undefined field distributions caused by signal reflections inside the cabin. The radio-frequency EMF was applied to the head via a special head set enabling hands free exposure of the subjects (Fig. 4). The head set was designed to expose the temporal area of the head, similar as it can be expected in the case of mobile phone usage. As signal source a generic UMTS signal generator (GUS 6960 S, University of Wuppertal, Germany) was used, providing a Wideband CDMA signal according to the UMTS specification (carrier frequency 1.97 GHz, 5 MHz bandwith). The envelope of the applied signal consisted of intervals of constant transmitted power as well as of intervals of strong variations of transmitted power (up to 30 dB fading) in order to simulate real conditions with respect to the UMTS transmission power-control algorithm at non constant receiving quality [see 20]. The power of the exposure signal was adjusted to levels aiming at a 10 g averaged specific absorption rate (SAR) in the test subject's head in the same order, but certainly below the currently recommended limit of 2 W/kg at the high-exposure condition. Application of exposure was controlled randomly and double blinded by a control and recording software operated by the test instructor. By definition of the agreed study protocol, test subjects were always exposed only with their left hemisphere, however, they were not informed about this fact. The applied EMF-power levels were recorded every 30 seconds. Evaluation and uncertainty considerations of the resulting exposure in the test subject's head was done based on the power recordings and on a series of numerical calculations using the SEMCAD® simulation platform (Schmid and Partner Engineering AG, Zurich, Switzerland) and a heterogeneous male head model (1.5 mm spatial resolution, 32 different tissues distinguished, see Fig. 5). The validity of the numerical antenna model was verified by comparisons of SAR measurements in a simplified homogeneous head phantom model and corresponding simulations, showing good agreement within ± 10 %. Variations in the relative position of the radiating antenna to the head, variations in head size (± 15 %) and variations in the dielectric properties of head tissues (± 20%) were considered for the uncertainty evaluation. As resulting exposure of the test subjects, a (10 g averaged) SAR value of 0.63 ± 0.31 W/kg (mean ± standard deviation) at the high-exposure condition was obtained. SAR at low-exposure condition was one tenth of high exposure. Sham-exposure was at least 50 dB below low exposure. For further details on technical aspects see "Final Report-Part II: Exposure System and dosimetric evaluation".

A *positive control* was added to all tests, except the critical flicker and fusion frequency measurement: In a last session following the three preceding sessions of high, low and sham-exposure flickering light instead of any EMF- or sham-exposure was applied to the test subject from the back (to avoid blinding) into the exposure cabin. These control sessions were carried out to check, whether implemented tests were sensitive enough to catch any alterations due to external influences, like EMF. To avoid possible negative impacts on the subjects health, a flickering light and not a high dose of EMF was chosen.

Fig. 4: Subject sitting inside cabin with special head set enabling hands free exposure

Fig. 5: Numerical heterogeneous head model and typical distribution of RF power absorption in the temporal area of the head



4. RESULTS

As a consequence of randomly assigned exposure levels, results of each test were compared firstly for **exposure level** and secondly for any effects of **test order on test results**.

Tables 2-17 and figures 6-21 show all results for each kind of test separately, starting off with comparisons between different exposure levels (sham, low, high) for each test (Fusion and Flicker Frequency, Contrast Sensitivity, Visual Pursuit Test, Tachistoscopic Traffic Test), followed by results of comparisons between 3 different trials (1st trial, 2nd trial, 3rd trial) irrespective of exposure level, but taking into account the sequencies of tests and possible learning effects or effects resulting from tiredness (Fusion and Flicker Frequency, Contrast Sensitivity, Visual Pursuit Test, Tachistoscopic Traffic Test). Scores of positive controls are listed in the exposure section where applicable in the last row of each table, with analysis of variances for 4 groups calculated separately. In case of homogeneity of variances and normal distribution, analysis of variances were calculated and F-values and p-values are indicated. In case of inhomogeneity of variances, results from Friedman tests (χ^2) are quoted. Type I error levels were set at a=0.05. Means and Standard Deviations (SD) or Median (high, low, sham, and positive, where applicable) and Percentiles are presented in table 2 to Tab. 17.

In the exposure sessions all variables of all tests did not differ significantly between the 3 exposure levels (low, high, sham). There were some effects of practice as a consequence of repeated measurements. This practice effect became statistically significant in the Tachistoscopic Traffic Test reflected in an increase in correct answers and a decrease in incorrect answers (see table 16 and 17). These results were even enforced in the last session of the positive control situation (see table 16 and 17). This result could be explained by an attention altering effect of the flickering light (attention enhancement), which also was reported by most of the subjects.

The threshold in the measurement of contrast sensitivity dropped as a function of time. In the last session the flickering light of the positive control elevated the threshold significantly (disturbing effect). Performance in the Visual Pursuit Test was not affected by the flickering light.

4.1 Tables and Figures (comparisons between exposure levels)

Results of performance in 4 different tests for 3 different exposure levels and positive controls are presented in table 2-9 and in figures 6-13.

Tab. 2: Fusion Frequency (Hz): Means, standard deviations (SD), range, and results of analysis of variances for 3 different exposure levels. There are no significant differences between the 3 different exposure conditions.

Trial	*Mean*	*SD*	*Range*	*F-value*	*p*
Low exposure (n=58)	39.9	2.16	35.4-46.2	.239	.788
High exposure (n=58)	40.2	2.23	35.5-45.5		
Sham exposure (n=58)	40.2	2.53	35.2-47.7		

Tab. 3: Flicker Frequency (Hz): Means, standard deviations (SD), range, and results of analysis of variances for 3 different exposure levels. There are no significant differences between the 3 different exposure conditions.

Trial	*Mean*	*SD*	*Range*	*F-value*	*p*
Low exposure (n=58)	41.9	3.02	36.0-49.0	.161	.851
High exposure (n=58)	41.8	3.05	36.9-51.1		
Sham exposure (n=58)	42.1	3.16	37.5-50.6		

Tab. 4: Contrast Sensitivity (contrast level between 1-20): Median, 25th and 75th percentile (perc.), range, and results of Friedman test for 3 different exposure levels & positive control. There are no significant differences between the 3 exposure conditions, but a significant difference between results in exposure conditions and results of positive control.

Trial	*Median*	*25perc.*	*75perc.*	*Range*	χ^2	*p*
Low exposure (n=58)	12	10	13	7-15	1.689	.430
High exposure (n=58)	12	10	13	8-15		
Sham exposure (n=58)	12	10	13	8-15		
Positive control (n=58)	12	12	13	10-15	21.252	.000

Tab. 5: Visual Pursuit Test (number of correct answers): Means, standard deviations (SD), range, and results of analysis of variances for 3 different exposure levels & positive control. There are no significant differences between the 3 exposure conditions, and no significant difference between results in exposure conditions and results of positive control. Possible maximum number of correct answers was 80.

Trial	*Mean*	*SD*	*Range*	*F-value*	*p*
Low exposure (n=58)	78.6	1.66	71-80	.451	.638
High exposure (n=58)	78.4	2.07	69-80		
Sham exposure (n=58)	78.3	1.69	73-80		
Positive control (n=58)	78.7	1.56	71-80	.694	.556

Tab. 6: Visual Pursuit Test (mean reaction time of correct answers; sec): Means, standard deviations (SD), range, and results of analysis of variances for 3 different exposure levels & positive control. There are no significant differences between the 3 exposure conditions, and no significant difference between results in exposure conditions and results of positive control.

Trial	*Mean*	*SD*	*Range*	*F-value*	*p*
Low exposure (n=58)	4.2	.82	2.8-6.9	.026	.975
High exposure (n=58)	4.2	.83	2.7-6.6		
Sham exposure (n=58)	4.2	.81	2.7-6.5		
Positive control (n=58)	4.0	.75	2.8-6.5	.827	.480

Tab. 7: Visual Pursuit Test ("Score"): Means, standard deviations (SD), range, and results of analysis of variances for the 3 different exposure levels & positive control. There are no significant differences between the 3 exposure conditions, and no significant difference between results in exposure conditions and results of positive control.

Trial	*Mean*	*SD*	*Range*	*F-value*	*p*
Low exposure (n=58)	66.9	13.26	27-80	.037	.964
High exposure (n=58)	67.5	12.88	20-79		
Sham exposure (n=58)	67.5	11.88	29-80		
Positive control (n=58)	70.4	10.47	29-79	.935	.424

Tab. 8: Tachistoscopic Traffic Test (Number of correct answers): Means, standard deviations (SD), range, and results of analysis of variances for the 3 different exposure levels & positive control. There are no significant differences between 3 exposure conditions, but a significant difference between results in exposure conditions and results of positive control (Friedman χ^2). Possible maximum number of correct answers was 56.

Trial	***Mean***	***SD***	***Range***	***F-value***	***p***
Low exposure (n=58)	51.2	3.46	38-56	.464	.629
High exposure (n=58)	51.5	3.34	41-56		
Sham exposure (n=58)	50.8	3.74	40-56		
				χ^2	***p***
Positive control (n=58)	53.2	1.99	48-56	35.140	.000

Tab. 9: Tachistoscopic Traffic Test (Number of incorrect answers): Means, standard deviations (SD), range, and results of analysis of variances for the 3 different exposure levels & positive control. There are no significant differences between 3 exposure conditions, and no significant difference between results in exposure conditions and results of positive control (Friedman χ^2). Possible maximum number of incorrect answers was 44.

Trial	***Mean***	***SD***	***Range***	***F-value***	***p***
Low exposure (n=58)	1.8	2.23	0-8	1.680	.189
High exposure (n=58)	1.7	1.79	0-9		
Sham exposure (n=58)	1.8	2.21	0-13		
				χ^2	***p***
Positive control (n=58)	1.2	1.45	0-7	4.658	.199

Fig. 6: Means of Fusion Frequency for sham, low and high exposure. There are no significant differences between the three conditions.

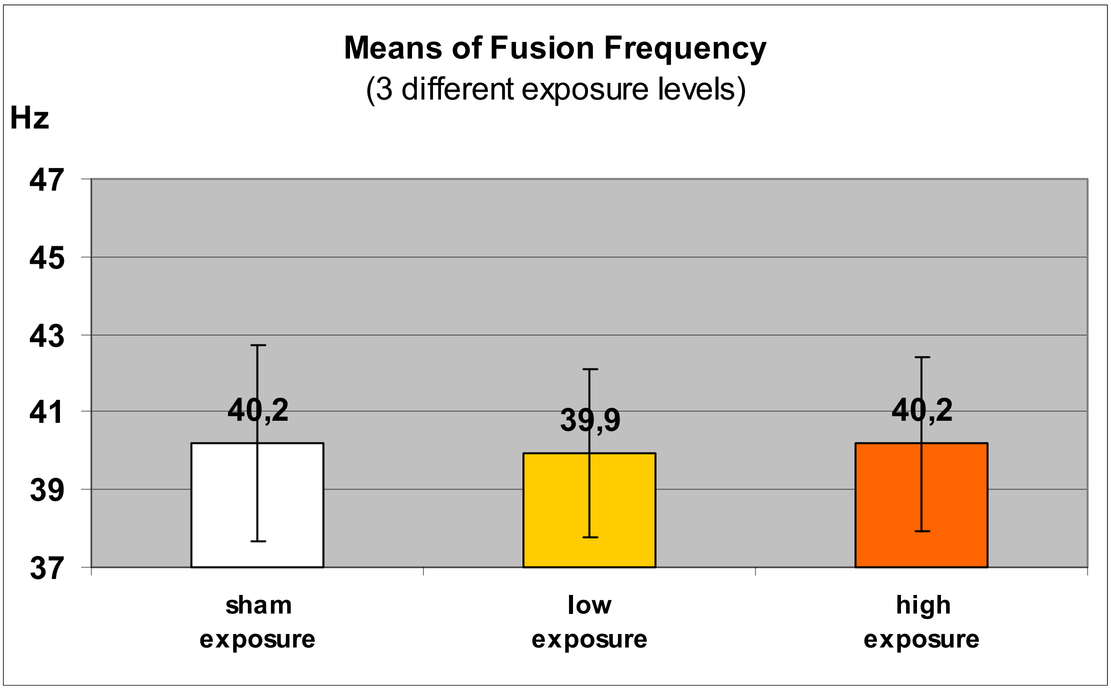


Fig. 7: Means of Flicker Frequency for sham, low and high exposure. There are no significant differences between the three conditions.

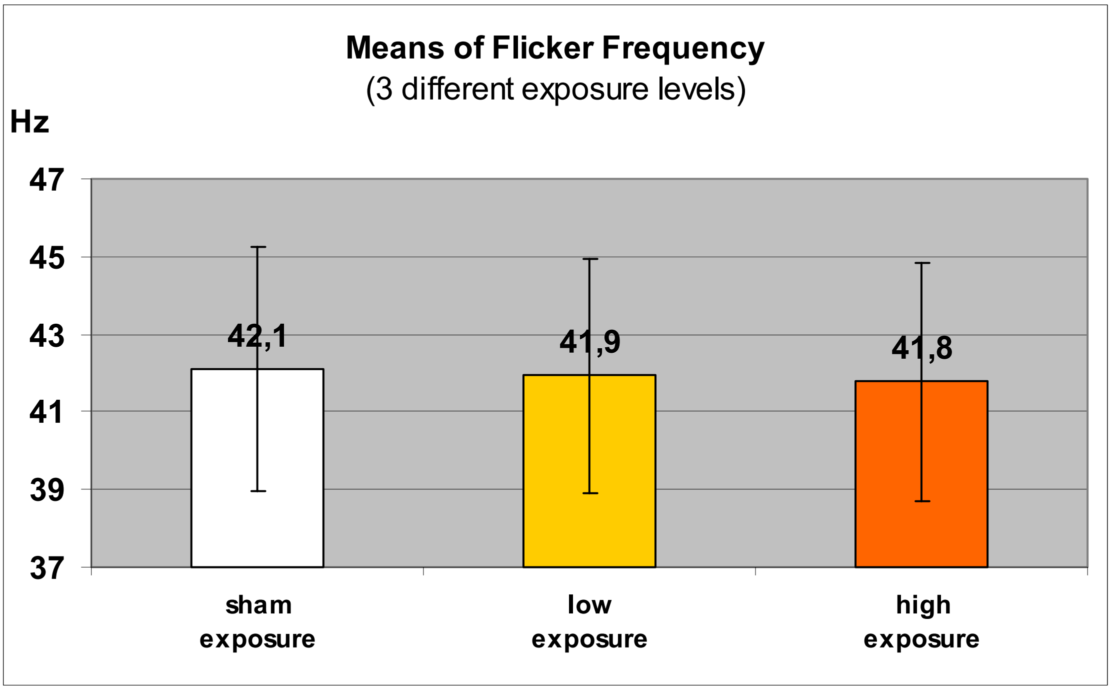


Fig. 8: Medians of Contrast Sensitivity (contrast level between 1 and 20) for sham, low and high exposure, and positive control. Low values indicate that subjects were able to identify grey symbols on a black background at a low contrast level. There are no significant differences between the three exposure conditions.

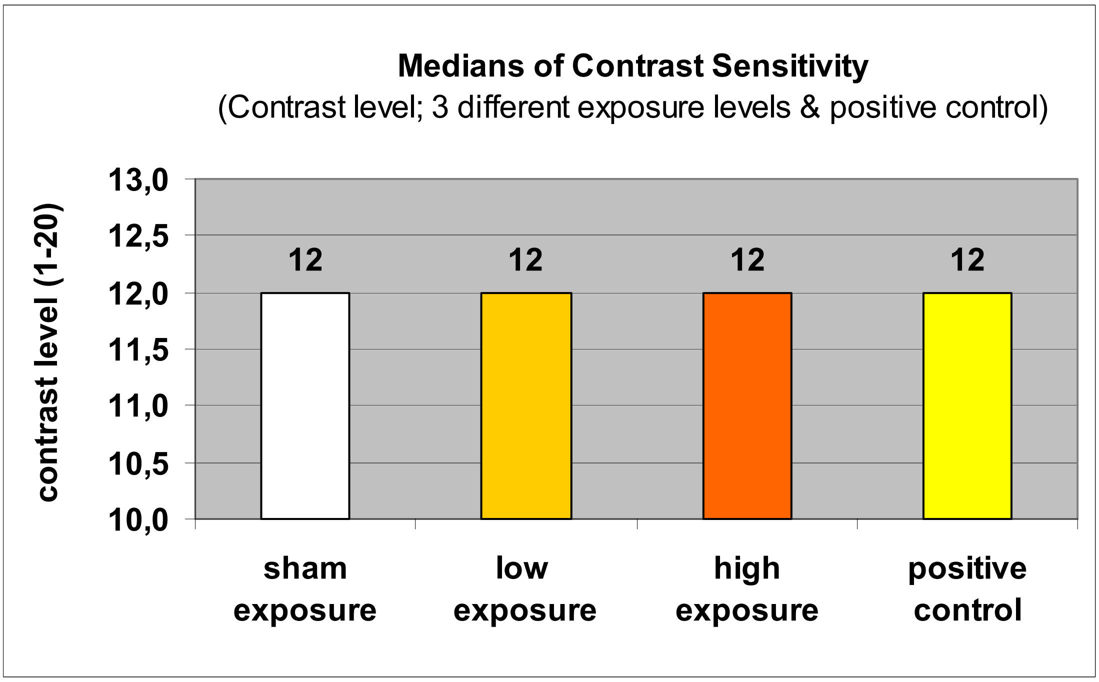


Fig. 9: Visual Pursuit Test: Correct Answers: Mean numbers for sham, low and high exposure, and positive control. The four conditions did not differ significantly.

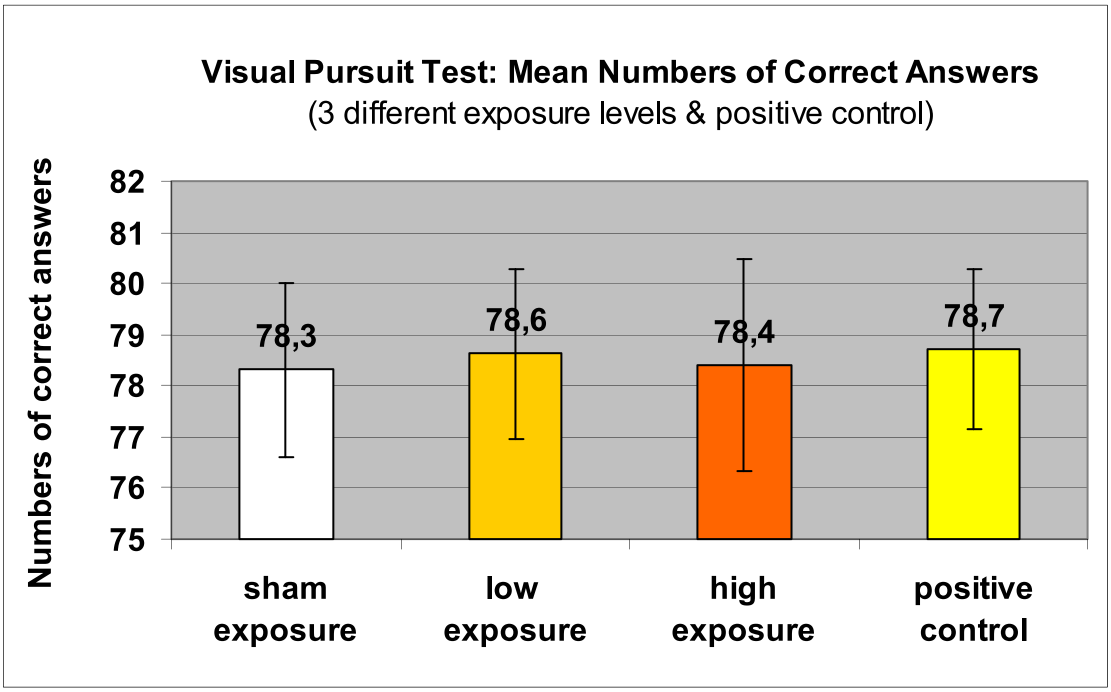


Fig. 10: Visual Pursuit Test: Mean reaction time (seconds) of correct answers for sham, low and high exposure, and positive control. The four conditions did not differ significantly. Mean reaction times (from the beginning of presentation of an item to pressing the right button) were calculated for all correct reactions per test.

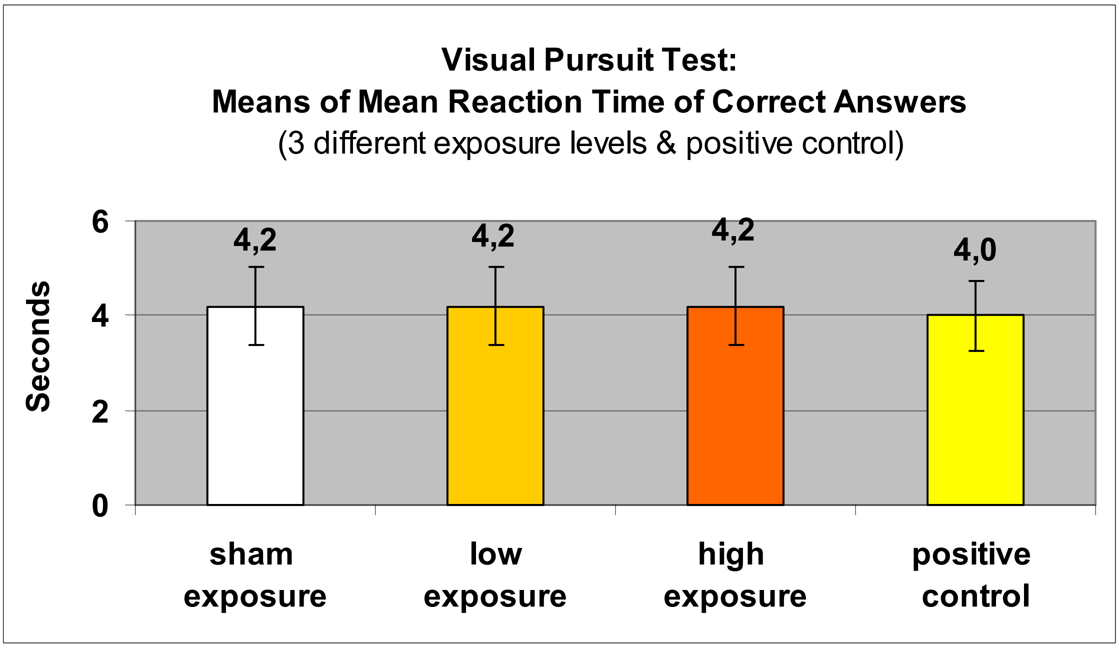


Fig. 11: Visual Pursuit Test: Mean "Scores" for sham, low and high exposure, and positive control. The test program calculates a "Score", which results from speed of working and accuracy of answers. These Scores did not differ between the 4 conditions.

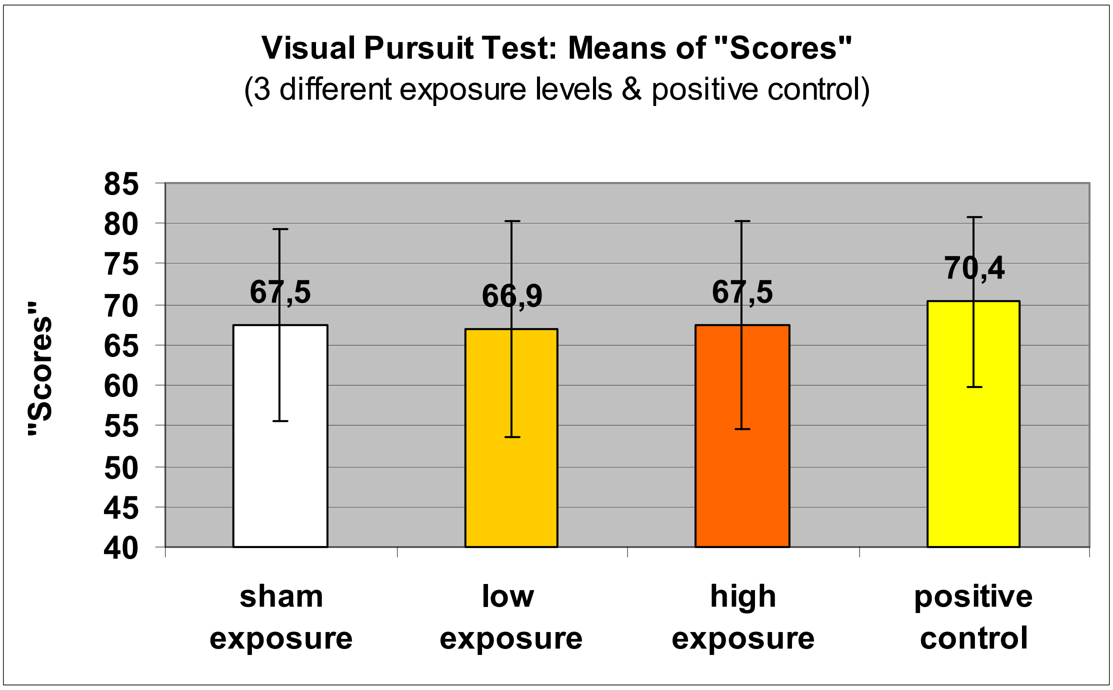


Fig. 12: Tachistoscopic Traffic Test: Mean numbers of correct answers for sham, low and high exposure, and positive control. There were no differences between the 3 exposure levels, but mean numbers increased in the positive control session, compared to the 3 exposure sessions.

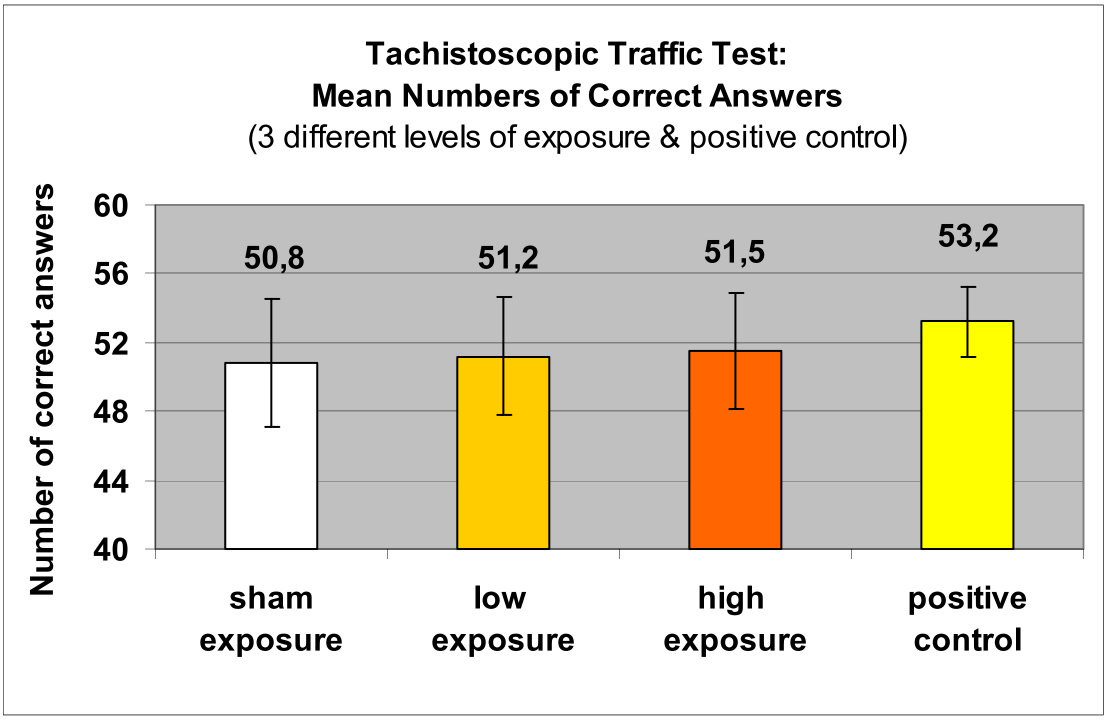
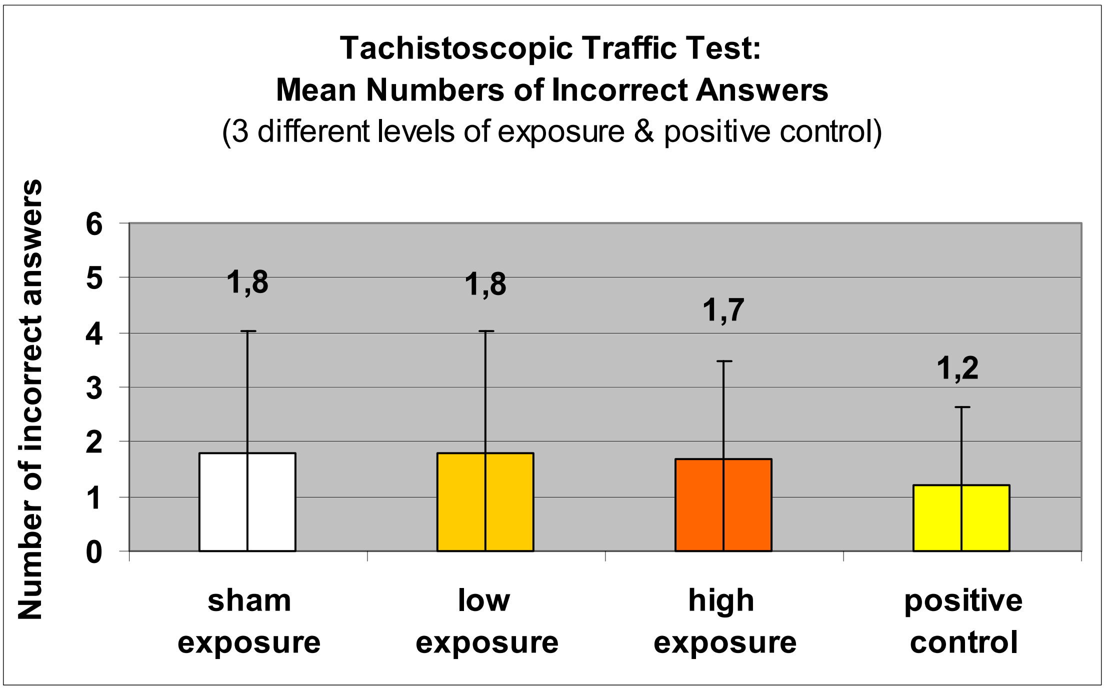


Fig. 13: Tachistoscopic Traffic Test: Mean numbers of incorrect answers for sham, low and high exposure, and positive control. There were no differences between the 3 exposure levels, and between the exposure conditions and the positive control sessions.



4.2 Tables and Figures (comparisons between test trials)

Tab. 10: Fusion Frequency (Hz): Means, standard deviations (SD), range, and results of analysis of variances for 3 trials. There are no significant differences between the 3 trials.

Trial	*Mean*	*SD*	*Range*	*F-value*	*p*
1st Test (n=58)	39.8	2.17	35.6-47.7	1.106	.333
2nd Test (n=58)	40.2	2.24	35.2-45.5		
3rd Test (n=58)	40.4	2.48	35.4-46.2		

Tab. 11: Flicker Frequency (Hz): Means, standard deviations (SD), range, and results of analysis of variances for 3 trials. There are no significant differences between the 3 trials.

Trial	*Mean*	*SD*	*Range*	*F-value*	*p*
1st Test (n=58)	42.1	3.11	38.0-50.6	.246	.782
2nd Test (n=58)	42.0	3.16	37.2-51.1		
3rd Test (n=58)	41.7	2.95	36.0-49.0		

Tab. 12: Contrast Sensitivity (contrast level between 1-20): Median, 25th and 75th percentile (perc), range, and results of Friedman test for the 3 trials. There are significant differences between the 3 and all trials.

Trial	*Median*	*25perc.*	*75perc.*	*Range*	$\chi 2$	*p*
1st Test (n=58)	12	11	13	8-15	7.161	.028
2nd Test (n=58)	12	10	13	8-15		
3rd Test (n=58)	11	10	13	7-15		
Positive control (n=58)	12	12	13	10-15	27.080	.000

Tab. 13: Visual Pursuit Test (number of correct answers): Means, standard deviations (SD), range, and results of analysis of variances for the 3 trials. There are no significant differences between the 3 trials.

Trial	**Mean**	**SD**	**Range**	*F-value*	*p*
1st Test (n=58)	78.5	1.76	71-80	.085	.919
2nd Test (n=58)	78.4	2.01	69-80		
3rd Test (n=58)	78.4	1.68	73-80		
Positive control (n=58)	78.7	1.56	71-80	.432	.730

Tab. 14: Visual Pursuit Test (mean reaction time of correct answers/ sec): Means, standard deviations (SD), range, and results of analysis of variances for the 3 trials. There are no significant differences between the 3 trials.

Trial	Mean	SD	Range	*F-value*	*p*
1st Test (n=58)	4.3	.86	2.7-6.5	2.081	.128
2nd Test (n=58)	4.1	.79	2.8-6.9		
3rd Test(n=58)	4.0	.76	2.7-6.6		
Positive control (n=58)	4.0	.75	2.8-6.5	2.265	.082

Tab. 15: Visual Pursuit Test (“Score”): Means, standard deviations (SD), range, and results of analysis of variances for the 3 trials. There are no significant differences between the 3 trials.

Trial	Mean	SD	Range	*F-value*	*p*
1st Test (n=58)	65.3	14.01	20-80	1.278	.281
2nd Test (n=58)	67.7	12.45	27-79		
3rd Test(n=58)	68.9	11.16	34-80		
Positive control (n=58)	70.4	10.47	29-79	1.195	.305

Tab. 16: Tachistoscopic Traffic Test (Number of correct answers): Means, standard deviations (SD), range, and results of analysis of variances for the 3 trials. There are significant differences between the 3 trials.

Trial	Mean	SD	Range	*F-value*	*p*
1st Test (n=58)	49.7	3.77	38-56	9.343	.000
2nd Test (n=58)	51.3	3.47	40-56		
3rd Test(n=58)	52.4	2.73	41-56		
				χ^2	*p*
Positive control (n=58)	53.2	1.99	48-56	69.209	.000

Tab. 17: Tachistoscopic Traffic Test (Number of incorrect answers): Means, standard deviations (SD), range, and results of analysis of variances for 3 trials. There are significant differences between the 3 trials.

Trial	Mean	SD	Range	χ^2	*p*
1st Test (n=58)	2.4	2.63	0-13	16.133	.000
2nd Test (n=58)	1.5	1.7	0-8		
3rd Test(n=58)	1.4	1.6	0-7		
				χ^2	*p*
Positive control (n=58)	1.2	1.45	0-7	19.145	.000

Fig. 14: Means of Fusion Frequency for test order (Hz). The exact time schedule is presented in table 1. There were no significant differences between the 3 trials.

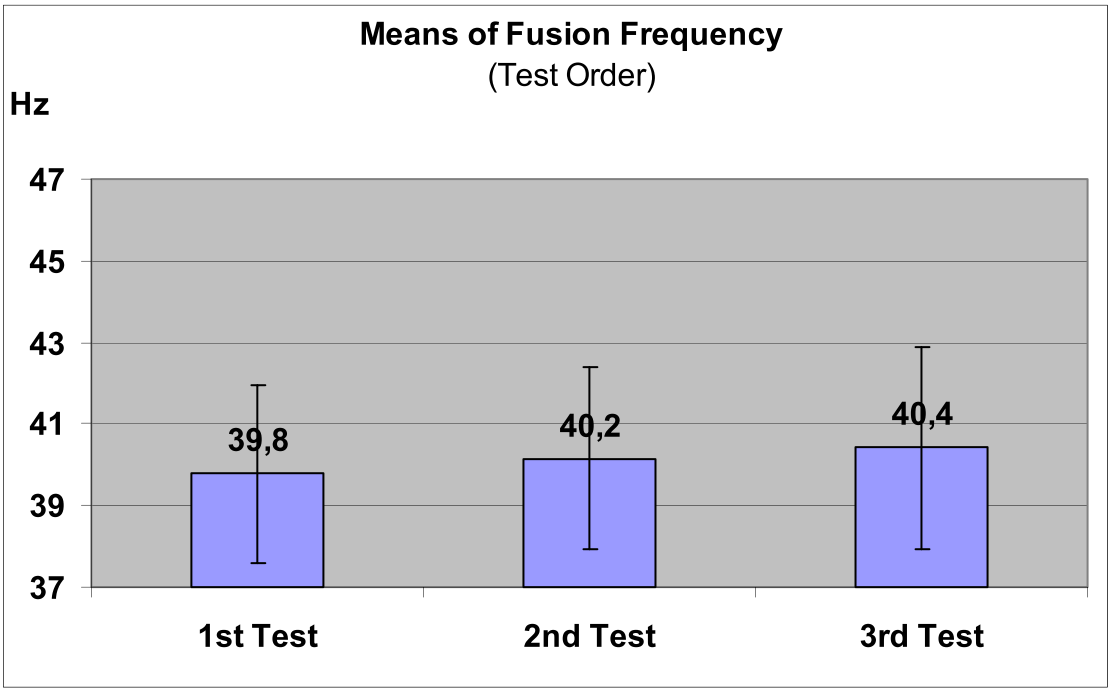


Fig. 15: Means of Flicker Frequency for test order (Hz). There were no significant differences between the 3 trials.

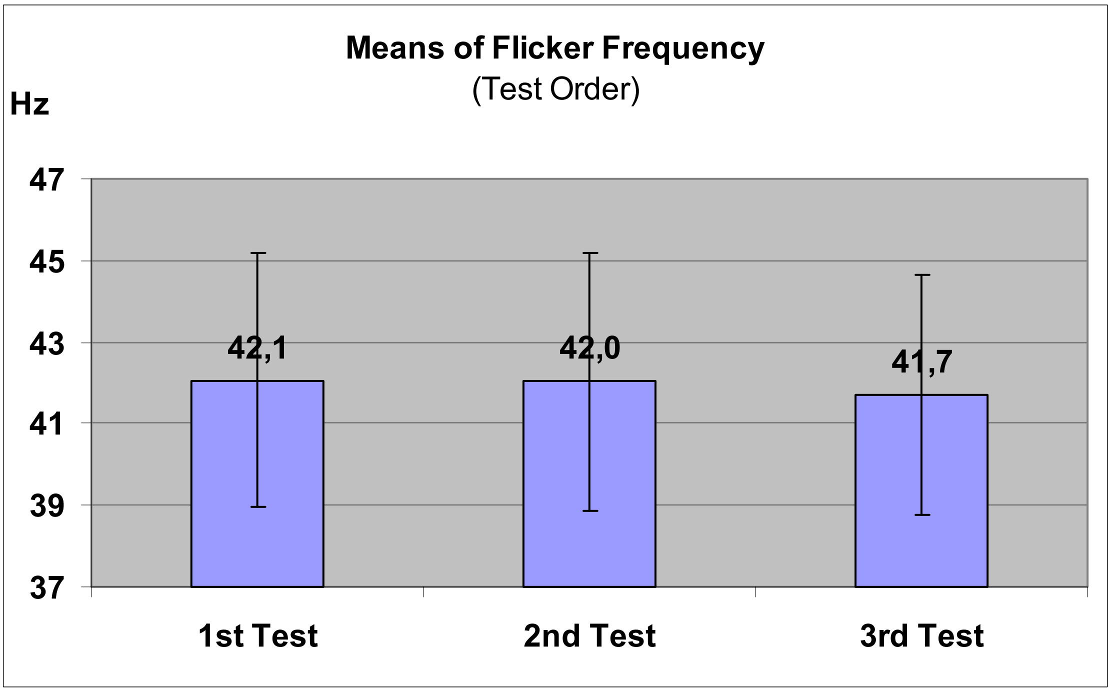


Fig. 16: Means of Contrast Sensitivity for contrast levels (minimum value 1, maximum value 20). Low values indicate that subjects were able to identify grey symbols on a black background at a low contrast level.

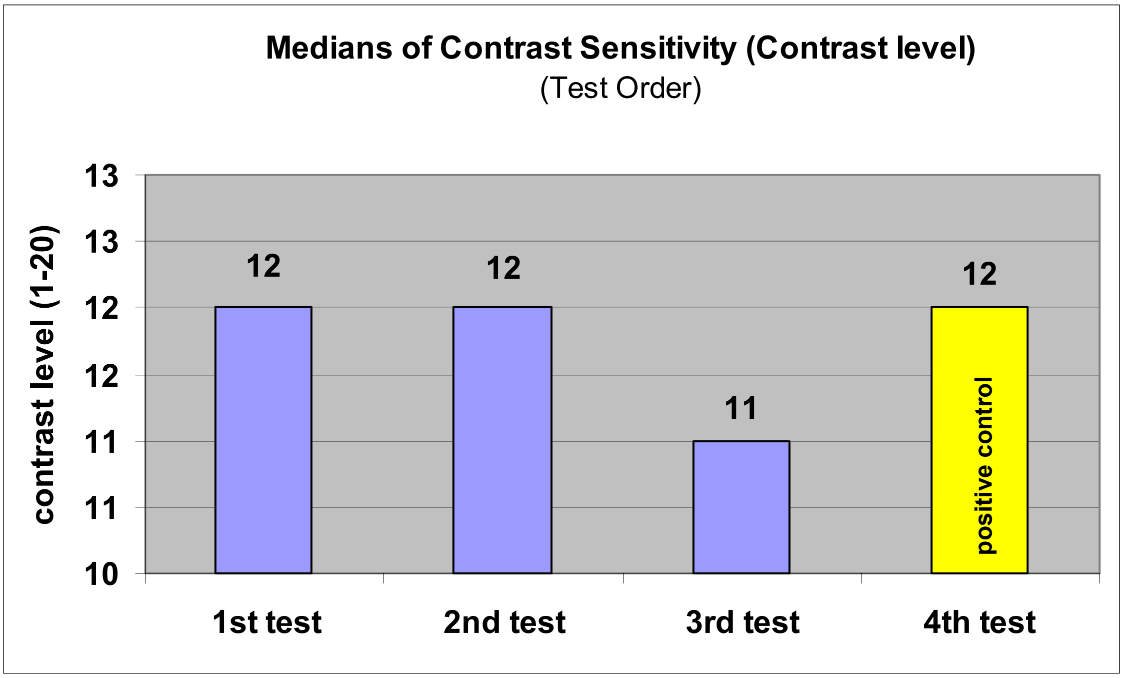


Fig. 17: Means of Visual Pursuit Test (correct answers) for test order. Performance did not change significantly between sessions.

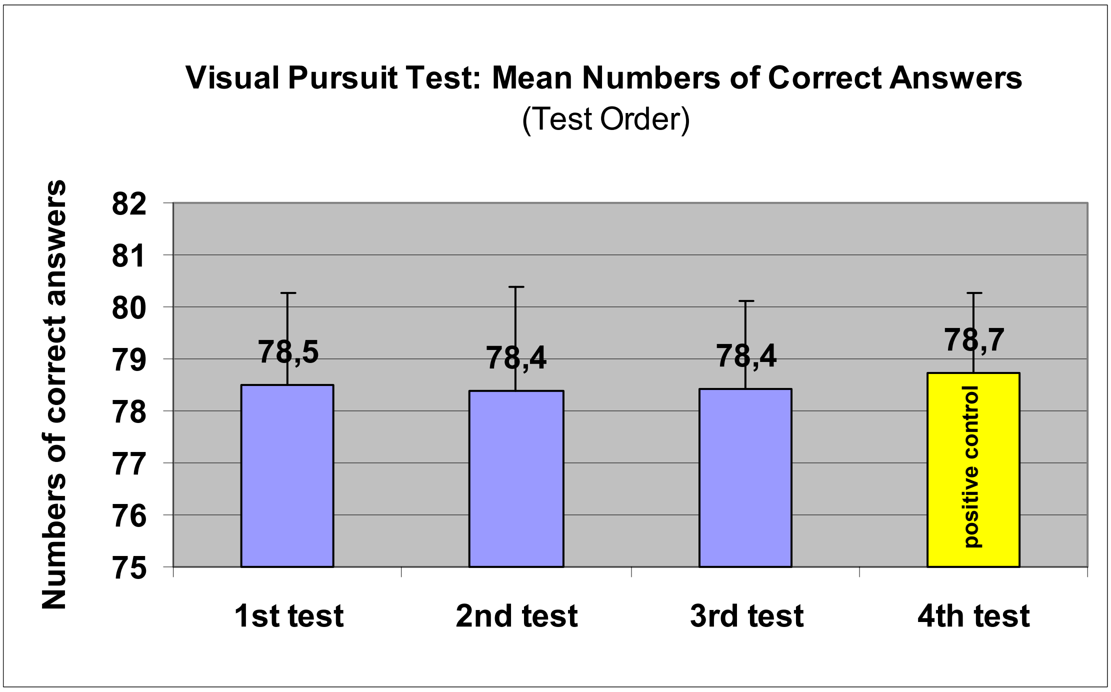


Fig. 18: Means of Visual Pursuit Test (mean reaction time of correct answers) for test order. Performance did not change significantly between sessions. Mean reaction times (from the beginning of presentation of an item to pressing the right button) were calculated for all correct reactions per test.

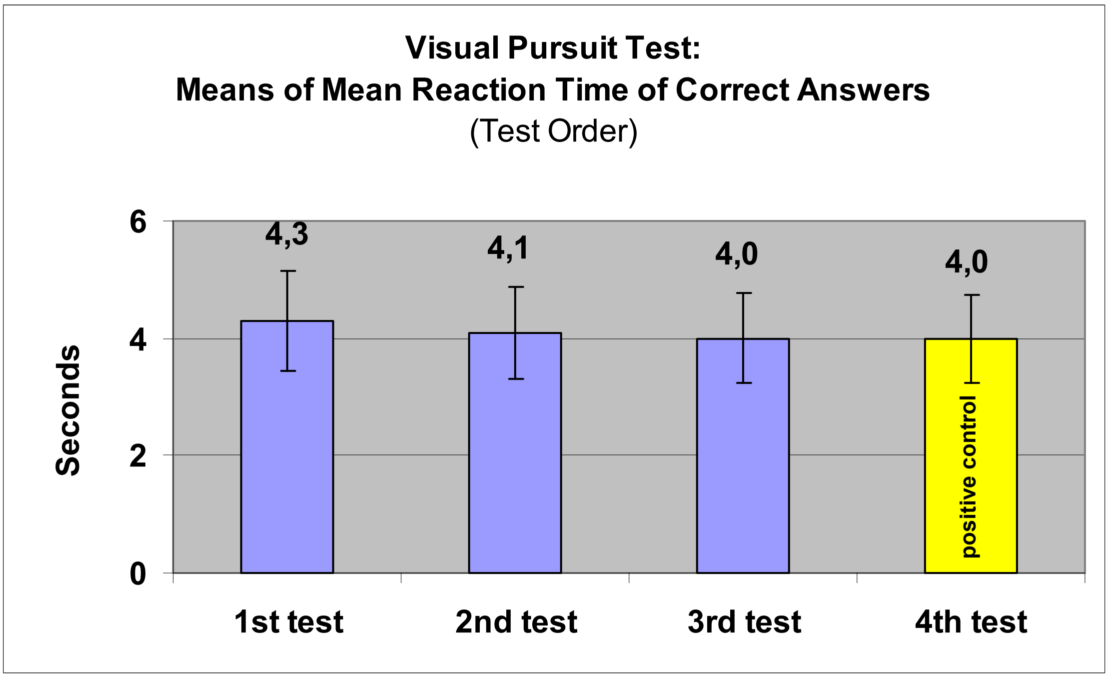


Fig. 19: Visual Pursuit Test: Mean "Scores" for test order . The test program calculates a "Score", which results from speed of working and accuracy of answers. These Scores did not differ between the 3 tests.

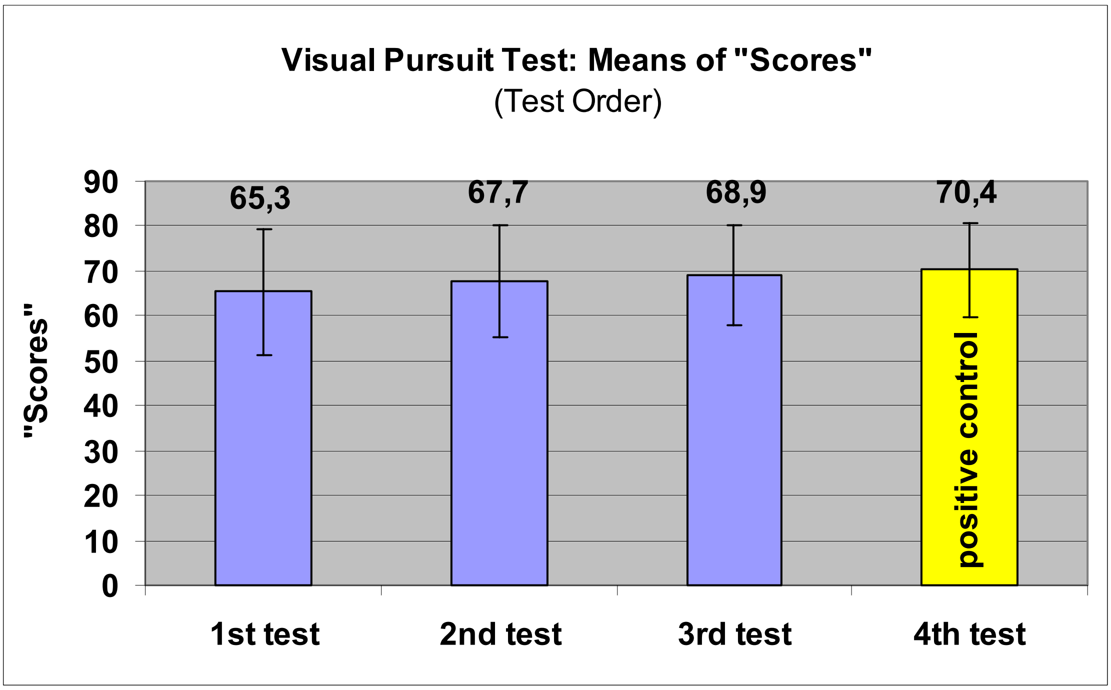


Fig. 20: Tachistoscopic Traffic Test: Mean numbers of correct answers for test order. There were significant differences between the 3 trials, resulting in an increase of correct numbers from the first trial to the last.

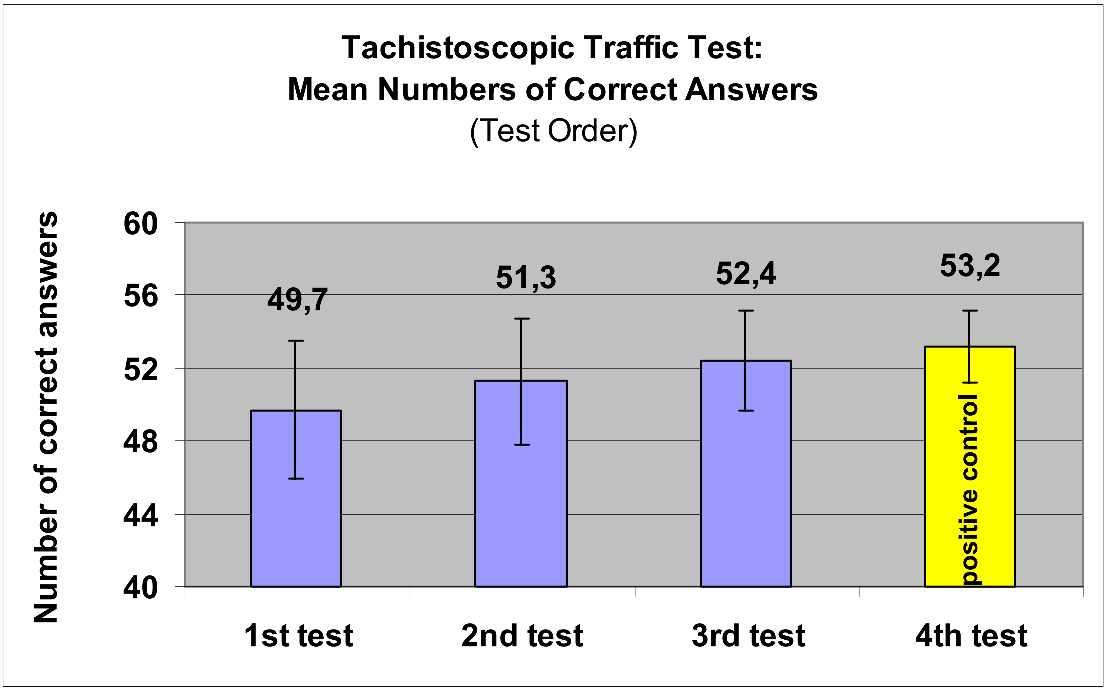
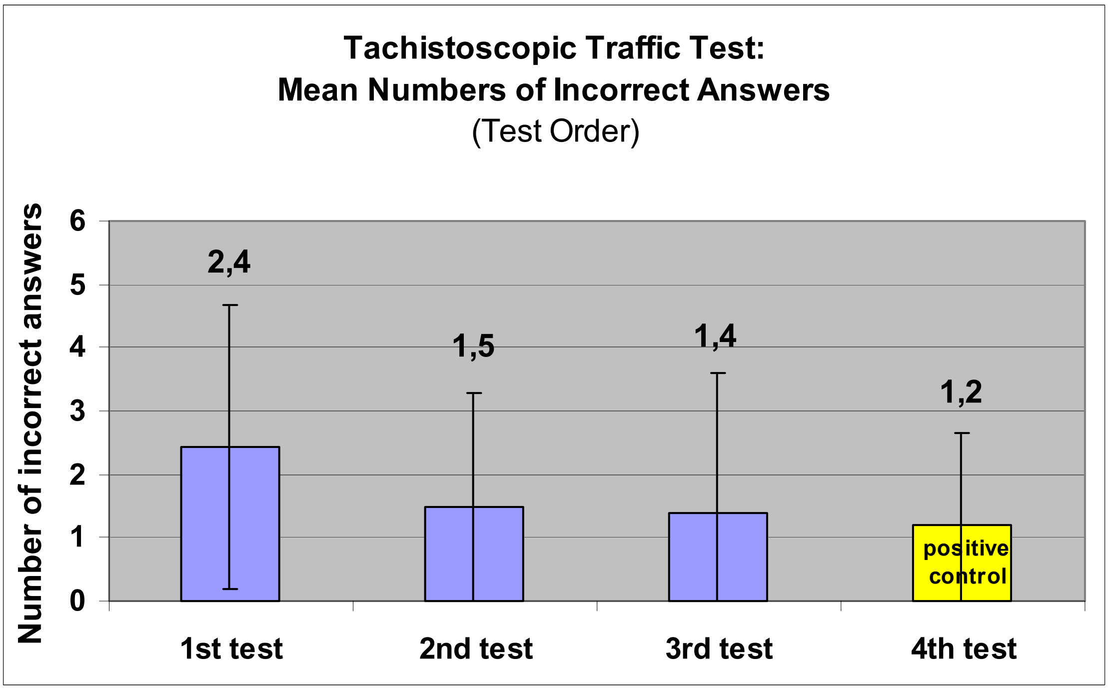


Fig. 21: Tachistoscopic Traffic Test: Mean number of incorrect answers for test order. There was a significant decrease in incorrect answers from the first trial to the last.



4.3 Visual Analogue Scales for Tiredness and Impairment

Subjects rated their subjective feelings of tiredness and impairment due to external factors (EMF, flicker light) on two 100 mm Visual Analogue Scales (VAS). On the VAS of Subjective Impairment high values indicate strong impairment (see Fig. 22) and on the VAS for Tiredness high values stand for increased tiredness (Fig. 23).

Fig. 22: Means of Visual Analogue Scale for Subjective Impairment (mm): Tests (FFF...Fusion & Flicker Frequency, CS...Contrast Sensitivity, VPT...Visual Pursuit Test, TTT...Tachistoscopic Traffic Test) in order of testing from (test trials "1" to "3") and positive control sessions (pos_control) where applicable at the end of the test procedures.

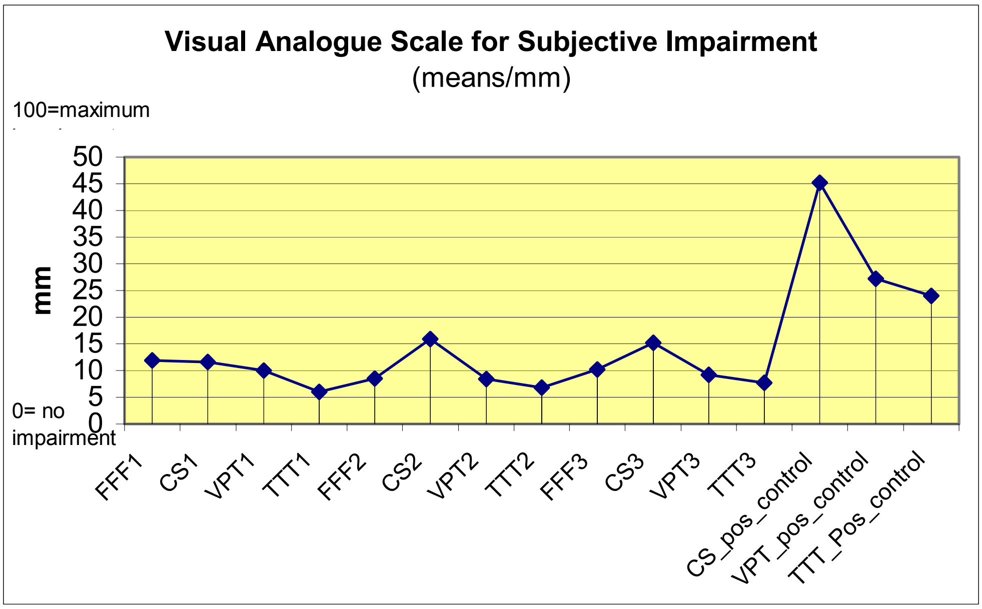
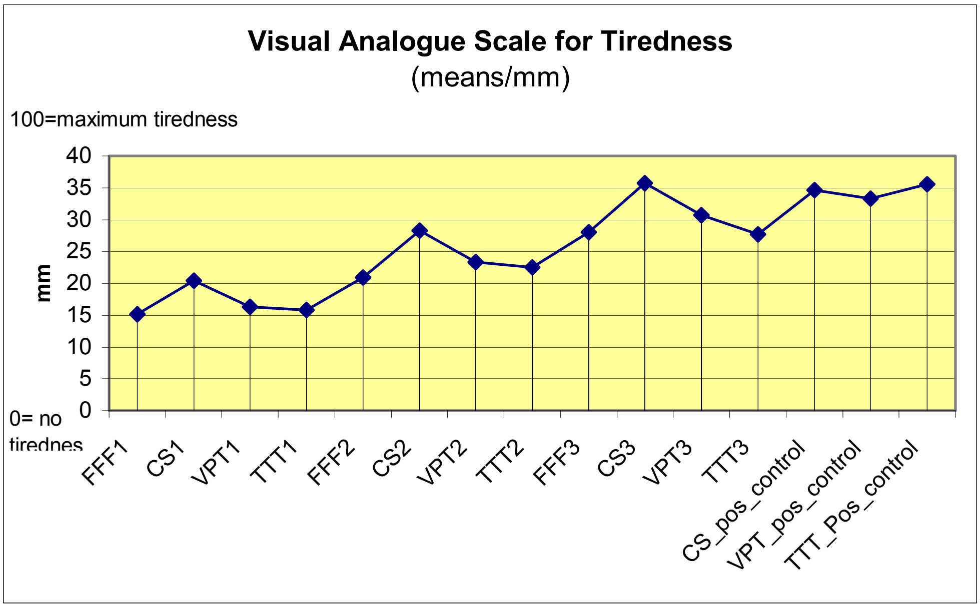


Fig. 23: Means of Visual Analogue Scale for Tiredness (mm): For abbreviations of tests see Fig. 22. High values (maximum 100 mm) indicate intense tiredness.



In general, the measurement of Contrast Sensitivity was judged to be the most strenuous and fatiguing task. Positive Control conditions (last 3 sessions, i.e. the positive control session, see Fig. 23) caused an increase in subjective impairment.

4.4 Subjective estimation of exposure condition

Subjects were asked to specify whether they thought they were exposed or not after each test. If they believed that they were exposed they had to choose whether EMF was applied to the left side, to the right side or to both sides. Subjects were informed that each test was done under 3 conditions (written information on subject consent). Nevertheless, 12 (20.7%; 6 female, 6 male) of 58 subjects stated that they did not believe or feel that they were exposed at any time of testing. A few of the other 46 subjects reported bodily sensations in and round the head and ears, strange noises or sounds or even head pain. Most of the participants obviously just guessed without feeling anything. In 8 out of all 12 tests (i.e. 66.6% per subject) persons were actually exposed, but only 4% of exposure situations were rated correctly from the total group, i.e. left side exposure was stated (see Fig. 24). Subjective ratings of female participants were significantly more often correct than the subjective ratings of men (6% vs. 2%). Taking into account correct subjective ratings in relation to actual exposure, but wrong classification of the side exposed (right, both sides), women and men did not differ from each other (11.5% & vs. 12.1%, see Fig. 24).

In case of de facto sham exposure, subjects rated “no-exposure” in 24% of sessions in contrast to 33.3% actual sham exposure, i.e. in 9.3% of actual sham exposure subjects stated incorrectly that they felt being exposed to EMF (see Fig. 24).

If all correct answers were summarised, i.e. if in case of exposure “left side” and if in case of sham exposure “no exposure” was stated, the percentage of right classifications was 27.8% for the total group. Statements of women were significantly more in accordance with the actual condition (EMF or sham exposure) than those of men (31.9% vs. 23.8%; see right columns Fig. 24).

By division of the group into “subjective exposed”, who stated that they have been exposed at least one time per whole session and a group of 12 “subjective non-exposed”, who quoted “no exposure” in all 12 sessions, the “ subjective non-exposed” group hit significantly ($p=0.012$) more correct answers in total (see Fig. 25).

In detail, in case of actual exposure the “subjective exposed” consequentially showed significantly more correct answers than the “subjective non-exposed” (see Fig. 25), in case of actual sham exposure, "subjective non-exposed" classified significantly more sham exposure conditions correctly.

Fig. 24: Correct Subjective Classification of Total Group, and female and male subjects separately (%). For details please refer to text.

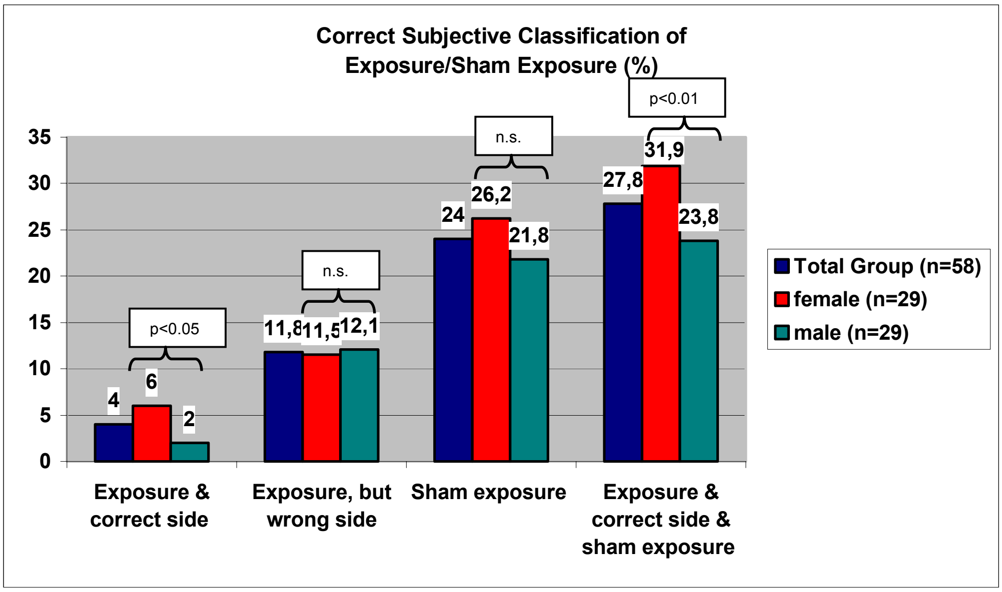


Fig. 25: Correct Subjective Classification of Exposure/Sham Exposure (%) for Total group, "Subjective exposed" and "Subjective Non-exposed". For details please refer to text.

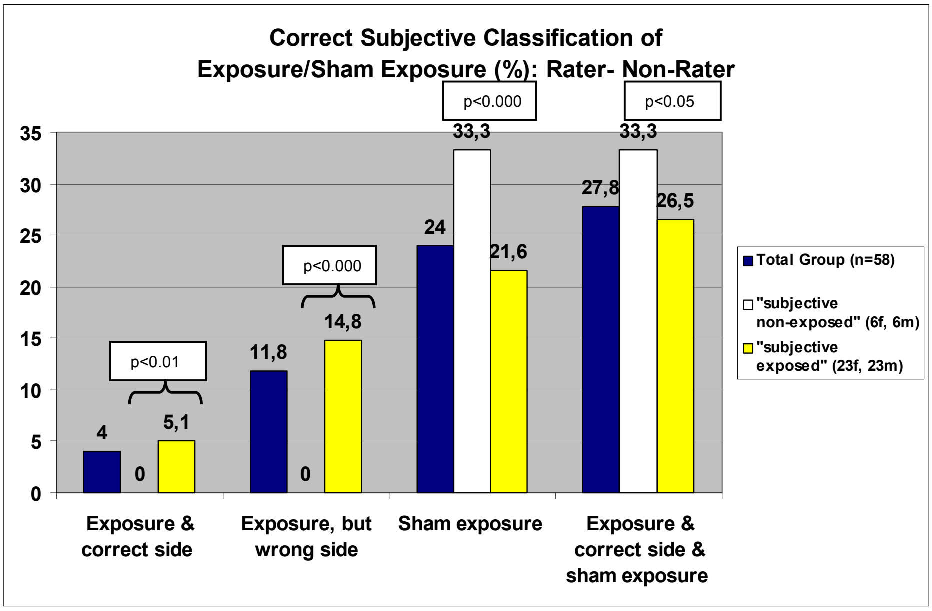


Fig. 26: Subjective estimation of exposure

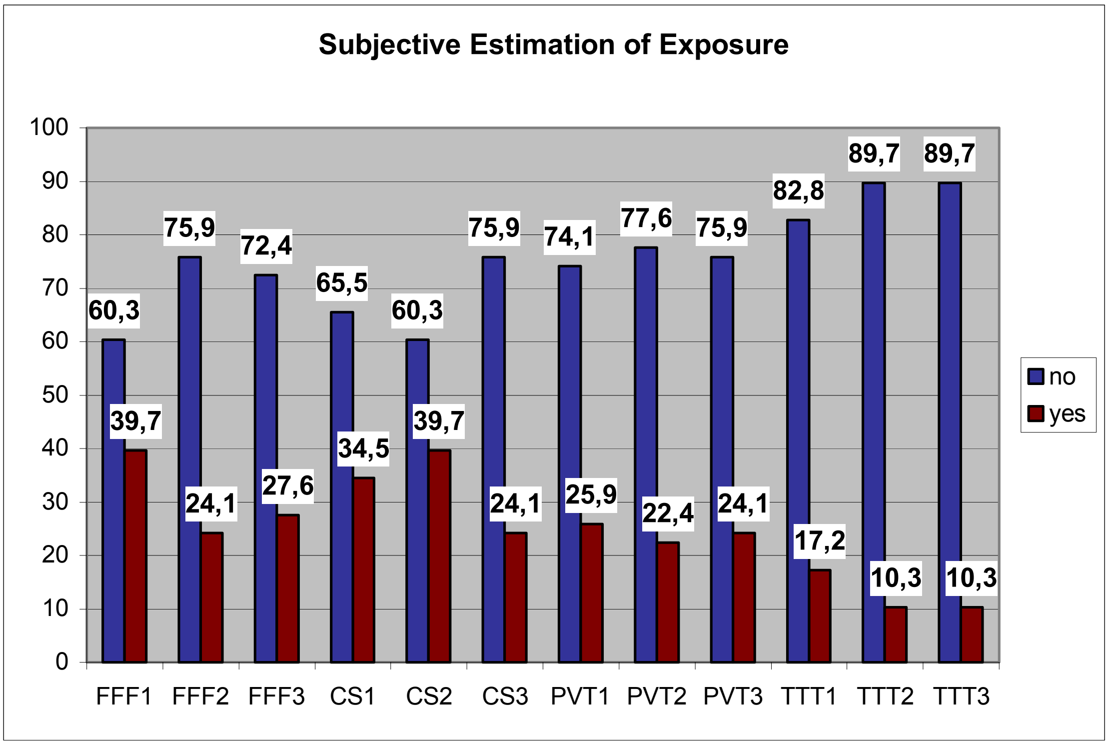


Figure 26 indicates all tests and percentage of subjective ratings of exposure for all subjects, irrespective of correctness of answers. In Test situations where tasks were perceived exhausting (FFF, CS) subjects believed that they were exposed more often than in less exhausting tasks (VPT, TTT), although chance of being exposed was 2:1 for all tests. Table 18 shows the distribution of answers on the question of subjective estimation of exposure in percent for all 58 subjects, and details of assumed side of subjective exposure.

Tab. 18: Answers of Subjective Estimation (%)

exposure	FFF1	FFF2	FFF3	CS1	CS2	CS3	VPT1	VPT2	VPT3	TTT1	TTT2	TTT3
no	60,3	75,9	72,4	65,5	60,3	75,9	74,1	77,6	75,9	82,8	89,7	89,7
left	6,9	6,9	8,6	6,9	8,6	3,4	3,4	5,2	8,6	1,7	3,4	10,3
right	13,8	5,2	6,9	6,9	6,9	3,4	6,9	8,6	6,9	6,9	1,7	0
both	19,0	12,1	12,1	20,7	24,1	17,2	15,5	8,6	8,6	8,6	5,2	0

5. DISCUSSION

The results of this double-blinded study suggest that there are no influences of EMF generated by UMTS at the applied exposure levels on 4 different tests of human visual performance of 10 to 25 minutes duration each. Critical Flicker and Fusion Frequency were not affected. Threshold of Contrast Sensitivity was not influenced, number of correct answers in the Visual Pursuit Test and Tachistoscopic Traffic Test remained constant with or without EMF exposure. The applied EMF did not influence reaction time in the Visual Pursuit Test. This is in contrast to other studies using cell phone signals in the 900 MHz band for exposure, which reported an increase in reaction speed on tests of reaction time and vigilance [14] and of a choice reaction time task [6]. Subjects were not able to detect whether they were exposed to sham or EMF exposure in most of the trials. Detection rate of subjective EMF-exposure was 4% in contrast to an actual exposure time of 66%, i.e. subjects were exposed in 8 of 12 trials, indicating that most of the subjects did not feel any subjective symptoms. For sham exposure, frequency of correctly rated exposure conditions reached 24%. This is in line with a study reported by Koivisto et al., 2001 [21], in which participants did not report any differences in subjective symptoms between a GSM EMF exposure (30-60 min) and a non-exposure trial. In the present study women were somehow more sensitive to EMF exposure than men. They rated the exposure situation more frequently correct than men.

Appraisal of being exposed was more related to tests which were attributed as strenuous, mainly due to monotony (Critical Flicker Fusion Frequency and Contrast Sensitivity tests). Positive Controls by adding flickering light from behind the volunteers at the end of the exposure series revealed comparable values for the sensitivity of tests to external influences, in most cases being clearly stronger than other external effects. Only the performance in the Visual Pursuit Task was not affected by the flickering light, because the background of the monitor in this test was white and therefore the light did only have a very little effect. To our knowledge this is the first study, which implemented a positive control session.

Repetition of tests led to a learning effect only in the Tachistoscopic Traffic Test, resulting in an increase of correct and a decrease in incorrect recognised pictures. The improvement in contrast sensitivity could be the effect of adaptation to light conditions in the exposure cabin.

This is the first study presenting results regarding effects of EMF with generic UMTS signal characteristics on human visual performance. The experiments in double-blinded design did not reveal any effects of EMF on visual performance in a group of 58 healthy regular users of GSM mobile phones.

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