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# Looking for traces of phylogenetic fears: Differences in EEG slow oscillations and complexity between spider- and flight phobic subjects[1]

Xavier Bornas[2] *(Universitat de les Illes Balears, Spain)*, Andreas Mühlberger *(University of Wurzburg, Germany)*, Jordi Llabrés *(Universitat de les Illes Balears, Spain)*, Georg Wiedemann *(University of Frankfurt, Germany),* and Paul Pauli *(University of Wurzburg, Germany)*

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**ABSTRACT.** Phylogenetic fears involve stimuli representing a real or potential threat to the species' evolutionary ancestors. We tested whether individuals with a phylogenetic fear (spider phobics, $n$ = 17) differed in EEG general activity (delta band power) of the oldest brain system and in complexity from individuals with a non-phylogenetic fear (flight phobics, $n$ = 15) during eyes open and eyes closed resting states. Delta band power was higher during the eyes-closed condition at central sites FZ, CZ and PZ as well as at frontal sites FP1, FP2, and F4. No differences existed in the upper bands theta, alpha, and beta. The EEG complexity was significantly lower among individuals with spider phobia. Differences were found under both eyes closed and eyes open conditions at FZ, F4, CZ, and C4. Lower complexity was also found at PZ and O2 during eyes open. In general, the results of this *ex post facto* study lend support to the hypothesized prevalence of slow oscillations in phylogenetic fears. Furthermore

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[2] Correspondence: Departament de Psicologia. Universitat de les Illes Balears. Edifici Guillem Cifre de Colonya. Carretera de Valldemossa km. 7.5, 07122 Palma de Mallorca (España). E-mail: xavier.bornas@gmail.com

these results show that the EEG output of spider phobic participants is less complex than the output from flight phobic participants. The prevalence of slow brain oscillations and the lowered EEG complexity could be interpreted as traces of phylogenetic fears.

**KEY WORDS.** Specific phobia. EEG. Complexity. *Ex post facto* study.

**RESUMEN.** Consideramos que en los miedos filogenéticos los estímulos temidos suponían una amenaza real o potencial para nuestros antepasados. En este estudio comprobamos si los individuos con un miedo filogenético (fobia a las arañas, $n$ = 17) difieren de los individuos con un miedo no filogenético (fobia a volar, $n$ = 15) en actividad general EEG (*power* de la banda delta) del sistema cerebral más antiguo y en complejidad, en condiciones de reposo con ojos abiertos y con ojos cerrados. El *power* de la banda delta fue superior en la condición de ojos cerrados en las localizaciones centrales FZ, CZ y PZ así como en las localizaciones frontales FP1, FP2 y F4. No se encontraron diferencias en las bandas superiores theta, alpha y beta. La complejidad del EEG fue significativamente inferior en los individuos con fobia a las arañas. Se encontraron diferencias tanto con ojos cerrados como con ojos abiertos en FZ, F4, CZ y C4. También se halló menor complejidad en PZ y O2 con los ojos abiertos. En general, los resultados de este estudio *ex post facto* apoyan la hipótesis de la prevalencia de las ondas lentas en los miedos filogenéticos. Además, los resultados muestran que la señal EEG de los participantes con fobia a las arañas es menos compleja que la de los participantes con fobia a volar. La prevalencia de las ondas cerebrales lentas y la menor complejidad del EEG se podrían interpretar como indicadores de miedos filogenéticos.

**PALABRAS CLAVE.** Fobia específica. EEG. Complejidad. Estudio *ex post facto*.

Differences between phylogenetic and ontogenetic fears have received increasing attention in the last years. Following Seligman's preparedness hypothesis, Mühlberger, Wiedemann, Herrmann, and Pauli (2006) carried out a covariation bias study. They compared 17 spider and 17 flight phobics in responses to fear-relevant (FR) stimuli (pictures of spiders or flight accidents) or fear irrelevant control pictures (mushrooms) randomly followed by either a startling noise or nothing. While both groups showed a disorder specific expectancy bias, only spider phobics exhibited a disorder specific covariation bias. Spider phobics also showed enhanced skin conductance response (SCR), event-related potentials (ERP) and startle responses in association with disorder specific FR pictures while flight phobics showed only disorder specific enhanced SCRs. In sum, the direct comparison between ontogenetic and phylogenetic phobias revealed that the former is characterized by biased and enhanced responses associated with disorder specific FR stimuli presumably based on a biological preparedness.

On the other hand, following the theoretical developments of MacLean (1985), Knyazev and Slobodskaya (2003) proposed an evolutionary-based interpretation of brain oscillations and suggested that delta, theta, and alpha oscillations reflect activities of three hierarchical phylogenetic brain systems. Briefly, delta oscillations would be linked with the most ancient system, including the brainstem among other structures,

which deals with biologically important goals (*e.g.*, physical maintenance). Theta waves are linked with the «second» brain, which involves mainly the limbic system. According to Knyazev, Savostyanov, and Levin (2004, p. 148) «theta system is linked with more flexible behavior regulation, which implies the matching of internal drives with acquired during lifetime experience». Finally, alpha oscillations are interpreted as manifestations of activities of the newest brain system (the neocortex), and the alpha system is engaged in perception and recognition of environmental patterns. In this line of reasoning, Knyazev *et al.* (2004) suggest that «the relative prevalence of some oscillations over others relate to stable behavioral patterns relevant to personality and psychopathology» (p. 148).

Accordingly, it could be speculated that phobias are related to a general hyperactivity of one of these specific brain systems. Furthermore, fears related to phylogenetic relevant stimuli may be related to a prevalence of the slow oscillations (especially delta and perhaps theta oscillations) in the brains' bioelectrical activity. Contrary, people suffering from only ontogenetic fear (ontogenetic relevant stimuli) may not show these enhanced slow wave amplitudes. Within a different theoretical context some evidence of such prevalence has been reported for panic disorder (Knott, Bakish, Lusk, Barkley, and Perugini, 1996) although in this study not only delta and theta but also the alpha power was higher in patients than in healthy control subjects. Further, differences between panic disorder and specific phobias are obvious despite they share the label of anxiety disorders.

Besides the spectral or power analysis of the Electroencephalograph (EEG), the seemingly chaotic fluctuations of the brain activity can be analyzed from a nonlinear perspective assuming the brain is a dynamical system. Instead of dividing the Electroencephalogram (EEG) signal into several frequency bands, some nonlinear techniques allow for the study of the original, non-divided signal. What we are looking for in this EEG signals is the complexity.

According to Freeman (2003) «... it appears that the brain maintains a state of self-organized criticality as the basis for its capacity for rapid adjustment to environmental challenges» (p. 1067). Self-organized criticality (Bak, Tang, and Wiesenfeld, 1987) implies phase transitions occurring everywhere in cortex at many different spatial and temporal scales. As phase transitions occur under complex, chaotic-like regimes, the permanent state of the brain system resembles a very chaotic one and it is characterized by a high level of complexity - what Freeman (2000) called «stochastic chaos». There are several complexity measures but the ones that work with low dimensional systems (*e.g.*, the correlation dimension) do not seem to be appropriate for the study of very complex, high dimensional systems like the brain (Freeman, 2000; Kantz and Schreiber, 1997), even though some authors have used them (*e.g.*, Aftanas *et al.,* 1997, 1998; Aftanas, Lotova, Koshkarov, and Popov, 1998, or more recently Chae *et al.,* 2004). One better way to estimate complexity is to calculate the entropy (*i.e*. the rate of generation of new information) in the system's output, in this case the EEG time series. Though some measures are not well suited either to the analysis of biological systems, Richman and Moorman (2000), based on previous developments made by Pincus (1995), introduced the Sample Entropy (SampEn) as a more appropriate measure for the study of biological

systems' complexity. SampEn (*m,r,N*) measures the logarithmic likelihood that runs of patterns that are close (within *r*) for *m* contiguous observations (*i.e. m* values along the time series of length *N*) remain close (within the same tolerance width *r*) on the next incremental comparison. SampEn is the negative natural logarithm of the conditional probability that two sequences similar for *m* points remain similar at the next point.

Going back to the differences between phylo- and ontogenetic fears, if there is a prevalence of slow oscillations in the former ones, and if this slow activity is linked with ancient brain structures (what Mülhberger *et al.* (2006) call the fear network), then low complexity could be expected in the EEG of spider phobics as compared with the complexity one could expect from the flight phobics. As we mentioned earlier, the delta system (the slowest one) deals with biological goals such as physical maintenance. Environmental demands challenging our physical status exist but they change slowly, and therefore adapting to these demands does not require much flexibility (complexity or entropy). On the other hand, the alpha system is engaged in sensory stimuli recognition and processing, and these tasks require rapid adjustments and therefore a fairly flexible background dynamics.

In a recent study on Alzheimer disease (AD), Abásolo, Hornero, Espino, Alvarrez, and Poza (2006) reported that AD patients had significantly lower SampEn values than control subjects at several electrodes. To us this finding fits in the Knyazev *et al.* (2004) evolutionary framework as an AD deteriorated brain would be, somehow, a more primitive (*i.e*. less evolved) brain. Also, there are several studies reporting decreased entropy in the EEG during anesthesia (Bruhn, Ropcke, and Hoeft, 2000), when the brain is working at very low load just to regulate the biological needs - a function mainly due to the ancient brain in MacLean's (1985) theory.

In summary, recent findings reported by Mühlberger *et al.* (2006), along with the theoretical developments by Knyazev and colleagues in the linear, spectral analysis tradition lead us to predict that delta power at rest should be higher in spider phobics than in flight phobics. In addition, taking the nonlinear perspective of Freeman (2000, 2003), which regards background brain activity as stochastic chaos needed for adaptation to environmental demands, together with the Knyazev and Slobodskaya's (2003) evolutionary based interpretation of that activity, we expected lower complexity in the EEG of spider phobics.

A last question has to do with the scalp locations where the above differences were expected to be found. Mühlberger *et al.* (2006, p. 587) reported that «Spider stimuli triggered in spider-phobic participants an enhanced ERP activity widely distributed across frontal and central brain areas, while airplane pictures elicited in flight-phobic participants enhanced ERP activity at one parietal location only. This topographical difference may indicate that the processing of phylogenetic relevant stimuli recruits widespread and/or deep neuronal networks, and especially the amygdala fear network with its strong associations to the frontal cortex may be involved. Unfortunately, ERP data do not allow clear topographic conclusions, and further research is needed to identify the involved neuronal sources.» Based on these considerations increased delta power and decreased complexity in spider phobics should not be restricted to any specific location. On the other hand, since slow oscillations have larger amplitudes and

more regular waveforms in frontal and central areas -*i.e*. FZ, CZ, PZ or association areas according to Basar, Schürmann, and Sakowitz (2001, p. 209)-, the larger differences between spider and flight phobics in these measures were expected in central areas. Furthermore, as pointed out by Basar (2004) «neuroscientists have come to the general conclusion that large numbers of brain regions have to cooperate for any brain function» (p. 365), and therefore, even at rest, the predicted differences were not expected at only one restricted location (*e.g.*, P3 or F4). The concept of selectively distributed oscillatory systems in the brain (Basar *et al.,* 2001) and the idea of macroscopic brain dynamics itself (Basar, 2004) suggests that differences would likely be found at several locations.

## Method

*Participants*

Participants were paid volunteers recruited through local newspaper articles informing about a research project on spider and flight phobia. The study included a picture presentation paradigm which is published elsewhere (Mühlberger *et al.,* 2006) as well as a spontaneous EEG measurement which is presented here. At the time of recruitment participants completed eight questions that were constructed according to the DSM-IV (American Psychiatric Association, 1994) criteria of specific phobia, the Fear of Flying Scale (FFS, Haug *et al.,* 1987), and the Spider Questionnaire (SPQ, Klorman, Weerts, Hastings, Melamed, and Lang, 1974). Exclusion criteria were fulfilling diagnostic criteria of both spider and flight phobia or showing enhanced questionnaire responses in the FFS and the SPQ (both scores in the upper 25 % quartile, for reference data see Johnsen and Hugdahl, 1990), taking drugs at presence, and taking part in psychotherapy at presence. 17 flight phobics (3 men, 14 women; age: $M$ = 44.20 years, $SD$ = 9.60 years) and 17 spider phobics (1 man, 16 women; age: $M$ = 27.40 years, $SD$ = 9.30) completed the study. All participants except two spider phobics were right-handed. There were no differences between groups in state or trait anxiety (Spielberger, Gorsuch, and Lushene, 1970; German version by Laux, Glanzmann, Schaffner, and Spielberger, 1981) or any index of the Symptom Check List (SCL90-R; Franke, 1995) (all $p > .20$). Two participants of the flight phobia group had to be excluded from the EEG analyses because they reported having had a brain surgery more than ten years earlier. Each participant received 4 euros per hour for participating in the study.

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*Procedure*

After obtaining informed consent for a picture presentation study including fear relevant pictures (see Mühlberger et al., 2006) participants of this *ex post facto* study (Montero and León, 2007) were seated in a comfortable chair in a sound-attenuated room next to the experimenter's room. Then, physiological sensors were attached. After a relaxation phase of one minute the spontaneous EEG was continuously recorded while participants were asked to further relax with their eyes alternatively open (two periods)

or closed (two periods) for a duration of 60 seconds each. The order of the eyes-open and eyes-closed condition was balanced over participants. All sessions started between 10 a.m. and 5 p.m. Most of the measures were taken in the afternoon.

*EEG recording and data reduction*

EEG was recorded continuously with a sampling rate of 200Hz with Ag/AgCl-electrodes from 13 sites according to the 10-20 system (frontal: FP1, FP2, F3, FZ, F4; central: C3, CZ, C4; parietal: P3, PZ, P4; and occipital: O1, O2) and the right mastoid (A2), all referenced to the left mastoid (A1). FCZ was used as ground. Electrooculographic artifacts were monitored with electrodes at supra- and infraorbital sites of the right eye for vertical eye movements and at outer canthi of both eyes for horizontal eye movements (both bipolar). EEG data were recorded with a Synamps amplifier set at 10 K gain in DC mode using the software Scan 4.1 (Neuroscan Inc.) with a low pass filter of 40 Hz.

Signals were analyzed offline with the BrainVision Analyser Software of BrainProducts Inc. First, data were re-referenced to linked mastoids. Then, ocular artifacts were corrected according to the algorithm of Gratton and Coles (see Gratton, 1998) with raw average subtraction for both horizontal and vertical EOG artifacts.

In order to calculate the amount of power in each band, we applied the integral squared amplitude in frequency domain between band limits (delta, 1-4 Hz; theta, 4-8 Hz; alpha-1, 8-10 Hz; alpha-2, 10-13 Hz; beta-1, 13-20 Hz; beta-2, 20-30 Hz; beta-3, 30-40 Hz). The calculation of the frequency domain was performed with the FFT routine of MATLAB Version 7 (R14) applied to a one minute of trend removed EEG signal.

Before conducting the Sample Entropy analysis, the EEGs were nonlinearly filtered with the ghkss program of the TISEAN software package (Hegger, Kantz, and Schreiber, 1999). This program performs a noise reduction as proposed in Grassberger and Hegger (1993). We set embedding dimension $m = 5$, number of iterations $i = 3$ and delay for the embedding $d = 1$. The length of each time series was 12000 points (1 min), $r$ was set to 20% of the standard deviation and m was set to 2.

The average values of the two open eyes periods and the average of the two closed eyes periods on the spectral and SampEn measures were used in all the following statistical analyses.

*Statistical data analysis*

Spectral power and entropy were analyzed with mixed ANOVAs with the between subject factor group (flight vs. spider phobia) and the within subject factors *eyes* (closed *vs.* opened) and *localization* (FP1, FP2, F3, FZ, F4, C3, CZ, C4, P3, PZ, P4, O1, O2). Measures with highly skewed distributions (*i.e.* spectral power measures) were ln transformed before conducting statistical analysis. Data analyses were performed with SPSS Version 11.0. If necessary, Greenhouse-Geisser epsilon were reported to correct for violation of the sphericity assumption.

## Results

*Spectral analysis*

The ANOVAs only revealed marginally significant group effects in delta band, $F_{(1, 30)} = 3.92$, $p = .057$, $\eta_P^2 = .115$. On the other frequency bands spider- and flight-phobic participants did not differ. The overall analysis in delta band also revealed significant localization, $F_{(12, 360)} = 40.69$ , $p < .001$, $= .576$, $\varepsilon = .355$, and eyes by localization, $F_{(12, 360)} = 14.76$, $p < .001$, $\eta_P^2 = .330$, $\varepsilon = .287$, effects. Table 1 shows contrasts within eyes and localization factors. All differences between groups (at FP1, FP2, FZ, F4, CZ, and PZ) were found only in the eyes closed condition except at C4, where differences were only significant when subjects had their eyes open. The largest between-groups difference was found at CZ.

**TABLE 1.** Delta band power contrasts between groups in open- and closed eyes conditions at each localization.

| | | *Spider-phobic (n=17)* | | *Flight-phobic (n =15)* | | | | |
|---|---|---|---|---|---|---|---|---|
| Loc | Eyes | *M* | *SD* | *M* | *SD* | *F* | *p* | $\eta_P^2$ |
| FP1 | close | 6.19 | .81 | 5.65 | .62 | 4.29 | .047 | .09 |
| | open | 6.98 | .99 | 6.49 | .88 | 2.14 | .154 | .06 |
| FP2 | close | 6.09 | .76 | 5.56 | .66 | 4.37 | .045 | .11 |
| | open | 6.73 | .66 | 6.24 | .83 | 3.37 | .076 | .09 |
| F3 | close | 5.80 | .71 | 5.46 | .68 | 1.96 | .170 | .06 |
| | open | 5.96 | .64 | 5.70 | .75 | 1.12 | .298 | .04 |
| FZ | close | 6.03 | .87 | 5.45 | .45 | 5.39 | .027 | .15 |
| | open | 5.99 | .58 | 5.84 | .95 | .311 | .581 | .01 |
| F4 | close | 5.81 | .73 | 5.26 | .47 | 6.28 | .018 | .14 |
| | open | 5.92 | .72 | 5.53 | .58 | 2.78 | .106 | .07 |
| C3 | close | 5.41 | .75 | 5.02 | .58 | 2.66 | .114 | .08 |
| | open | 5.43 | .78 | 5.12 | .64 | 1.56 | .221 | .05 |
| CZ | close | 6.85 | .47 | 6.43 | .37 | 7.72 | .009 | .19 |
| | open | 6.83 | .41 | 6.65 | .61 | .99 | .327 | .04 |
| C4 | close | 5.20 | .78 | 4.73 | .53 | 3.70 | .064 | .09 |
| | open | 5.30 | .76 | 4.81 | .52 | 4.28 | .047 | .09 |
| P3 | close | 5.92 | .82 | 5.51 | .79 | 2.04 | .163 | .10 |
| | open | 5.69 | .57 | 5.42 | .82 | 1.16 | .290 | .06 |
| PZ | close | 5.95 | .81 | 5.45 | .47 | 4.49 | .042 | .17 |
| | open | 5.80 | .57 | 5.44 | .51 | 3.51 | .071 | .14 |
| P4 | close | 5.83 | .81 | 5.50 | .99 | 1.06 | .311 | .06 |
| | open | 5.59 | .56 | 5.60 | 1.33 | .001 | .975 | .00 |
| O1 | close | 6.11 | 1.26 | 5.46 | .55 | 3.41 | .075 | .11 |
| | open | 5.97 | .95 | 5.60 | .62 | 1.61 | .214 | .05 |
| O2 | close | 5.96 | 1.09 | 5.35 | .59 | 3.71 | .064 | .14 |
| | open | 5.83 | .73 | 5.46 | .68 | 2.10 | .158 | .08 |

*Entropy analysis*

The overall ANOVA returned significant group, $F_{(1, 30)} = 6.37$, $p < .05$, $\eta_P^2 = .175$, eyes, $F_{(1, 30)} = 23.17$, $p < .001$, $\eta_P^2 = .436$, localization, $F_{(12, 360)} = 11.17$, $p < .001$, $\eta_P^2 = .271$, $\varepsilon = .223$, and eyes by localization, $F_{(12, 360)} = 6.79$, $p < .001$, $\eta_P^2 = .185$, $\varepsilon = .250$, effects (see Table 2). Between-groups differences were found at C4, CZ, FZ, and F4 under both eyes closed and open conditions, and O2 and PZ only when participants had their eyes open. All these differences were rather large (all $p$ values < .05). No differences were found at any of the left-sided localizations though values in Table 2 show the same pattern at those sites, so that mean entropy values of spider phobics were lower everywhere.

**TABLE 2.** Entropy (SampEn) contrasts between groups in open- and closed eyes conditions at each localization.

| | | *Spider-phobic (n = 17)* | | *Flight-phobic (n = 15)* | | | | |
|---|---|---|---|---|---|---|---|---|
| Loc | Eyes | *M* | *SD* | *M* | *SD* | *F* | *p* | $\eta_P^2$ |
| FP1 | close | 1.12 | .18 | 1.21 | .23 | 1.57 | .221 | .05 |
| | open | 1.11 | .23 | 1.22 | .18 | 1.99 | .17 | .06 |
| FP2 | close | 1.13 | .21 | 1.19 | .25 | .59 | .45 | .02 |
| | open | 1.15 | .23 | 1.26 | .19 | 2.16 | .15 | .07 |
| F3 | close | 1.03 | .11 | 1.11 | .20 | 2.07 | .16 | .07 |
| | open | 1.10 | .13 | 1.20 | .14 | 3.70 | .06 | .11 |
| FZ | close | .93 | .12 | 1.05 | .15 | 6.96 | .01 | .19 |
| | open | .97 | .09 | 1.07 | .15 | 5.86 | .02 | .16 |
| F4 | close | 1.04 | .13 | 1.18 | .18 | 6.37 | .02 | .18 |
| | open | 1.14 | .16 | 1.27 | .10 | 7.31 | .01 | .20 |
| C3 | close | .97 | .11 | 1.08 | .17 | 3.91 | .06 | .12 |
| | open | 1.04 | .13 | 1.13 | .12 | 4.14 | .05 | .12 |
| CZ | close | .92 | .10 | 1.03 | .12 | 7.88 | .01 | .21 |
| | open | .96 | .10 | 1.06 | .12 | 7.81 | .01 | .21 |
| C4 | close | .98 | .11 | 1.12 | .20 | 6.64 | .02 | .18 |
| | open | 1.05 | .13 | 1.17 | .12 | 7.20 | .01 | .19 |
| P3 | close | .87 | .14 | .97 | .23 | 2.07 | .16 | .07 |
| | open | 1.00 | .16 | 1.10 | .18 | 2.78 | .11 | .09 |
| PZ | close | .85 | .16 | .97 | .22 | 3.19 | .08 | .10 |
| | open | .96 | .14 | 1.10 | .15 | 6.76 | .01 | .18 |
| P4 | close | .87 | .17 | .96 | .25 | 1.39 | .25 | .04 |
| | open | 1 | .18 | 1.09 | .24 | 1.50 | .23 | .05 |
| O1 | close | .93 | .29 | 1.03 | .29 | 1.01 | .32 | .03 |
| | open | 1.05 | .31 | 1.20 | .20 | 2.29 | .14 | .07 |
| O2 | close | .94 | .31 | 1.10 | .30 | 2.26 | .14 | .07 |
| | open | 1.05 | .32 | 1.26 | .22 | 5.01 | .03 | .14 |

## Discussion

In this study we compared the power of brain slow oscillations and the EEG complexity of a group of spider phobics and a group of flight phobics during eyes open and eyes closed resting states before an experiment that included fear relevant pictures. Spider phobia represents a phylogenetic fear and we assumed that people who have such a fear might have a generally enhanced activity of phylogenetic older brain systems in contrast to people who have an ontogenetic fear (flying phobia). The age difference between our spider- and flight-phobic samples reflects these groups' age difference in the general population. Although this difference could affect results, it is well known that flight phobia appears much later than spider and animal phobias in general (Fredrikson, Annas, Fischer, and Wik, 1996; Öst, 1987) In a sociodemographic study with 419 fear of flying patients, Van Gerwen (2003) reports a mean age of 40.90 years ($SD$ = 10.40) which is very close to the mean age of the study's flight phobic sample. Therefore, trying to control for age would be a serious error: as pointed out by Miller and Chapman (2001) «age would be systematically related to the defining characteristic of the groups, so removing variance associated with age would, in effect, corrupt the grouping variable itself» (p. 44). In other words, even if we could get two age-matched samples of spider- and flight phobic subjects, a bigger problem would come up since these samples would not represent the general populations of spider- and flight phobic people.

As regards to the slow oscillatory brain activity our hypothesis was that it would prevail in spider phobics. The overall ANOVA revealed a marginally significant group effect ($p$ = .057), and differences were found in delta (1-4Hz) band power in several scalp localizations, mainly in the middle (CZ and PZ) cortical areas where these slow waves show larger amplitude (Basar *et al*., 2001), and also in frontal areas (FP1, FP2, and F4). All but one of such differences appears only when subjects close their eyes.

As we mentioned in the introduction, Knyazev *et al*. (2004) suggested that «the relative prevalence of some oscillations over others relate to stable behavioral patterns relevant to personality and psychopathology» (p.148). In agreement with this rationale, the prevalence of slow oscillations could be related to a specific form of psychopathology, namely phylogenetic specific phobia. On the other hand, our results might reveal the EEG traces of phylogenetic fears representing a real or potential threat to the species' evolutionary ancestors and for which the human beings would be biologically prepared (Seligman, 1971). Spider phobic participants should show a general higher activity of the oldest brain system, which may have made them vulnerable to develop their phylogenetic relevant fear.

The analysis of spectral power in the theta (4-8Hz) band did not reveal any significant difference between both groups. If the Theta system is related with the limbic system activity, and the limbic system has deep emotional responsibilities, then differences could be expected in the theta band also. The non-significant trend in our results was that spider phobic participants had more theta power, and perhaps a study with larger samples would find statistically significant differences. Further, the limits of each band are somewhat arbitrary. Thus, some studies defined the theta band as 3.5-7 Hz (Basar,

2004), so that differences could appear when using lower band limits. More interesting, however, is the fact that the ANOVAs performed in upper bands ( > 8Hz) did not reveal any difference between spider and flight phobic subjects. Therefore the results of the study did not show a generalized power increase but a specific higher power in the slowest EEG oscillations of spider phobic subjects. This specificity gives stronger support to the above mentioned idea that slow oscillations could be related to phylogenetic specific phobia.

The observed differences are small, but it should be noticed that we are comparing two very close anxiety disorders, in fact two specific phobias. They share many clinical and pathophysiological characteristics, and therefore any significant difference, even the smallest one, has to be acknowledged could be surprising to some extent. EEG differences between persons with anxiety disorder and healthy individuals have been observed previously -*e.g*. Knott *et al*. (1996) compared EEG spectral measures in panic disorder patients and healthy controls-, but it is far more unusual to report resting EEG differences between two subgroups of participants belonging to the same diagnostic category.

Taking a dynamical systems perspective, the second hypothesis of this study was that the EEG of spider phobics would be less complex than the bioelectrical brain activity of flight phobics. Complexity allows for the most efficient adaptation of any system to the ever-changing environmental demands it has to cope with. The oldest brain - according to MacLean's (1985) triune brain theory - is in charge of satisfying environmental demands that do not change quickly, so that it needs less complexity than the newest brain, which copes with perceptual demands. Efficient and fast adaptation to the incoming physical and social demands requires more complexity. Therefore, if there is some prevalence of the activity of the oldest brain in spider phobics then we should find their EEG time series to be less complex than the EEG signals from flight phobics. The results of this study lend partial support to this hypothesis as significantly lower complexity was found in the right central cortical areas (CZ, C4, FZ, F4) of the spider phobics' brains. All these differences were seen either when subjects had their eyes open or closed.

Finally, if we compare the two EEG measures used in the study, the entropy seems to be better than the spectral measure. First, between-groups differences are larger on entropy than on delta band power. Second, SampEn is calculated on the original EEG signal, there is no need (unlike power measurement) to divide the EEG time series (the signal) into bands which limits can be somewhat arbitrary. Third, according to our results the entropy measure allows to distinguish spider- and flight phobics either when they have their eyes open or closed. On the contrary, the spectral delta band power measure only distinguishes both groups under the eyes closed condition.

One limitation of the current study is the small sample size, that may have limited the power of the study. Furthermore, although the age difference between our spider and flight phobic samples reflects these groups' age difference in the general population, this difference may have affected results. One more limitation of this study comes from the complex nature of flight phobia. It is well known that patients can suffer one or more specific phobias (heights, dying and so on), and some of them are phylogenetic. Therefore, groups in future studies should be even more different from each other than in the present one. A third limitation that should be addressed in future research is the lack of control groups. Although the purpose of this study was to examine whether there are any differences between the two kinds of phobia, it would be interesting to know also if non-phobic people show different delta power and/or entropy at rest - *e.g.* Sachs *et al*. (2004) found frontotemporally decreased delta and theta band power in social phobics when compared to non-phobic controls, both in a vigilance condition and at rest.

In sum, our study revealed differences in resting EEG between phylogenetic and ontogenetic relevant phobics that point toward a higher activation of more ancient brain systems in phylogenetic relevant phobias compared to ontogenetic relevant phobias. This result is in line with the prediction deducted from the theory of Knyazev and Slobodskaya (2003) and the results of Mühlberger *et al.* (2006) who found stronger physiological activation in spider phobics compared to flight phobics towards fear relevant stimuli in the same sample. However, further research is needed to systematically replicate these results using larger samples and extend these results to other phylogenetic (*e.g.*, snakes) and ontogenetic phobias as well as to show differences between phobias and other anxiety disorders (*e.g.*, panic disorder).

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