

6 Correlation of Biometric Variables Measured with Biograph Infinity Biofeedback Device and Psychometric Scores of Burnout and Anxiety

6.1 Background

The Procomp Infinity encoder and Biograph Infinity program allows the recording, analysis and playback of various physical variables, with the aim of teaching a subject self-regulation of normally subconscious processes. As discussed before, these variables are indices of autonomic nervous system (ANS) balance and affective state, and their levels are in theory reflections of the levels of stress experience by the individual.

Whether the information obtained by biofeedback apparatus, a system primarily intended for training of these subconscious variables, are indeed good enough for the estimation of stress levels needs to be evaluated.

In previous chapters the heart rate variability (HRV) values obtained by biofeedback was firstly compared to that obtained by an instrument specifically intended for the assessment of HRV, i.e. the Actiheart system. Secondly, in a study examining autonomic nervous system function relative to the degree of anxiety and burnout the outcome was compare between that where biofeedback was used for the assessment of ANS function to those where Actiheart was used.

In the present chapter the biometric data was correlated to scores on the Maslach Burnout Inventory – General Survey (MBI – GS) and the State-Trait Anxiety Inventory (STAI – Y) in an attempt to assess the validity of the markers measured with the biofeedback apparatus. Although it is recognised that anxiety and burnout do not represent gold standards for stress, their levels are closely linked to stress levels.

The parameters tested included:

- HRV with an Electrocardiogram (ECG)
- HRV with a Blood-volume-pulse sensor (BVP)
- BVP amplitude
- Pulse transit time
- Muscle tension

- Fingertip temperature
- Respiration rate and amplitude
- Skin conductivity
- Quantitative Electroencephalography (QEEG)

6.2 Materials and Methods

Clearance for the study was obtained from the Ethics Committee of the Faculty of Health Sciences (reference number S56/2010), University of Pretoria and all subjects signed informed consent documents.

6.2.1 Study Subjects

Twenty-one individuals took part in the study. There were nine women and twelve men, with a mean age of 30.8 (SD=13.4) years and a mean body mass index (BMI) of 26.5 (SD=7.4) kg.m⁻². The exclusion criteria were a history of convulsive disorders, noradrenergic stimulants, anti-depressants, beta-blockers or any medication that could influence ANS functioning. The demographic information for the study subjects are summarized in Table 6.2.

Each subject completed an MBI-GS and a STAI-Y psychometric questionnaire. Both of the questionnaires are discussed in detail in Chapter 5. For the MBI, the mean Exhaustion subscale frequency was 2.7 (SD=1.2), the mean Cynicism subscale frequency was 1.9 (SD=1.1) and the mean Professional efficacy subscale frequency was 4.6 (SD=0.8). Each subject's score was ranked as high, moderate or low according to the guidelines in the MBI manual (1) (See Table 6.3).

For the STAI, the raw score is given a percentile rank according to age and sex normalized data in the STAI manual (2) (See Table 6.4). The mean state anxiety (Y1) percentile rank score was 48 (SD=22.7) and the mean trait anxiety (Y2) percentile rank score was 77.8 (SD=15.4). It is worth noting that the state anxiety was average, but the mean trait anxiety for the group was quite high.

6.2.2 Equipment and Channel sets

As before, the biofeedback equipment used was the Thought Technology Procomp Infinity encoder unit (Thought Technology, Montreal West, Quebec, Canada), with the following sensors and electrodes:

- For Quantitative electro-encephalography (QEEG), two EEG-Z sensors, 2 DIN cable extender kits with connectivity cables, gold-plated cup electrodes and gold-plated ear clip electrodes. The two cortical sites used were F3 and F4 of the international 10/20 system.
- For electromyography (EMG), a pro/flex EMG sensor with a disposable triode sticker was placed on the body of the left trapezius muscle
- For electrocardiography (ECG), a pro/flex ECG sensor with extender cables and disposable paediatric Ag/AgCl multi-purpose ECG electrodes was used. The active and ground leads were placed on the left forearm and the reference lead on the right forearm
- For the electrodermal response, a skin conductivity (SC) sensor was strapped to the middle phalanx of the index and little fingers of the left hand
- For blood-volume pulse (BVP), a pro/flex BVP sensor, also called a photoplethysmography (PPG) sensor was held to the palmar surface of the tip of the right index finger with an elastic band
- a fingertip temperature sensor was strapped to the palmar surface of the tip of the right ring finger
- a respiration sensor with an elastic band was placed around the thorax

The Biograph Infinity version 5 biofeedback software was used to run the measurement sessions, and the Developer Tools were used to create custom channel sets, screens and scripts, as described in Chapter 2, 3 and 4. The recording sessions were structured in the same way as described in Chapter 4 and 5, with four steps (Baseline 1, Baseline 2, Challenge and Recovery).

The heart rate variability (HRV) variables were calculated in the same way as described in Chapter 4 and 5. The additional variables used in this chapter were:

- The amplitude of the BVP signal
- The pulse transit time (time delay between the QRS complex of the ECG and the arrival of the pulse of blood at the fingertip, where it is registered by the BVP sensor)
- The muscle tension in the left trapezius muscle
- The skin conductivity
- The fingertip temperature
- The respiration rate and depth
- EEG activity from the left and right frontal lobes (F3 & F4)

Similar to Chapter 3, the EEG activity was processed with a fast Fourier transformation, after which the % of total power of each frequency band was calculated. The frequency bands with their upper and lower limits are listed in Table 6.1.

The peak frequency in the Alpha band (8 to 12 Hz) and whole EEG band (0.5 to 42 Hz) was determined for the left and right hemispheres, as well as three ratios: Alpha/Theta, Alpha/Beta1 and Theta/Beta1.

The inter-hemisphere comparisons were done as amplitude asymmetry, coherence and phase. Amplitude asymmetry refers to the difference in power between two cortical sites of a frequency band. Coherence is an indication of the similarity of the frequency at two cortical sites. Phase is a measure of the time delay between the activities at two cortical sites with regard to a frequency band (3,4).

The help file accompanying the Biograph Infinity Developer Tools recommended using the frequency bands Delta, Theta, Alpha and Beta for the inter-hemisphere calculations, not smaller sub-frequencies like high or low Alpha.

Table 6.1 The EEG frequency bands with upper and lower cut-off values

EEG Frequency Band	
Delta	0.5 – 4 Hz
Theta	4 – 8 Hz
Low Alpha	8 – 10 Hz
High Alpha	10 – 12 Hz
Whole Alpha	8 – 12 Hz
SMR	12 – 15 Hz
Beta 1	15 – 18 Hz
Beta 2	18 – 22 Hz
High Beta (2 – 5)	18 – 38 Hz
Gamma	38 – 42 Hz

EEG – Electroencephalography, Hz – Hertz (cycles per second), SMR – Sensorimotor Rhythm

6.2.3 Statistics

In this chapter, the mean, standard deviation and coefficient of variation was calculated for each variable of interest, for each of the four steps. It was decided to use both the standard deviation and the coefficient of variation (which is the SD divided by the mean to adjust for scale) as indicators of variability, because both had correlations with the psychometric data but neither had a clear superiority over the other with regards to the correlations. For the same reason, the Response was calculated in two different ways:

1. The difference between Baseline 2 and Challenge (Ch-B2)
2. The relative difference between Baseline 2 and Challenge $((Ch-B2)/B2)*100$

The biometric variables and psychometric item scores were compared with the STATISTICA program (5), using Spearman ranked correlations. As in Chapter 5, the raw scores as well as the percentile rank scores for the STAI Y was used.

6.3 Results

Table 6.2 Demographics of the study subjects.

Study Number	Age (yrs)	Sex	Height (m)	Weight (kg)	BMI (kg.m ⁻²)	Smoker # p/d	Chronic Conditions	Medication
A20	35	F	1.68	71	25.20	0	None	None
A32	25	F	1.75	75	24.49	0	None	None
B04	28	F	1.59	45	17.80	Y	None	None
B09	29	M	1.77	98	31.28	20	None	None
C03	29	F	1.72	54	18.25	20	Hypotension	None
C30	26	F	1.70	56	19.40	20	None	None
D28	27	F	1.55	68	28.30	25	None	Warfarin
F26	21	M	1.74	74	24.44	10	None	None
G33	29	M	1.88	85	24.05	0	None	None
J14	74	M	1.90	60	16.60	0	None	None
K24	26	M	1.80	120	37.00	0	Hypertension	None
L01	25	F	1.80	140	43.20	0	Hypertension	None
L02	26	M	1.70	87	30.10	10	None	None
L29	26	M	1.85	80	23.38	20	None	None
L05	26	M	1.63	70	26.35	14	None	None
N11	23	F	1.76	90	29.06	8	Hypertension	None
P34	27	M	1.78	53	16.73	0	None	None
P06	27	M	1.81	134	40.90	20	None	None
S19	66	F	1.65	84	30.85	0	None	Eltroxin (Thyroxine), Femigel (Estradiol)
S25	24	M	1.74	79	26.09	6	None	None
S31	27	M	1.80	74	22.80	20	None	None

Table 6.3 The results of the MBI-GS questionnaire. For each subscale, the raw score and subscale frequency is given, as well as the score rank. From (1)

Study Number	MBI EX			MBI CY			MBI PE		
	Raw	(Fr)	Rank	Raw	(Fr)	Rank	Raw	(Fr)	Rank
A20	10	2.0	Mod	8	1.8	Mod	23	3.8	Low
A32	23	4.6	High	11	2.2	Mod	34	5.7	High
B04	10	2.0	Mod	8	1.6	Mod	30	5.0	High
B09	15	3.0	Mod	3	0.6	Low	23	3.8	Low
C03	10	2.0	Mod	9	1.8	Mod	25	4.2	Mod
C30	20	4.0	High	6	1.2	Mod	35	5.8	High
D28	20	4.0	High	22	4.4	High	31	5.2	High
F26	14	2.8	Mod	5	1.0	Low	34	5.7	High
G33	8	1.6	Mod	9	1.8	Mod	25	4.2	Mod
J14	3	0.6	Low	7	1.4	Mod	31	5.2	High
K24	20	4.0	High	14	2.8	High	29	4.8	Mod
L01	5	1.0	Low	1	0.2	Low	30	5.0	High
L02	14	2.8	Mod	9	1.8	Mod	27	4.5	High
L29	19	3.8	High	20	4.0	High	30	5.0	High
L05	17	3.4	High	13	2.6	High	17	2.8	Low
N11	21	4.2	High	8	1.8	Mod	25	4.2	Mod
P34	11	2.2	Mod	6	1.2	Mod	27	4.5	High
P06	7	1.4	Low	5	1.0	Low	32	5.3	High
S19	6	1.2	Low	9	1.8	Mod	25	4.2	Mod
S25	14	2.8	Mod	19	3.8	High	24	4.0	Mod
S31	18	3.6	High	8	1.8	Mod	23	3.8	Low

MBI – Maslach burnout inventory, GS – General survey, EX – Exhaustion subscale, CY – Cynicism subscale, PE – Professional efficacy subscale, Fr – Subscale frequency, Mod - Moderate

Table 6.4 The results of the STAI Y questionnaire. (For each subscale, the raw score and percentile rank of the score is given. The percentile rank is corrected for age and sex. From (2)

Study Number	STAI - Y1		STAI - Y2	
	Raw	(Pr)	Raw	(Pr)
A20	41	73	42	76
A32	29	34	53	93
B04	32	44	42	76
B09	36	55	48	88
C03	27	21	51	93
C30	31	41	47	89
D28	37	62	42	76
F26	30	31	45	83
G33	47	85	37	63
J14	37	66	39	74
K24	41	70	53	95
L01	45	81	45	86
L02	30	31	34	52
L29	28	25	40	71
L05	52	92	52	94
N11	30	40	52	93
P34	26	16	32	43
P06	31	36	36	59
S19	30	47	42	92
S25	32	39	35	57
S31	27	19	44	81

STAI – State-trait anxiety inventory, Y1 – Sheet Y1 or state anxiety, Y2 – Sheet Y2 or trait anxiety, (Pr) – Percentile rank

The Spearman ranked correlations between the psychometric scores and the physiological variables are found in Table 6.5 to Table 6.39. Only the correlations that are significant ($p < 0.05$) and approaching significant ($0.05 < p < 0.1$) are shown. Scatterplots of some of the significant results were made to illustrate the direction of the response to the challenge. The figures were created with STATISTICA (5), and the label on the Y – axis refers to the step during which the correlation was observed (Baseline 1, Baseline 2, Challenge or Recovery). For the responses, either Delta 2 (The absolute response, namely Challenge-Baseline2) or Delta2% (the relative response, namely Challenge-Baseline2/Baseline2) were used as labels. Please note that no ‘2’ is used when reference is made to the Delta EEG frequency band.

6.3.1 Blood-Volume-Pulse Amplitude

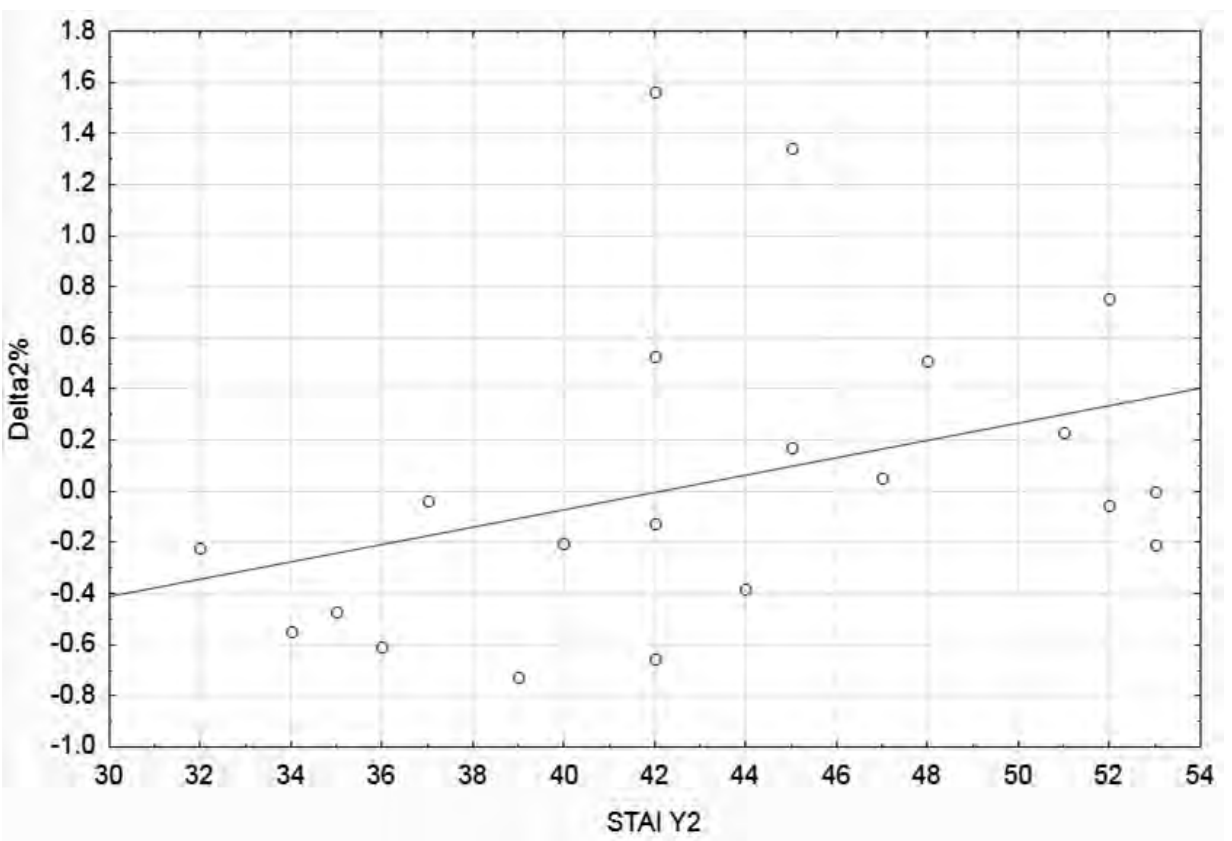
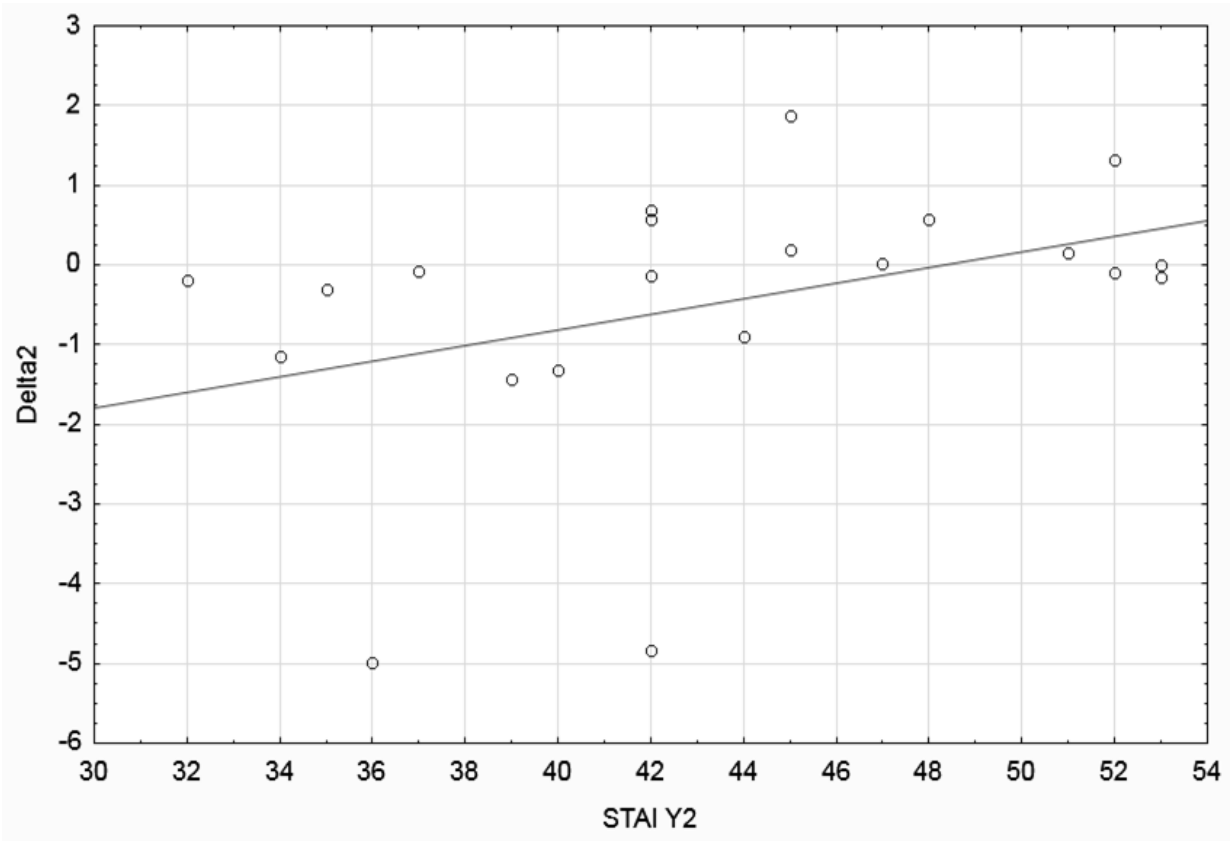
Table 6.5 Spearman ranked correlations between the Blood-Volume-Pulse Amplitude variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
BVP Amplitude CoefVar	Challenge	MBI Cy	-0.4946	0.0226
BVP Amplitude CoefVar	Baseline1	MBI Pe	0.4387	0.0466
BVP Amplitude CoefVar	Baseline2	MBI Pe	0.3728	0.096
BVP Amplitude Mean	Baseline1	MBI Pe	-0.4145	0.0617
BVP Amplitude CoefVar	Recovery	STAI Y1	-0.387	0.0831
BVP Amplitude CoefVar	Baseline2	STAI Y1 Pr	-0.3973	0.0745
BVP Amplitude CoefVar	Recovery	STAI Y1 Pr	-0.4982	0.0215
BVP Amplitude CoefVar	(Ch-B2)/B2	STAI Y2	0.5295	0.0136
BVP Amplitude CoefVar	Ch-B2	STAI Y2	0.5647	0.0076
BVP Amplitude StdDev	(Ch-B2)/B2	STAI Y2	0.5197	0.0157
BVP Amplitude StdDev	Ch-B2	STAI Y2	0.5302	0.0134
BVP Amplitude CoefVar	(Ch-B2)/B2	STAI Y2 Pr	0.4518	0.0398
BVP Amplitude CoefVar	Ch-B2	STAI Y2 Pr	0.5026	0.0202
BVP Amplitude StdDev	(Ch-B2)/B2	STAI Y2 Pr	0.4844	0.0261
BVP Amplitude StdDev	Ch-B2	STAI Y2 Pr	0.4974	0.0218

BVP – Blood – volume – pulse, Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response



BVP Amplitude Standard deviation



BVP Amplitude Standard deviation

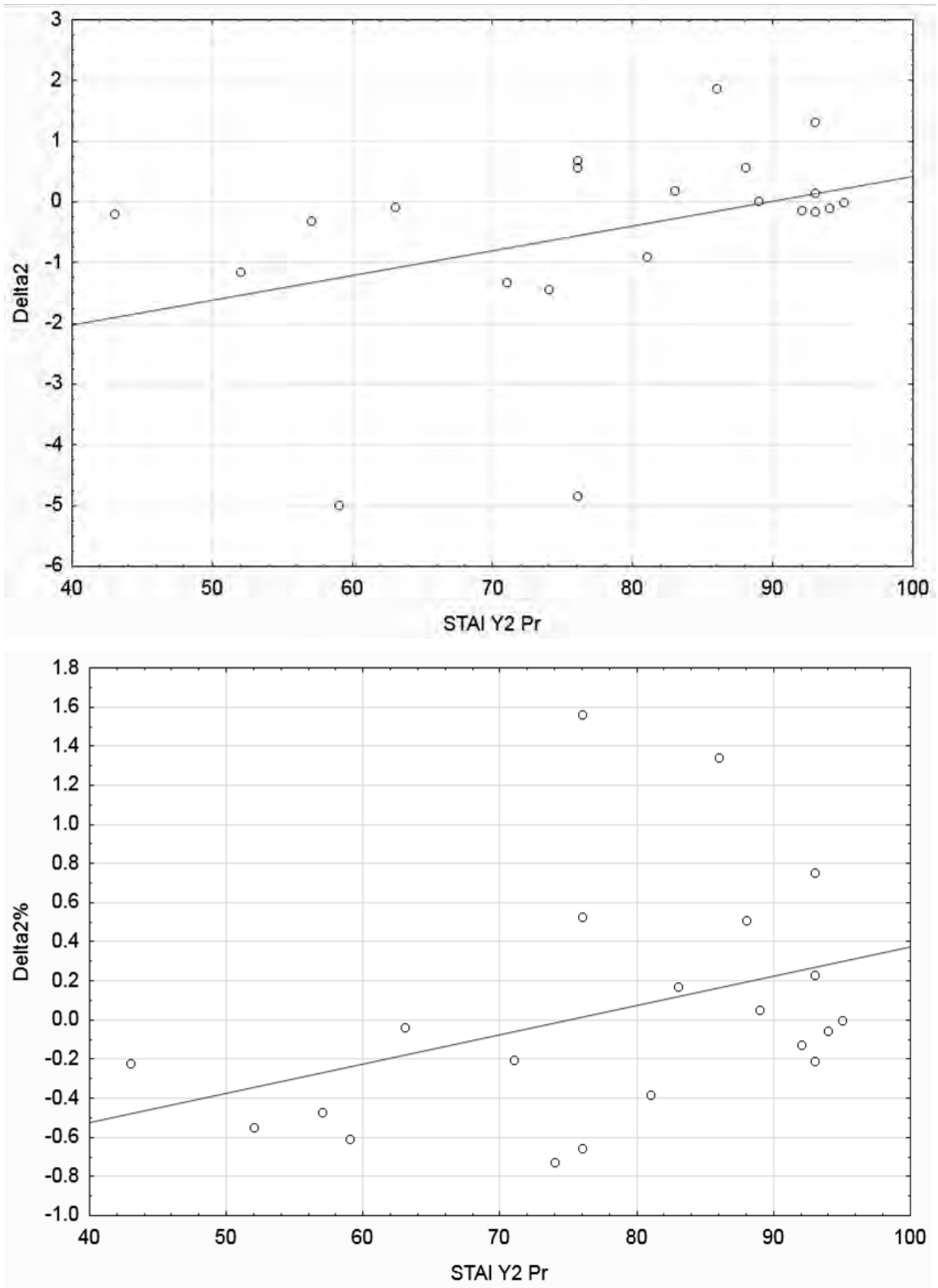
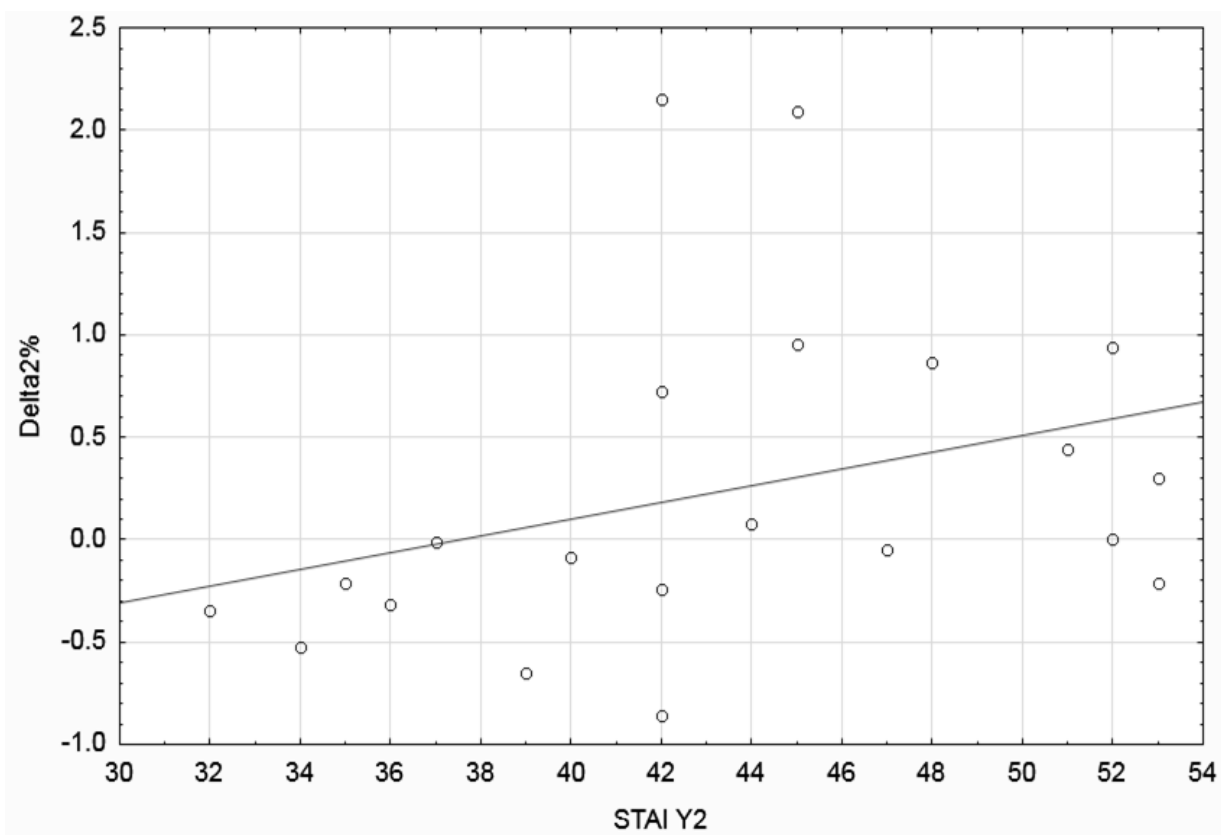
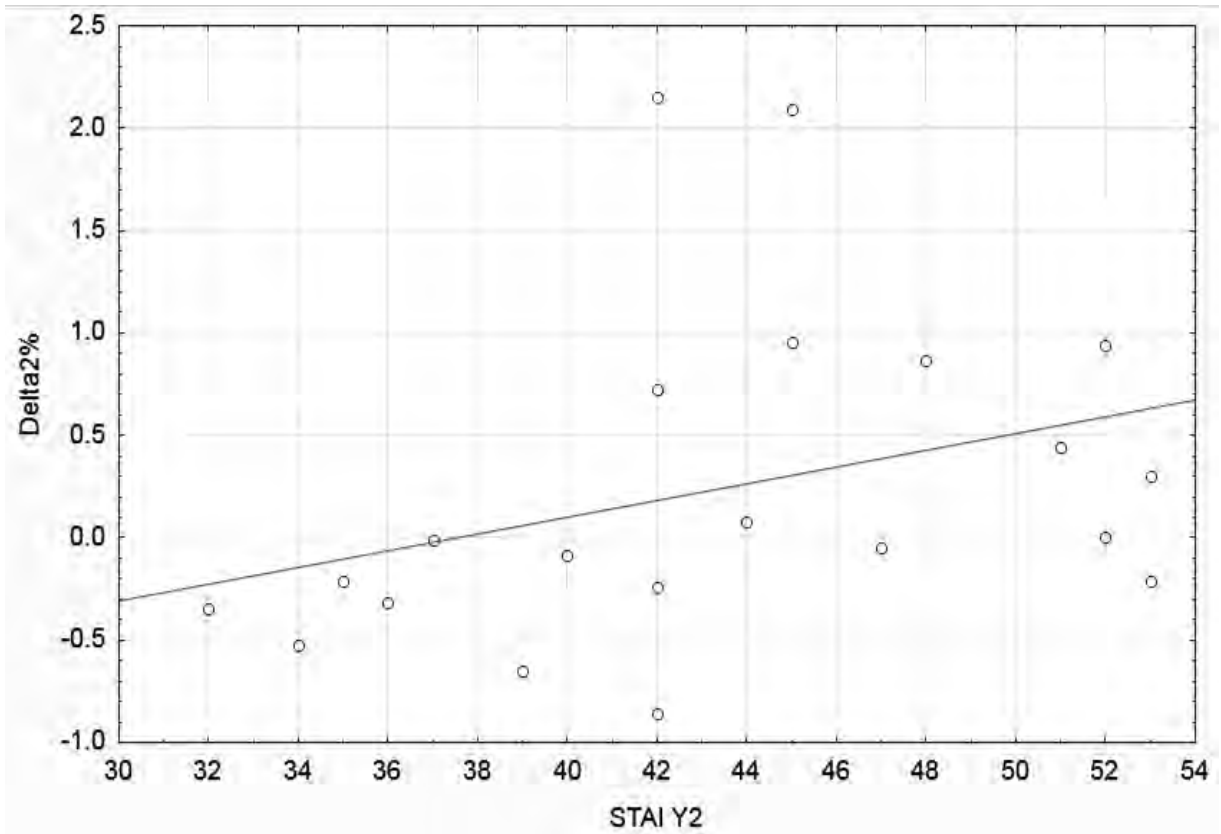


Figure 6.1 Scatterplots of BVP Amplitude Standard Deviation response and State Anxiety scores.

BVP Amplitude Coefficient of Variation



BVP Amplitude Coefficient of Variation

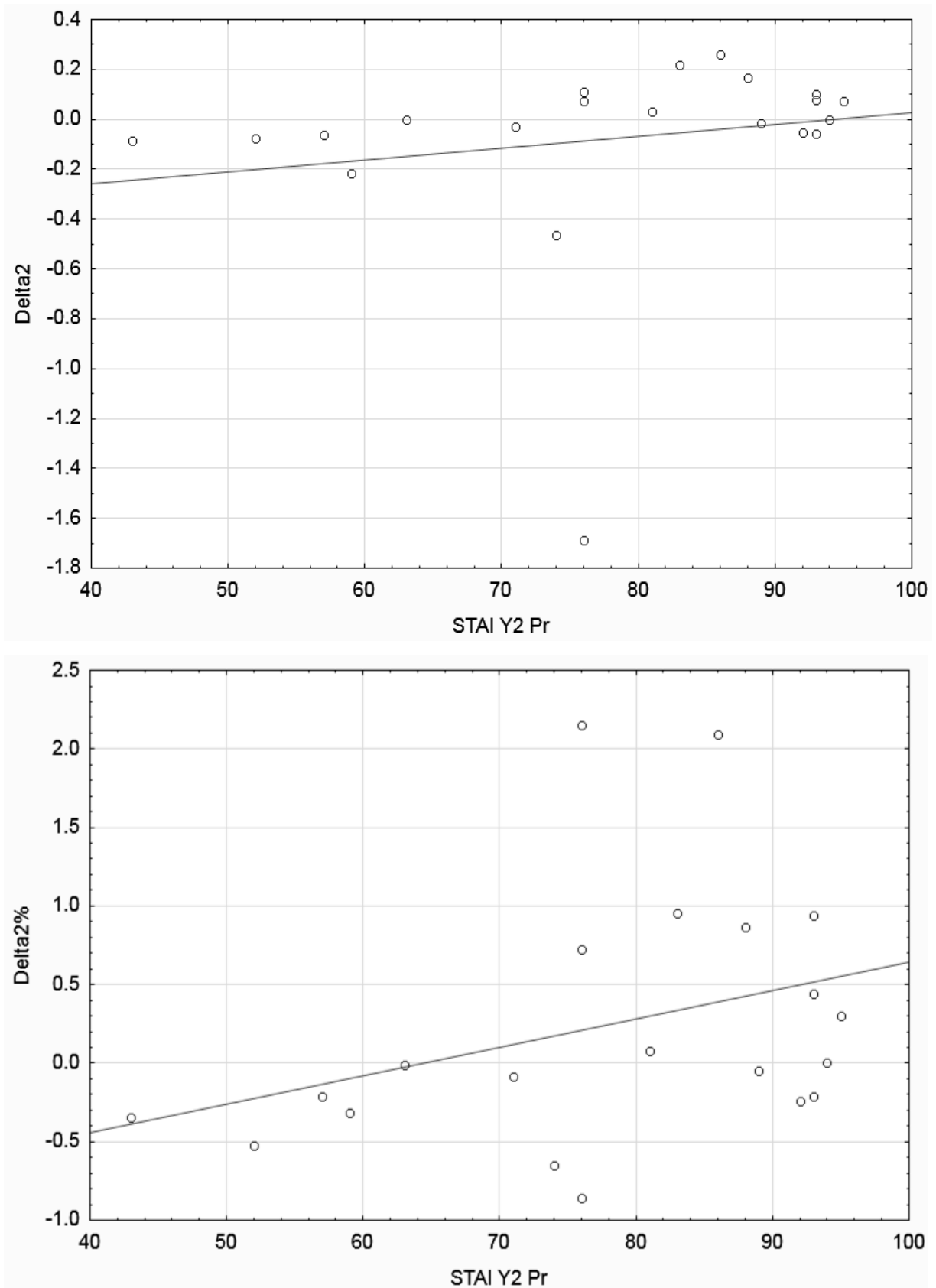


Figure 6.2 Scatterplots of BVP Amplitude Coefficient of Variability responses and Trait Anxiety scores.

6.3.2 BVP Time-Domain HRV

Table 6.6 Spearman ranked correlations between the BVP HRV time domain variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
BVP pNN50	Ch-B2	MBI Ex	0.3695	0.0993
BVP Heart Rate Mean	Baseline1	MBI Pe	0.4348	0.0489
BVP Heart Rate Mean	Baseline2	MBI Pe	0.4224	0.0565
BVP Heart Rate Mean	Challenge	MBI Pe	0.4217	0.0569
BVP Heart Rate Mean	Recovery	MBI Pe	0.4256	0.0544
BVP Heart Rate CoefVar	Recovery	STAI Y1 Pr	-0.4607	0.0356
BVP Heart Rate StdDev	Baseline2	STAI Y1 Pr	-0.4001	0.0723
BVP Heart Rate StdDev	Recovery	STAI Y1 Pr	-0.4924	0.0234
BVP Heart Rate CoefVar	(Ch-B2)/B2	STAI Y2	0.3821	0.0874
BVP Heart Rate CoefVar	Ch-B2	STAI Y2	0.4054	0.0683
BVP Heart Rate StdDev	Ch-B2	STAI Y2	0.4024	0.0706
BVP NN50	Baseline2	STAI Y2 Pr	-0.4033	0.0699
BVP NN50	Challenge	STAI Y2 Pr	-0.4227	0.0563
BVP NN50	Recovery	STAI Y2 Pr	-0.3948	0.0765
BVP pNN50	Baseline2	STAI Y2 Pr	-0.4109	0.0642
BVP pNN50	Recovery	STAI Y2 Pr	-0.3895	0.081

BVP – Blood – volume – pulse, Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response, NN50 – Normal-to-normal intervals lasting longer than 50 ms, pNN50 – Percentage of normal-to-normal intervals lasting longer than 50 ms.

6.3.3 BVP Frequency-Domain HRV

Table 6.7 Spearman ranked correlations between the BVP HRV frequency domain variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
BVP HF%Power Mean	Baseline2	MBI Cy	-0.4513	0.04
BVP HF%PowerCoefVar	Ch-B2	MBI Ex	0.4876	0.0249
BVP HF%PowerCoefVar	(Ch-B2)/B2	MBI Ex	0.4733	0.0302
BVP HF%PowerCoefVar	Baseline2	MBI Ex	-0.4025	0.0705
BVP HF%Power StdDev	(Ch-B2)/B2	MBI Ex	0.4628	0.0346
BVP HF%Power StdDev	Ch-B2	MBI Ex	0.4316	0.0508
BVP HF%Power StdDev	Baseline2	MBI Ex	-0.4289	0.0523
BVP HF%Power StdDev	Recovery	MBI Ex	0.3833	0.0863
BVP LF%PowerCoefVar	Baseline2	MBI Ex	-0.5197	0.0157
BVP LF%PowerCoefVar	Ch-B2	MBI Ex	0.4147	0.0616
BVP LF%PowerCoefVar	(Ch-B2)/B2	MBI Ex	0.4107	0.0644
BVP LF%Power StdDev	Baseline2	MBI Ex	-0.5189	0.0159
BVP LF%Power StdDev	Ch-B2	MBI Ex	0.395	0.0763
BVP LF/HF CoefVar	Baseline2	MBI Ex	-0.4146	0.0617
BVP LF/HF CoefVar	Ch-B2	MBI Ex	0.3911	0.0796
BVP HF%Power Mean	Recovery	MBI Pe	0.4511	0.0401
BVP LF%Power Mean	Recovery	MBI Pe	-0.4099	0.0649
BVP LF%Power StdDev	Recovery	MBI Pe	-0.4995	0.0211
BVP LF/HF Mean	Recovery	MBI Pe	-0.4274	0.0533
BVP LF/HF StdDev	Recovery	MBI Pe	-0.4413	0.0452
BVP HF%PowerCoefVar	Challenge	STAI Y1 Pr	-0.4378	0.0472
BVP HF%Power Mean	Challenge	STAI Y1 Pr	-0.4209	0.0574
BVP HF%Power StdDev	Challenge	STAI Y1 Pr	-0.4235	0.0557
BVP LF/HF Mean	Challenge	STAI Y1 Pr	0.3741	0.0947
BVP HF%PowerCoefVar	Ch-B2	STAI Y2	0.418	0.0593
BVP HF%PowerCoefVar	(Ch-B2)/B2	STAI Y2	0.3978	0.0741
BVP HF%Power StdDev	Baseline2	STAI Y2	-0.3691	0.0996
BVP LF%PowerCoefVar	Baseline2	STAI Y2	-0.4009	0.0717
BVP LF%Power StdDev	Baseline2	STAI Y2	-0.4089	0.0657
BVP HF%Power Mean	Ch-B2	STAI Y2 Pr	-0.3789	0.0903

BVP – Blood – volume – pulse, Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response, HF% - High frequency power, LF% - Low frequency power, LF/HF – Ratio between high and low frequency power.

BVP HF% Standard Deviation

BVP HF% Standard Deviation

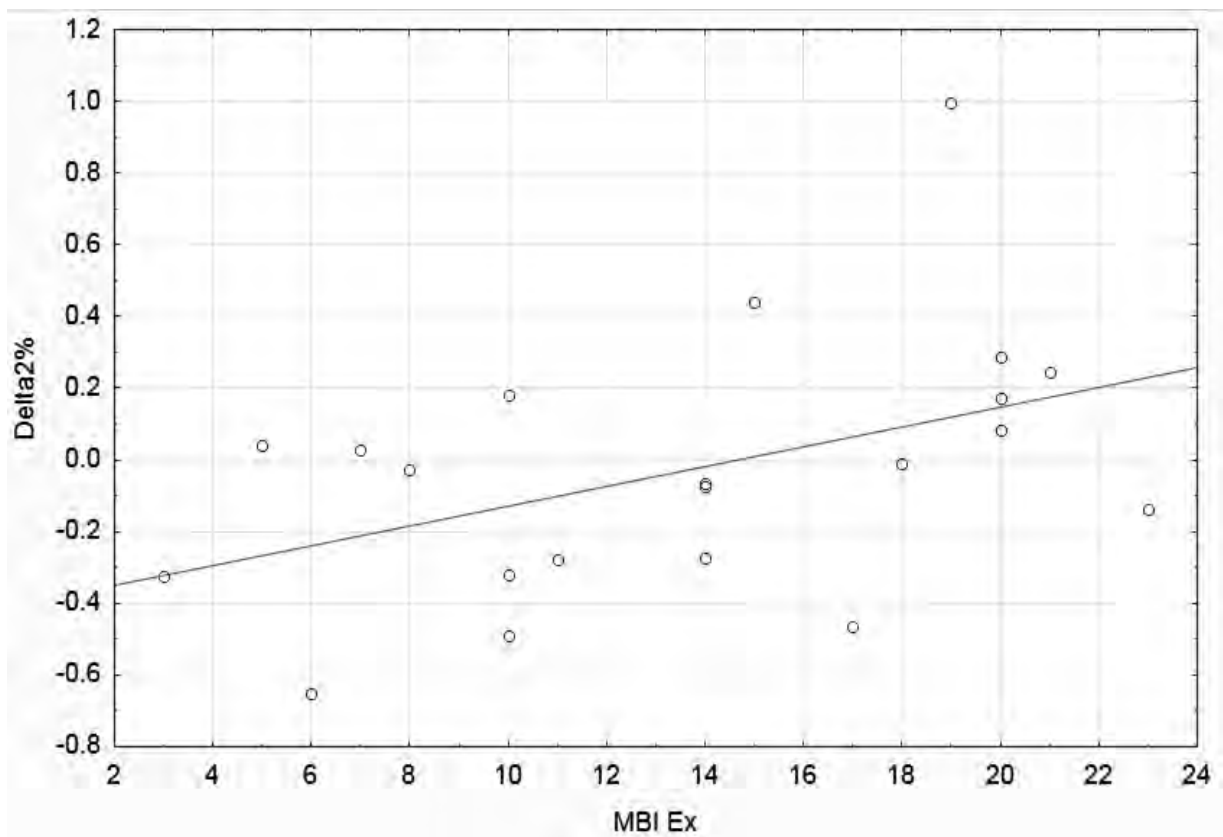
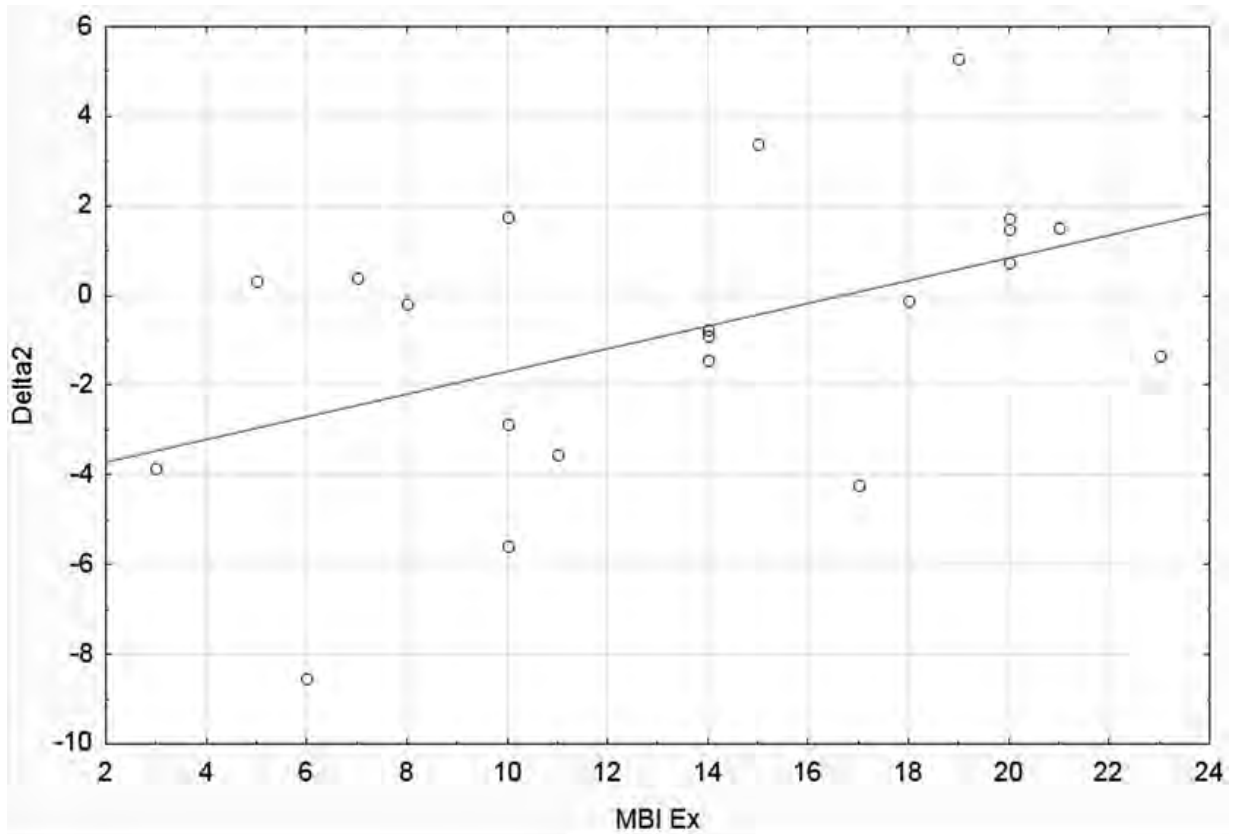


Figure 6.3 Scatterplots of BVP HF% Standard Deviation responses and MBI Exhaustion scores.

BVP HF% Coefficient of Variation

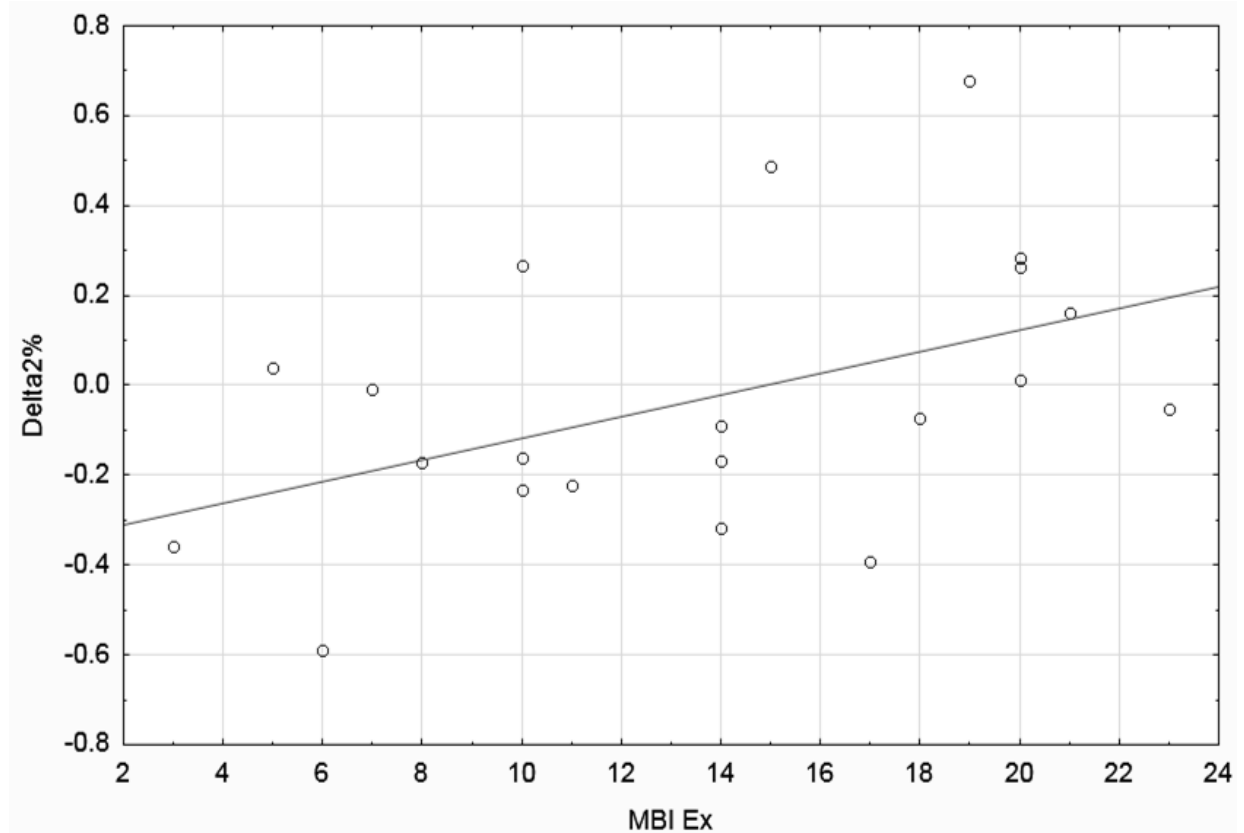
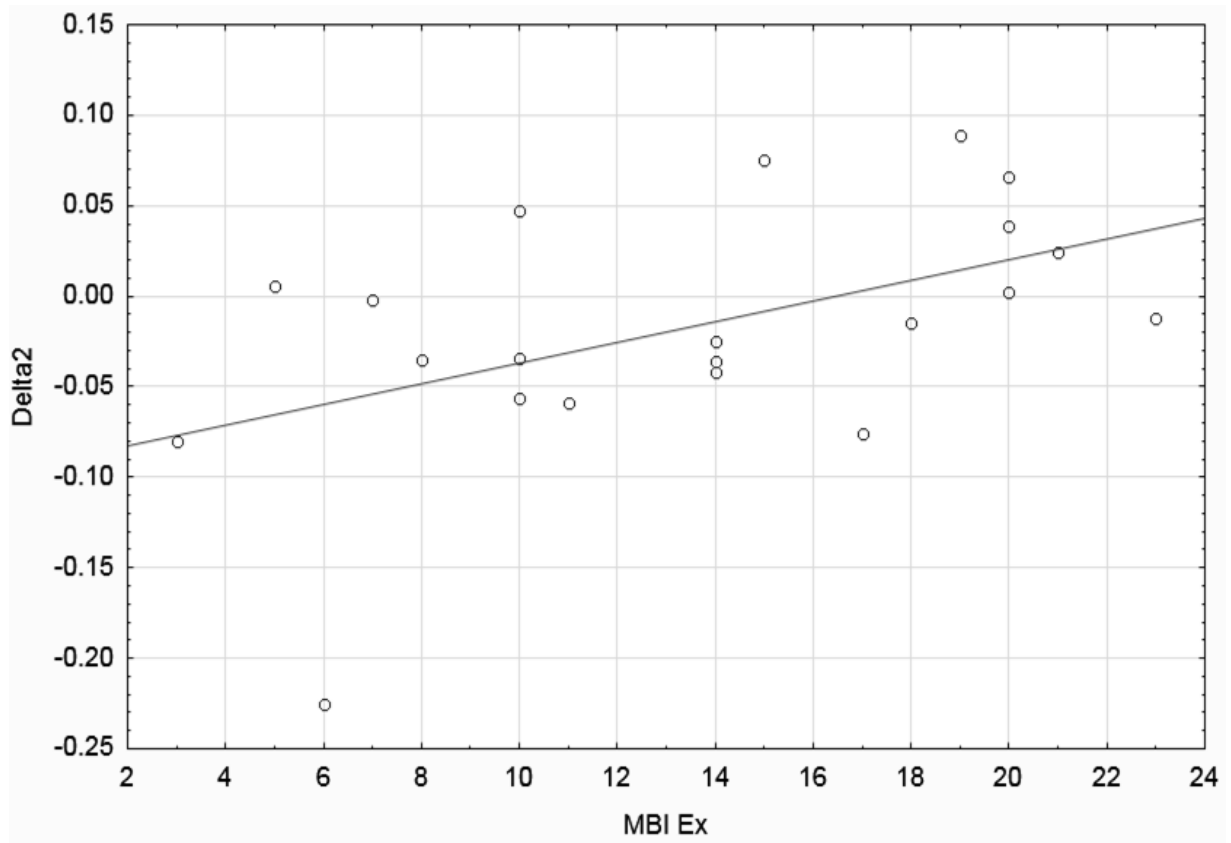


Figure 6.4 Scatterplots of BVP HF% Coefficient of Variation response and MBI Exhaustion.

6.3.4 ECG Time-Domain HRV

Table 6.8 Spearman ranked correlations between the ECG HRV time domain variables and the psychometric items. N=21, except where marked with *, then N=20.

Variable Name	Step	Psychometric	Spearman r	p-value
ECG Heart Rate Coefvar	Challenge	MBI Cy	0.3736	0.0953
ECG Heart Rate StdDev	Challenge	MBI Cy	0.3924	0.0785
ECG NN50	Ch-B2	MBI Cy	0.4635	0.0343
ECG Heart Rate Coefvar	(Ch-B2)/B2	MBI Ex	0.4389	0.0466
ECG Heart Rate Coefvar	Ch-B2	MBI Ex	0.3937	0.0774
ECG Heart Rate StdDev	(Ch-B2)/B2	MBI Ex	0.3794	0.0898
ECG Heart Rate StdDev	Challenge	MBI Ex	0.4159	0.0608
ECG NN50 *	(Ch-B2)/B2	MBI Ex	0.5223	0.0182
ECG Heart Rate Mean	Baseline2	MBI Pe	0.4629	0.0346
ECG Heart Rate Mean	Challenge	MBI Pe	0.491	0.0238
ECG Heart Rate Mean	Recovery	MBI Pe	0.3688	0.1
ECG Heart Rate StdDev	Baseline1	MBI Pe	0.3851	0.0847
ECG NN50	Recovery	MBI Pe	-0.3959	0.0756
ECG pNN50	Recovery	MBI Pe	-0.39	0.0805
ECG Heart Rate Coefvar	Baseline1	STAI Y1 Pr	-0.3711	0.0977
ECG Heart Rate StdDev	Baseline1	STAI Y1 Pr	-0.4177	0.0596
ECG NN50	Baseline2	STAI Y2	-0.3972	0.0746
ECG NN50	Recovery	STAI Y2	-0.5151	0.0169
ECG pNN50	Recovery	STAI Y2	-0.526	0.0143
ECG NN50	Baseline2	STAI Y2 Pr	-0.4136	0.0623
ECG NN50	Challenge	STAI Y2 Pr	-0.402	0.0709
ECG NN50	Recovery	STAI Y2 Pr	-0.4694	0.0318
ECG pNN50	Recovery	STAI Y2 Pr	-0.4768	0.0289

ECG - Electrocardiogram, Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response, NN50 – Normal-to-normal intervals lasting longer than 50 ms, pNN50 – Percentage of normal-to-normal intervals lasting longer than 50 ms

ECG NN50 count

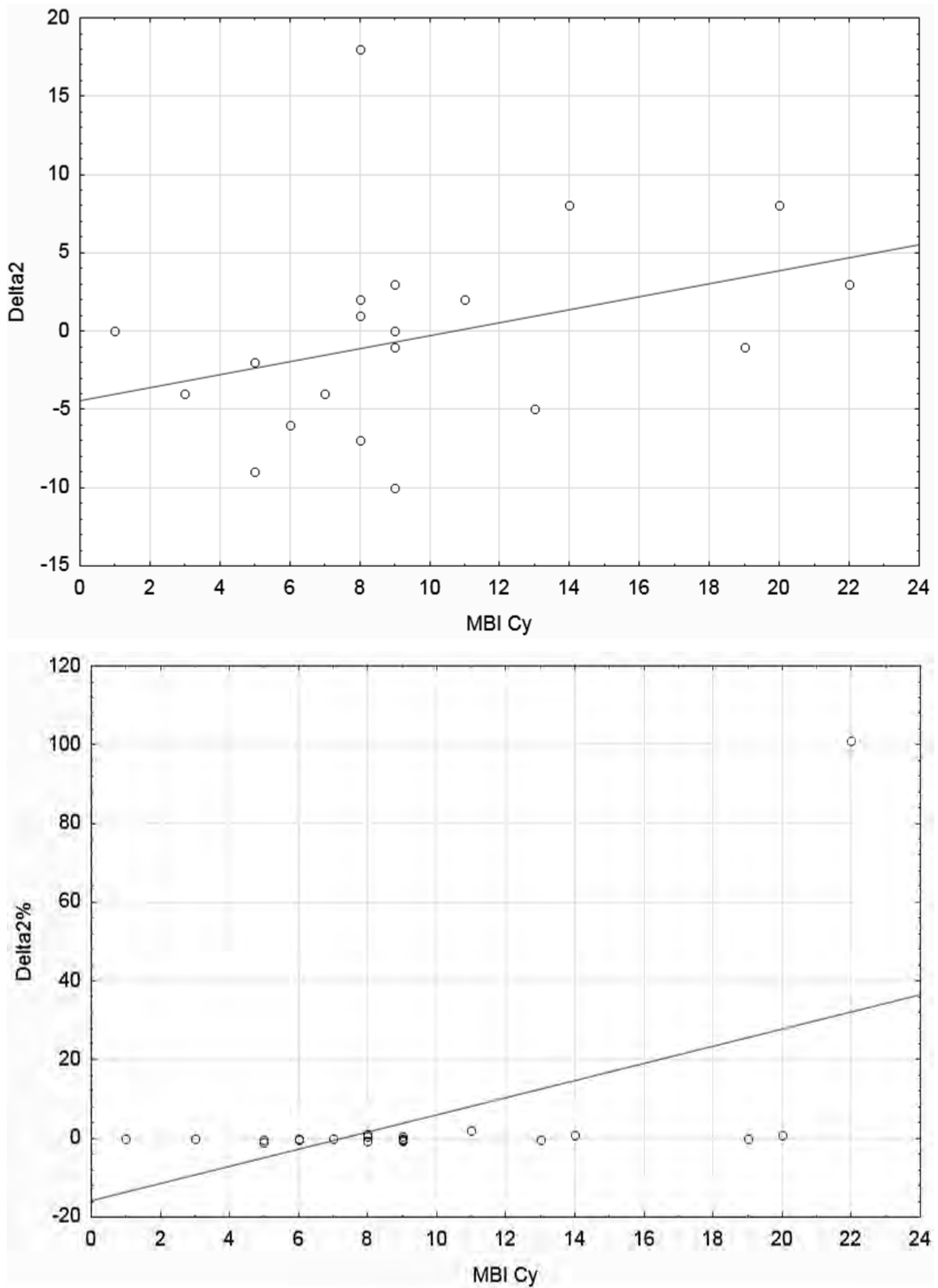


Figure 6.5 Scatterplots of The ECG NN50 count response and MBI Cynicism.

ECG NN50 count

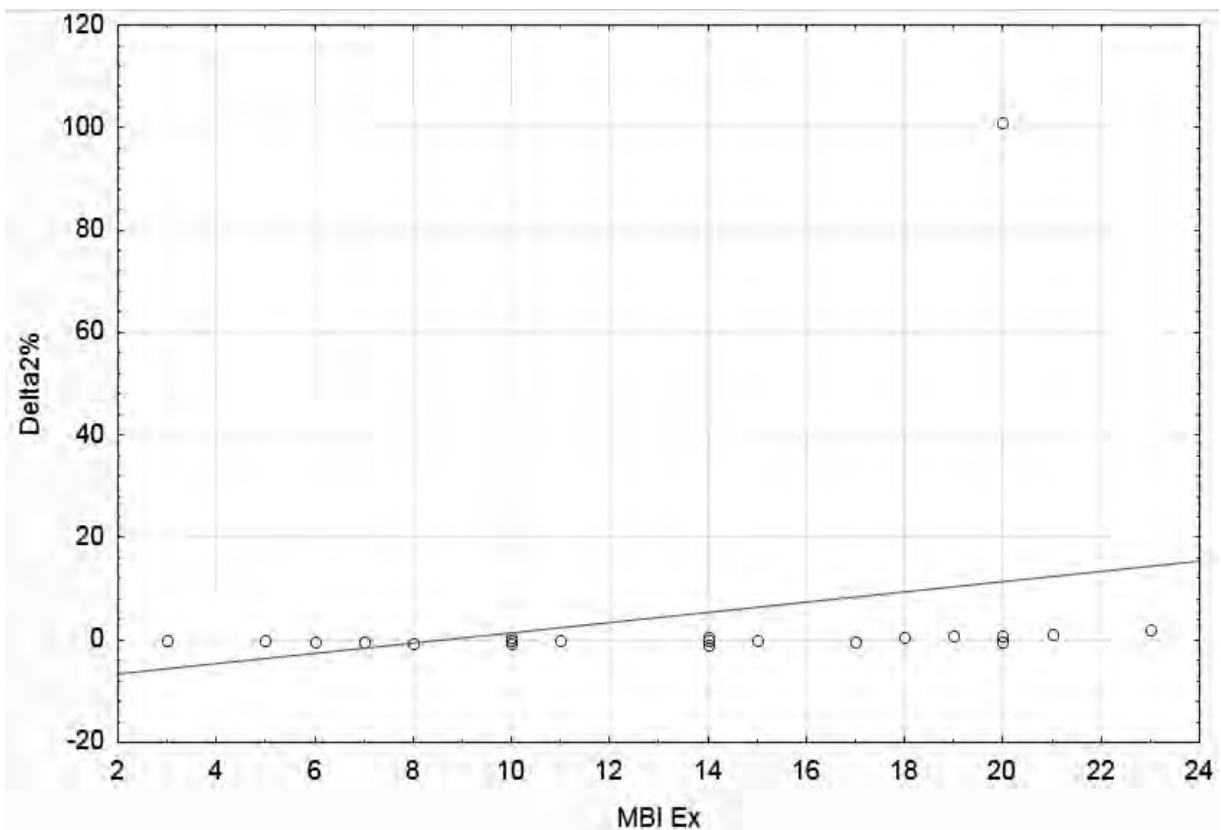
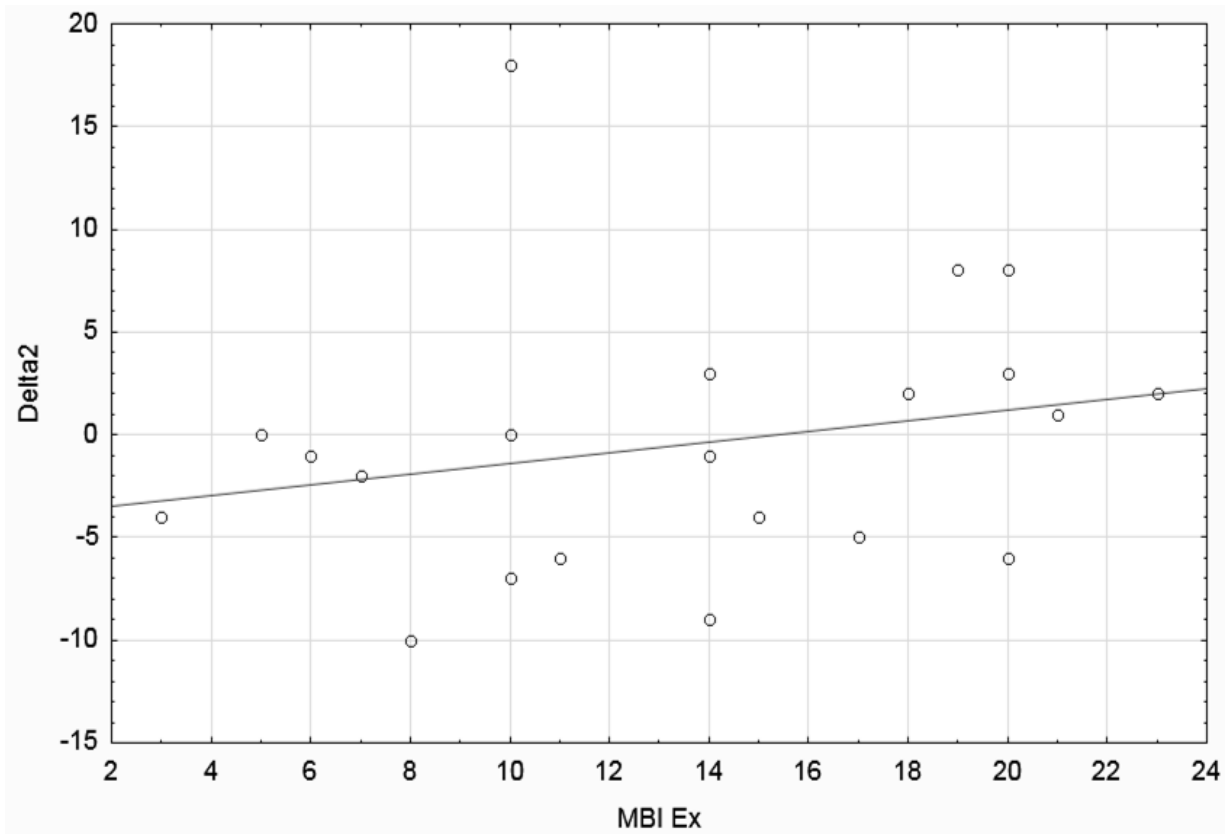


Figure 6.6 Scatterplots of The ECG NN50 count response and MBI Exhaustion.

ECG Heart Rate Coefficient of Variation

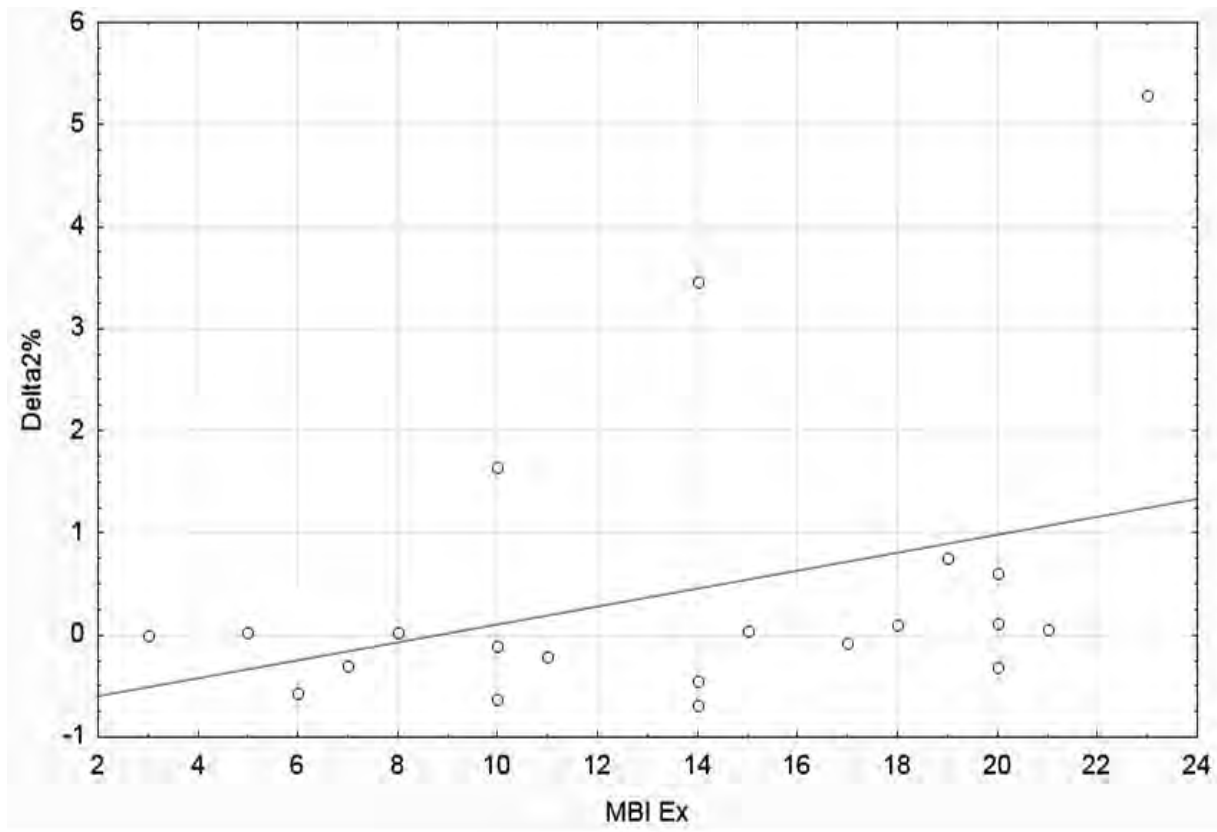


Figure 6.7 Scatterplot of ECG Heart Rate Coefficient of Variation response and MBI Exhaustion scores.

6.3.5 ECG Frequency-Domain HRV

Table 6.9 Spearman ranked correlations between the ECG HRV frequency domain variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
ECG HF%PowerCoefVar	(Ch-B2)/B2	MBI Ex	0.4056	0.0681
ECG HF%PowerCoefVar	Ch-B2	MBI Ex	0.3874	0.0828
ECG HF%Power StdDev	(Ch-B2)/B2	MBI Ex	0.5567	0.0088
ECG HF%Power StdDev	Baseline2	MBI Ex	-0.528	0.0139
ECG HF%Power StdDev	Ch-B2	MBI Ex	0.5593	0.0084
ECG LF%PowerCoefVar	Baseline2	MBI Ex	-0.3776	0.0915
ECG LF%PowerCoefVar	Recovery	MBI Ex	0.5346	0.0125
ECG LF%Power Mean	Baseline2	MBI Ex	-0.4081	0.0663
ECG LF%Power StdDev	(Ch-B2)/B2	MBI Ex	0.631	0.0022
ECG LF%Power StdDev	Baseline2	MBI Ex	-0.7236	0.0002
ECG LF%Power StdDev	Ch-B2	MBI Ex	0.5828	0.0056
ECG LF%Power StdDev	Recovery	MBI Ex	0.5737	0.0065
ECG LF/HF CoefVar	(Ch-B2)/B2	MBI Ex	0.5945	0.0045
ECG LF/HF CoefVar	Baseline2	MBI Ex	-0.6623	0.0011
ECG LF/HF CoefVar	Ch-B2	MBI Ex	0.5608	0.0082
ECG LF/HF Mean	(Ch-B2)/B2	MBI Ex	0.3937	0.0774
ECG LF/HF Mean	Baseline2	MBI Ex	-0.4524	0.0395
ECG LF/HF Mean	Ch-B2	MBI Ex	0.4511	0.0401
ECG LF/HF StdDev	(Ch-B2)/B2	MBI Ex	0.6206	0.0027
ECG LF/HF StdDev	Baseline2	MBI Ex	-0.7067	0.0003
ECG LF/HF StdDev	Ch-B2	MBI Ex	0.6336	0.002
ECG LF%Power StdDev	Baseline2	MBI Pe	-0.3988	0.0733
ECG HF%PowerCoefVar	Baseline1	STAI Y1	-0.4533	0.039
ECG HF%Power StdDev	Baseline1	STAI Y1	-0.4633	0.0344
ECG HF%PowerCoefVar	Baseline1	STAI Y1 Pr	-0.449	0.0412
ECG HF%Power StdDev	Baseline1	STAI Y1 Pr	-0.4352	0.0486
ECG LF%PowerCoefVar	Recovery	STAI Y2	0.4617	0.0351
ECG LF%Power StdDev	(Ch-B2)/B2	STAI Y2	0.3697	0.099
ECG LF%Power StdDev	Recovery	STAI Y2	0.4597	0.036
ECG LF%PowerCoefVar	Recovery	STAI Y2 Pr	0.3737	0.0952

ECG - Electrocardiogram, Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response, HF% - High frequency power, LF% - Low frequency power, LF/HF – Ratio between high and low frequency power.

ECG LF% Standard Deviation

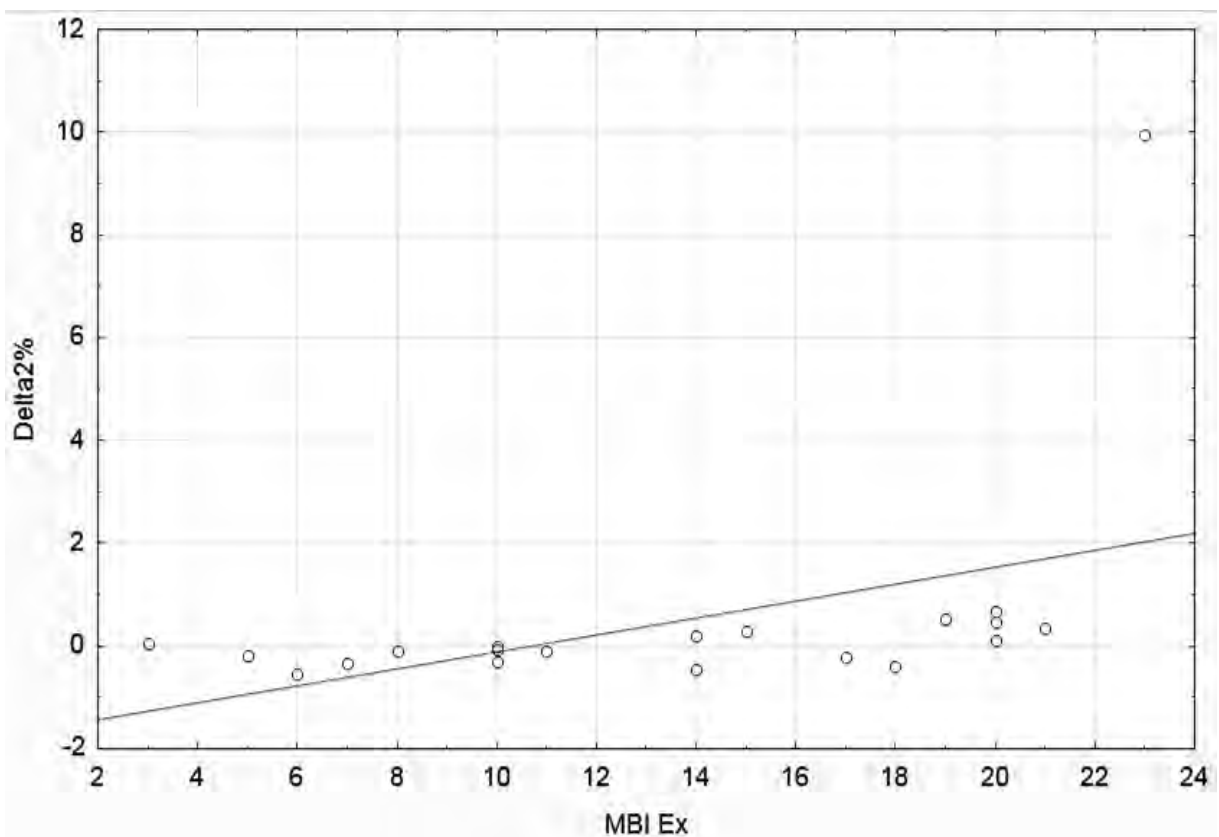
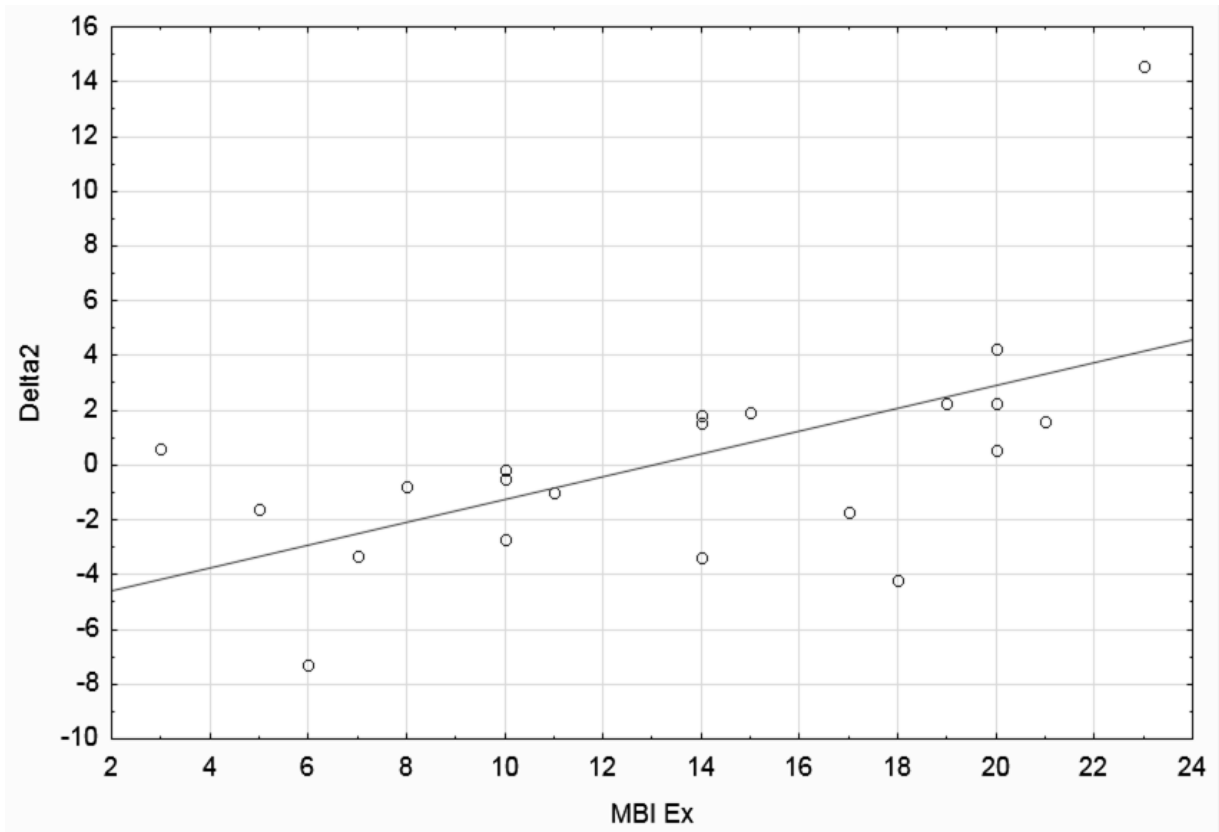


Figure 6.8 Scatterplots of ECG LF% Standard Deviation response and MBI Exhaustion scores.

ECG HF% Standard Deviation

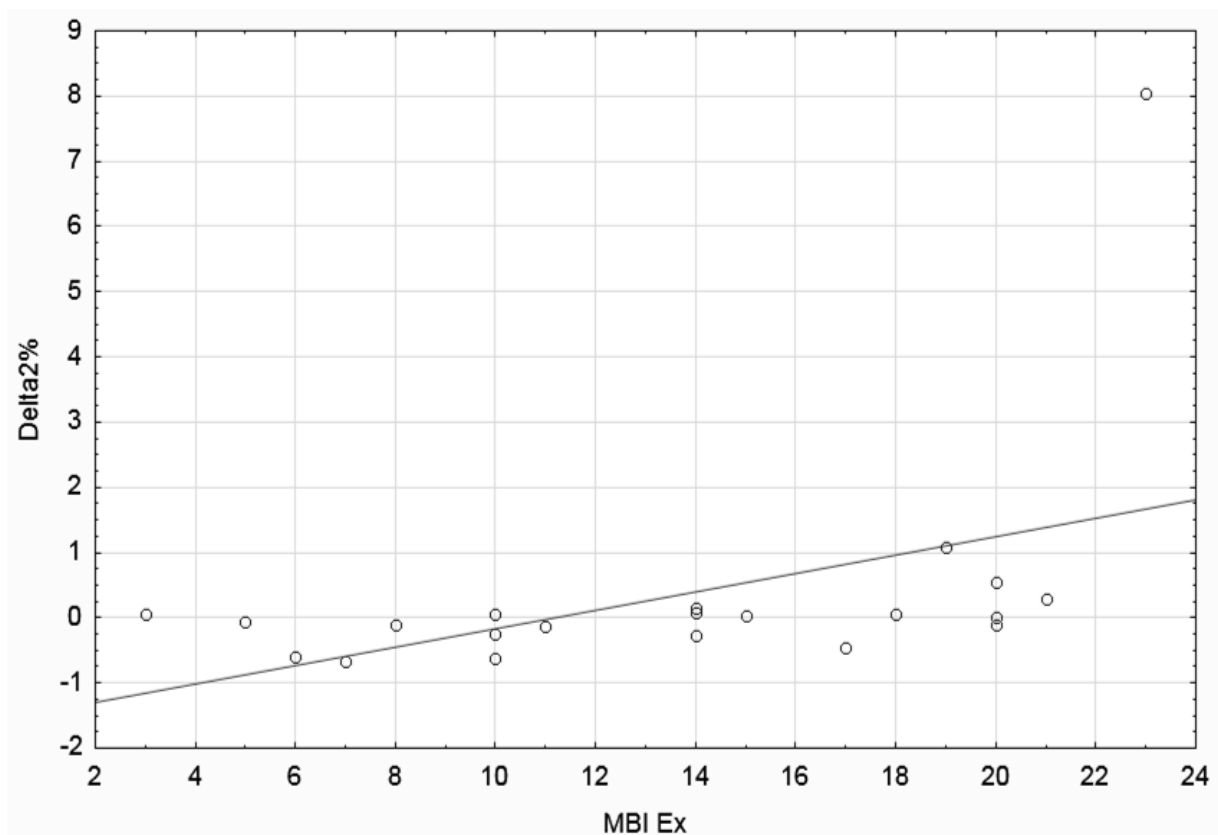
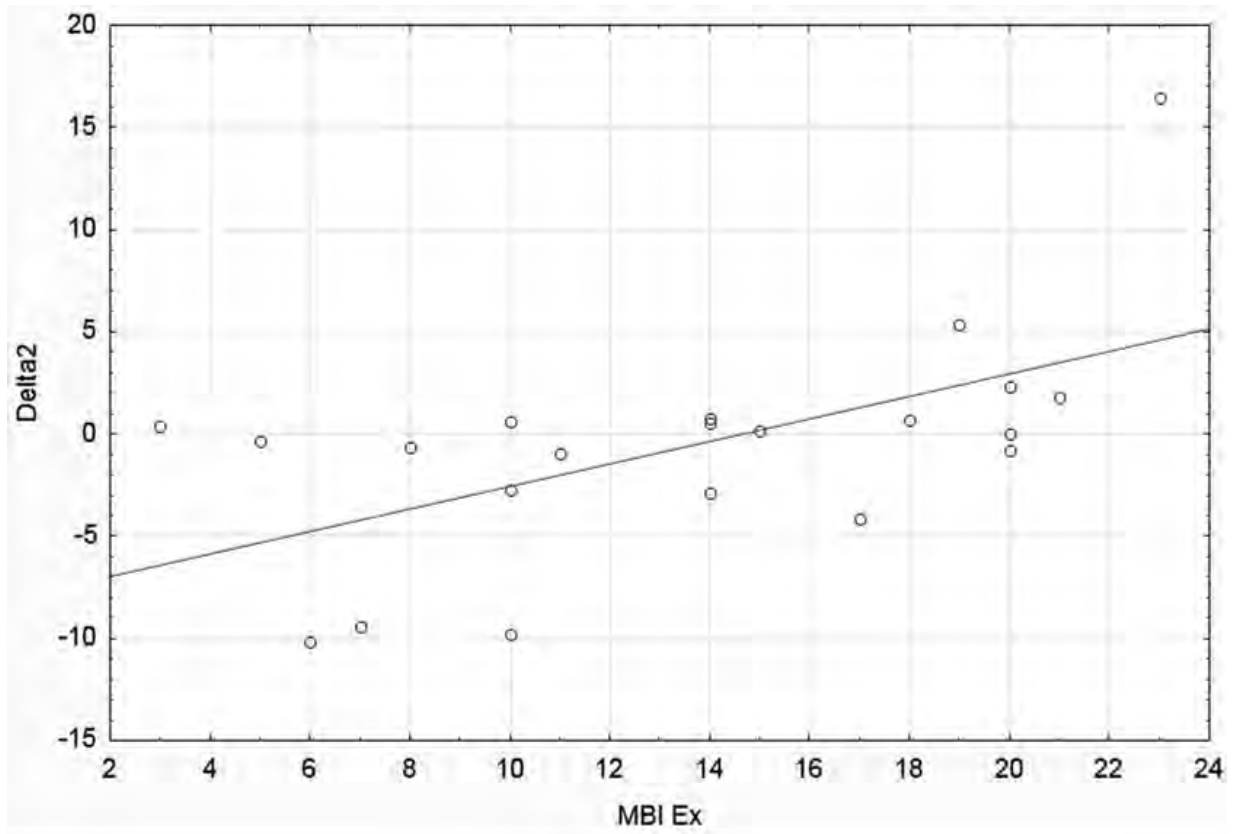


Figure 6.9 Scatterplots of ECG HF% Standard Deviation response and MBI Exhaustion.

ECG LF/HF Standard Deviation

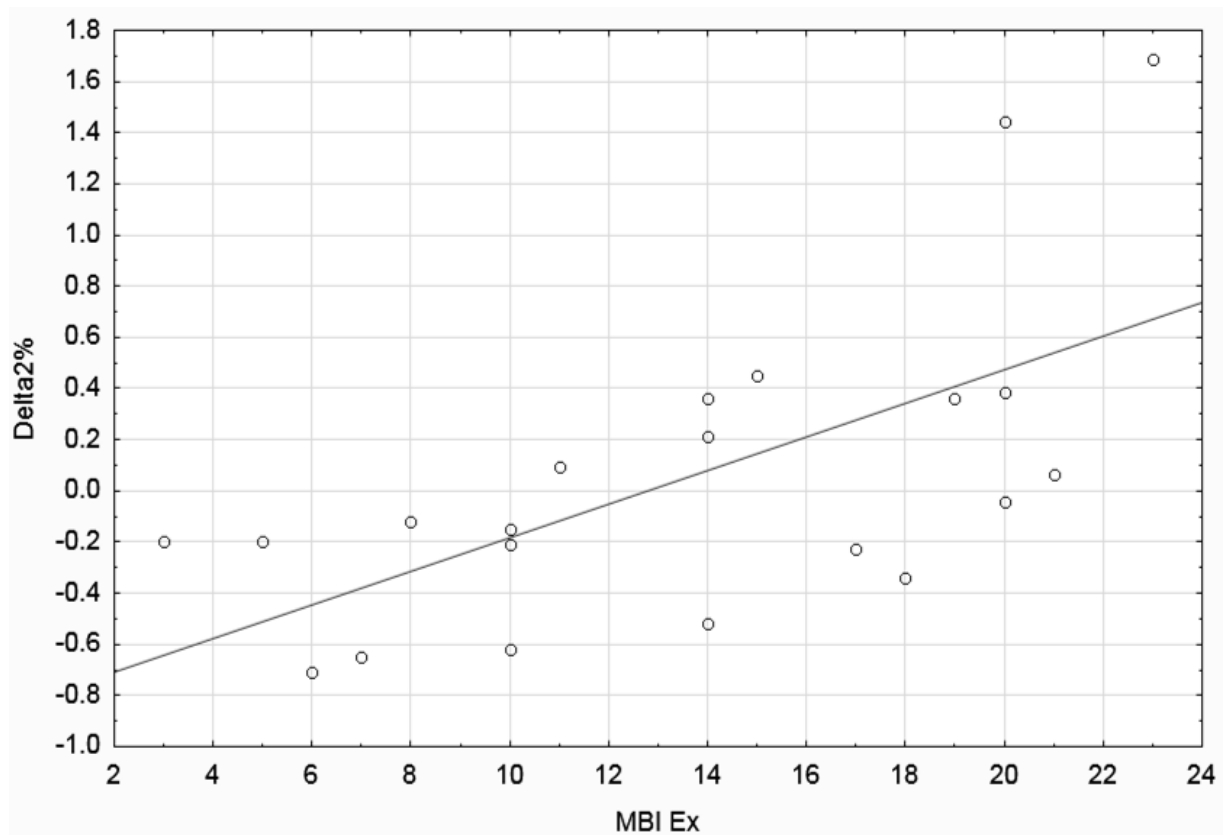
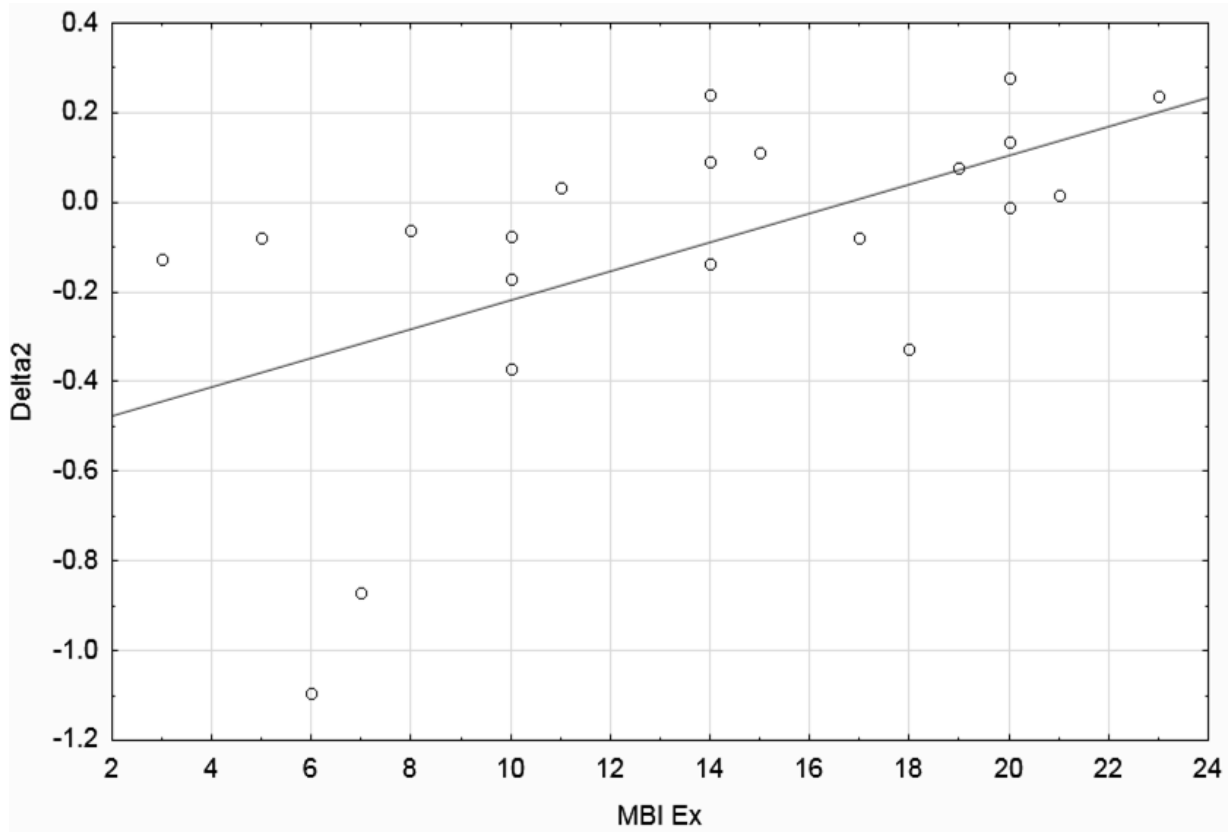


Figure 6.10 Scatterplots of ECG LF/HF Standard Deviation response and MBI Exhaustion.

ECG LF/HF Coefficient of Variation

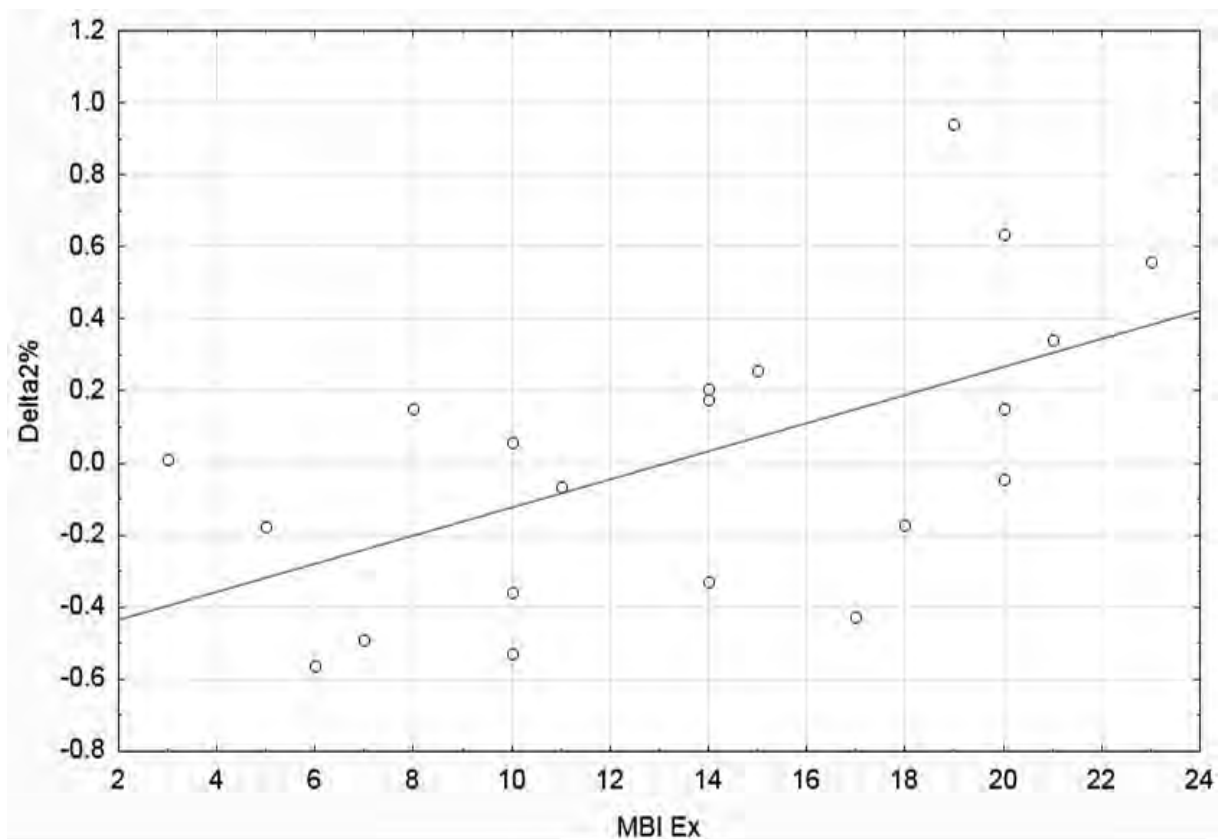
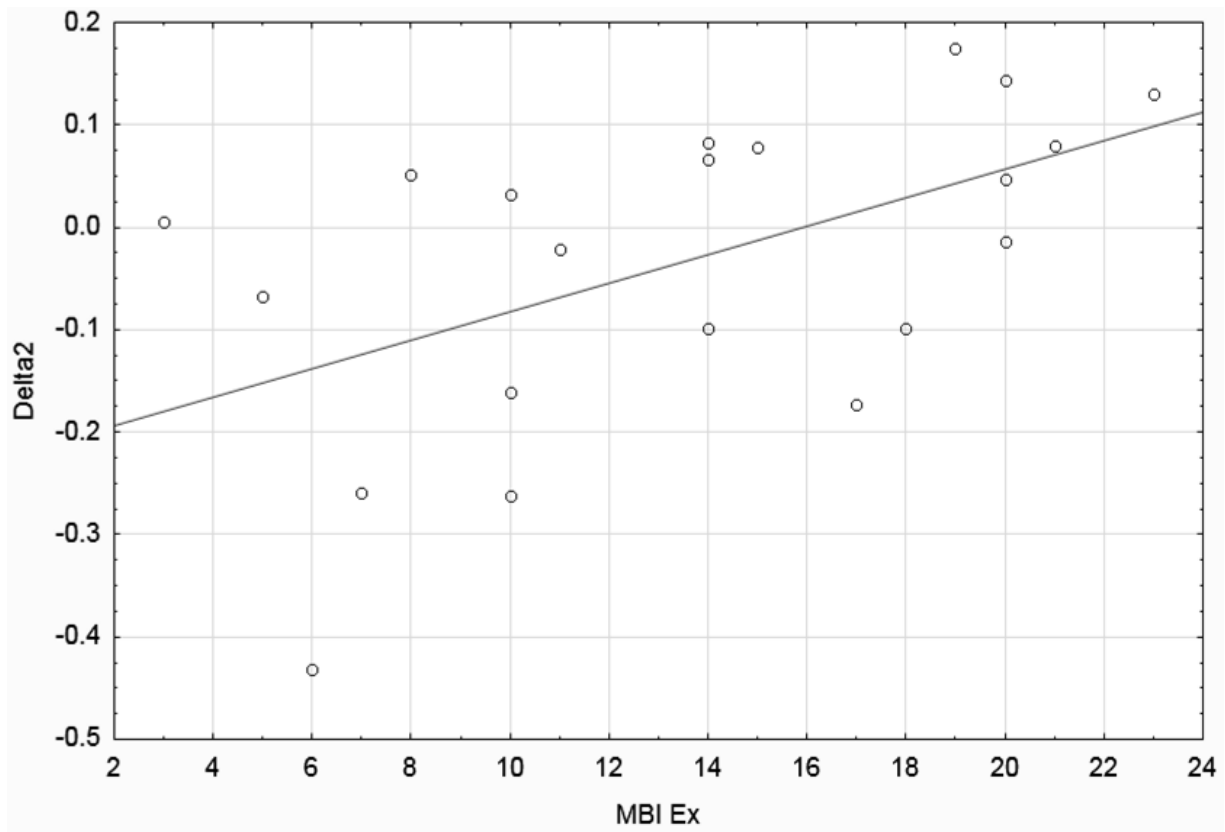


Figure 6.11 Scatterplots of ECG LF/HF Coefficient of Variation response and MBI Exhaustion scores.

ECG LF/HF Standard Deviation

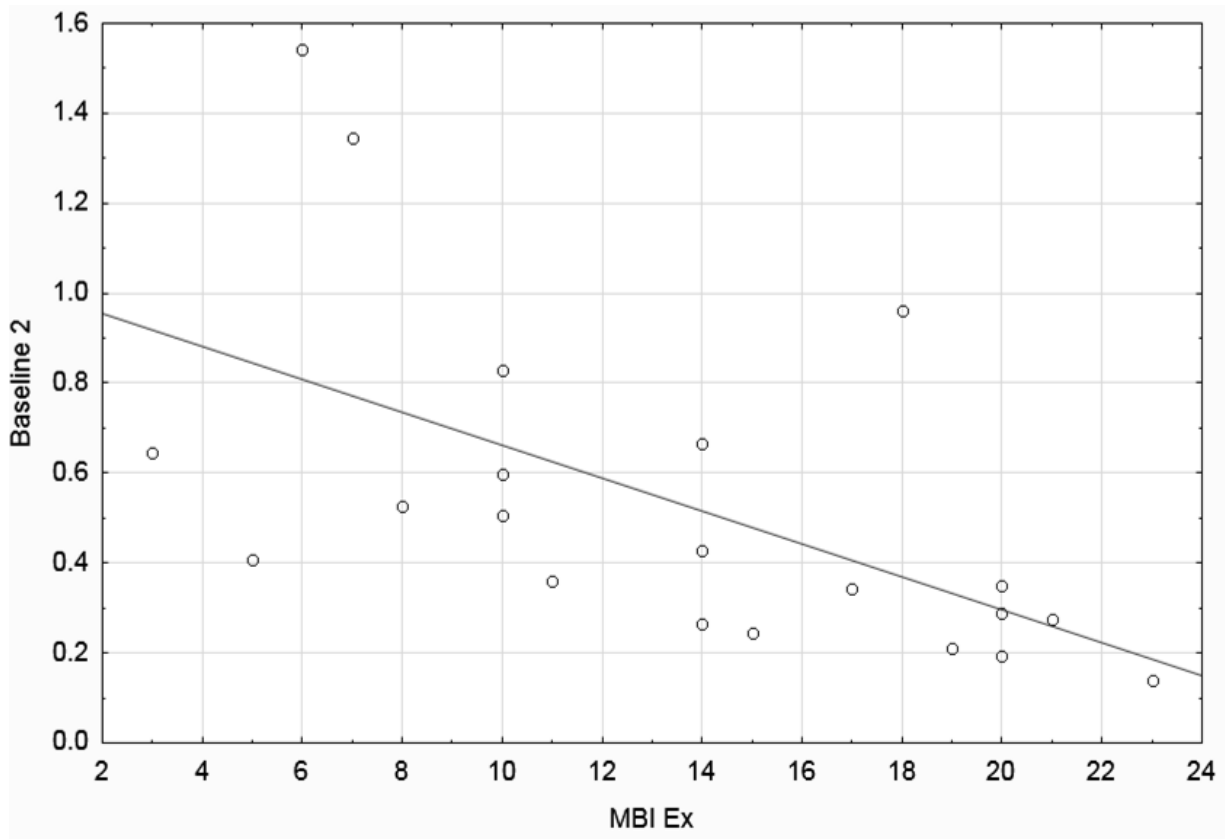


Figure 6.12 Scatterplot of ECG LF/HF Standard Deviation at Baseline 2 and MBI Exhaustion.

ECG LF/HF Coefficient of Variation

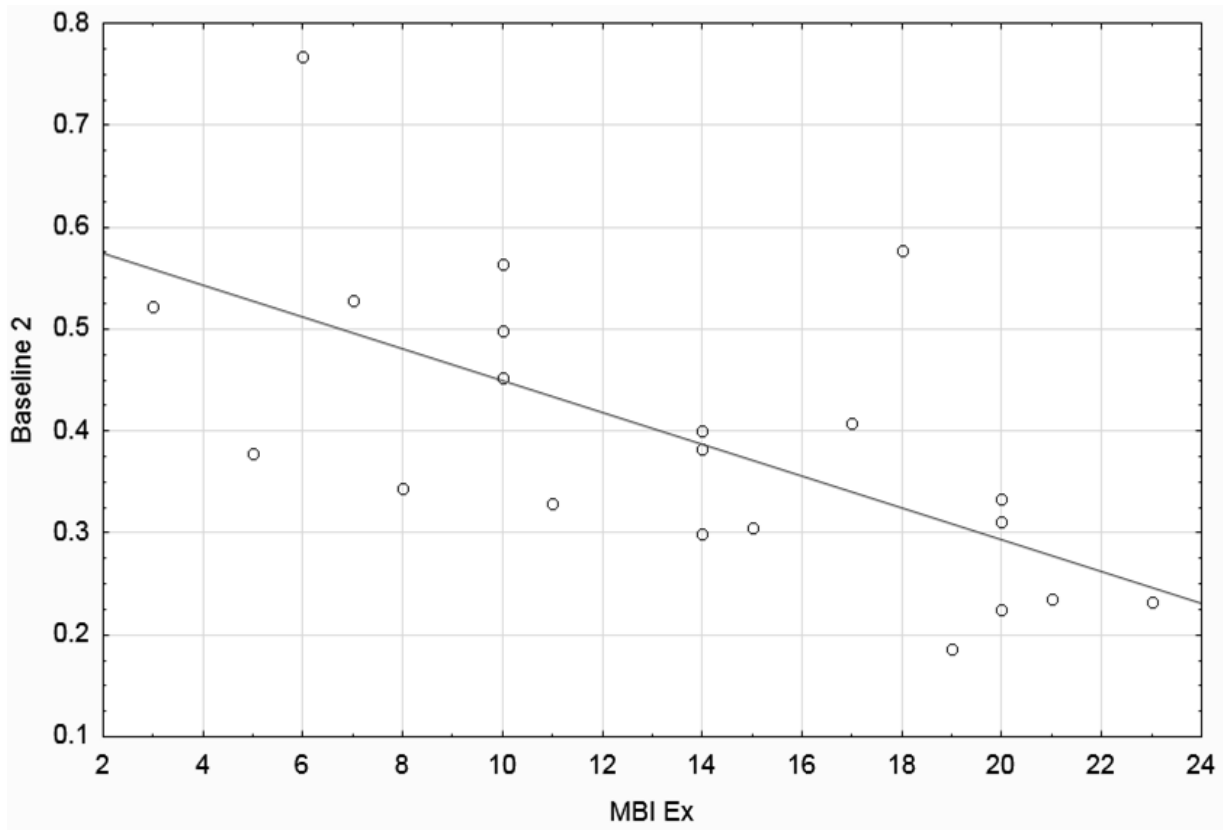


Figure 6.13 Scatterplot of ECG LF/HF Coefficient of Variation at Baseline 2 and MBI Exhaustion.

ECG LF/HF Ratio Mean

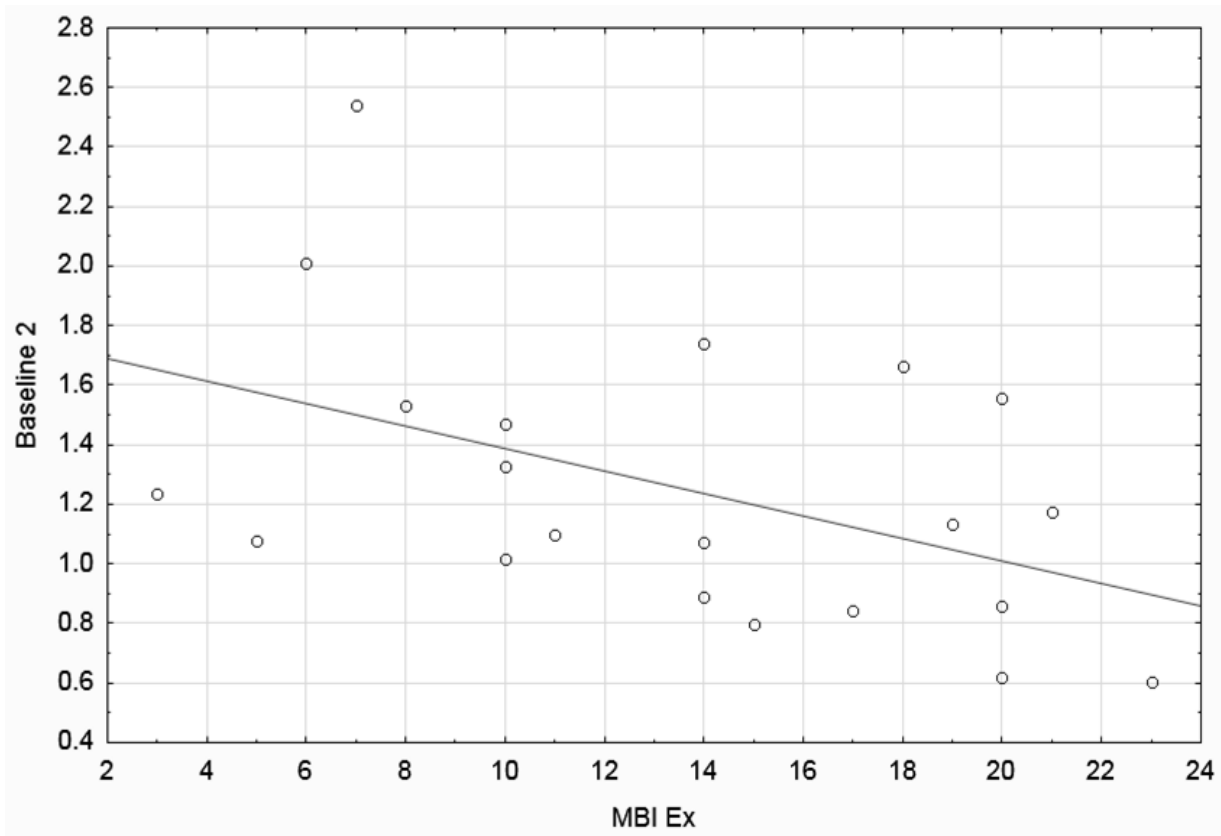


Figure 6.14 Scatterplot of ECG LF/HF Ratio Mean at Baseline 2 and MBI Exhaustion scores.

ECG LF/HF Ratio Mean

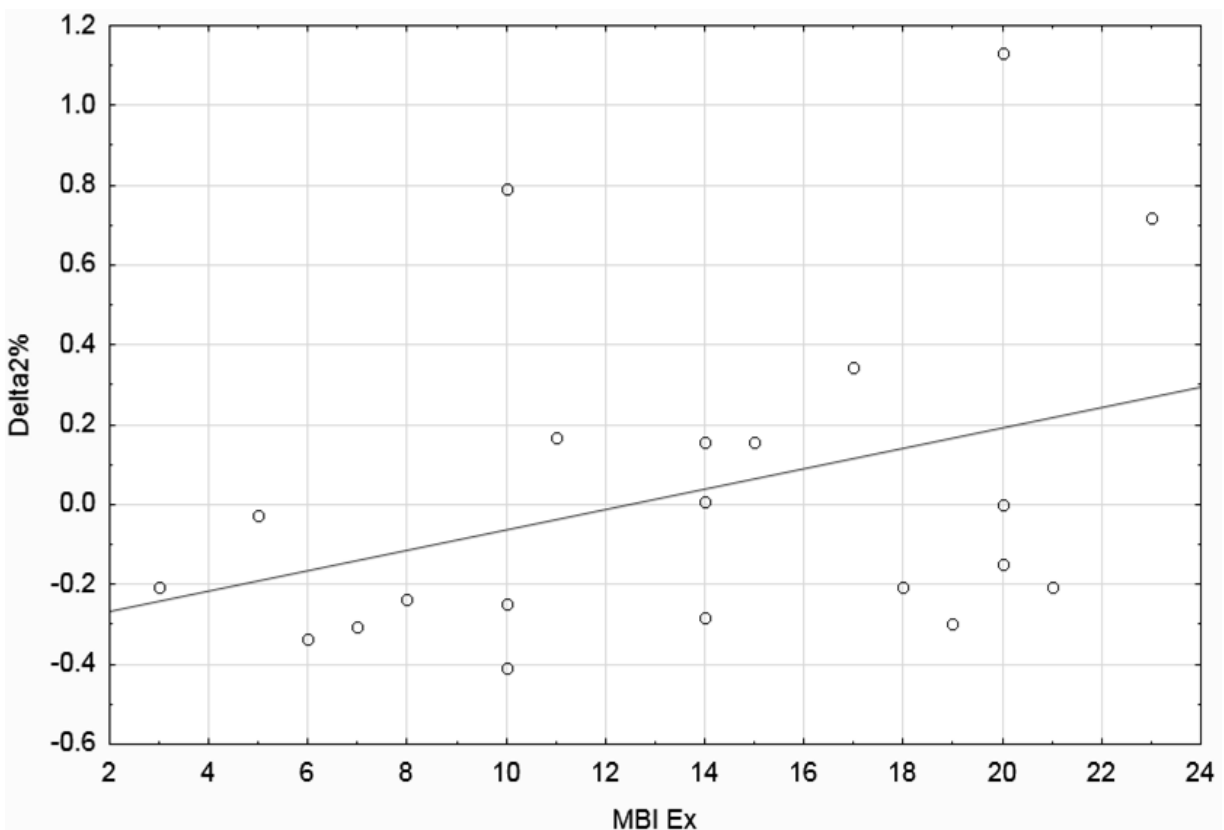
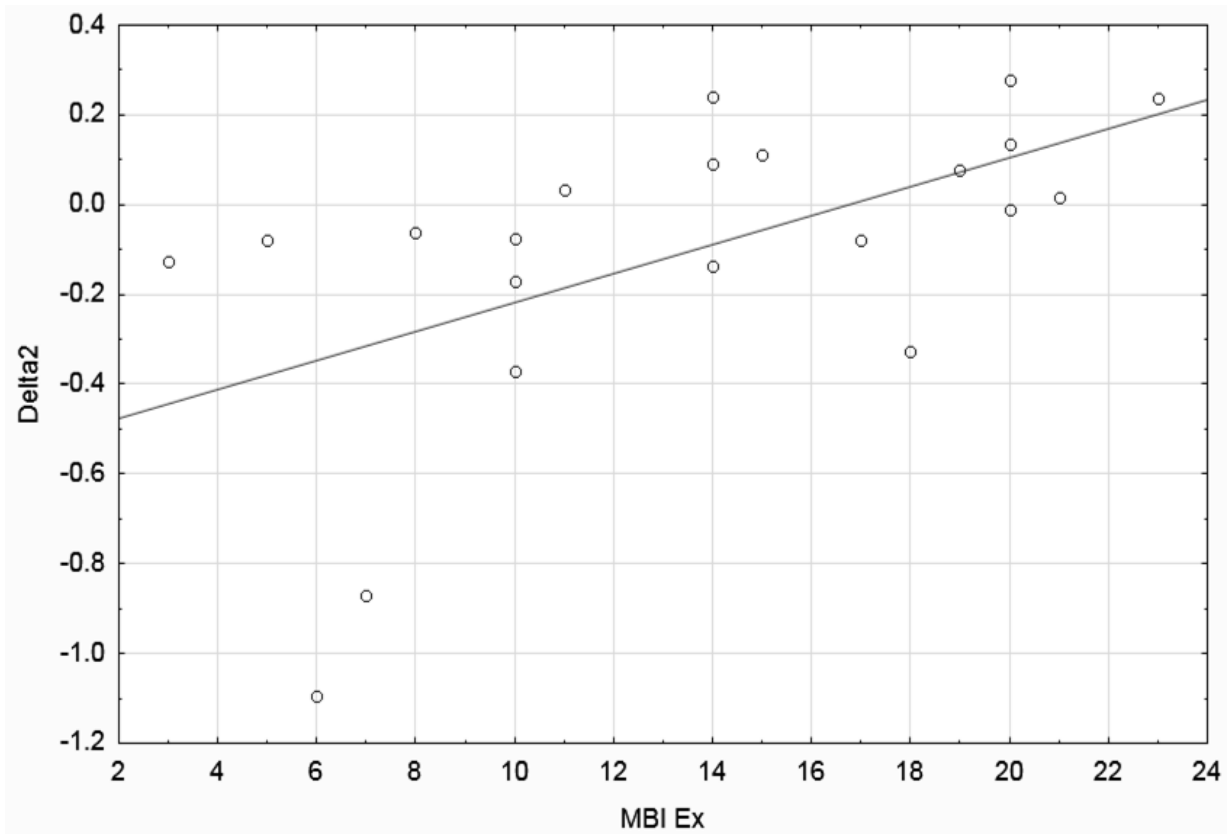


Figure 6.15 Scatterplots of ECG LF/HF Ratio Mean response and MBI Exhaustion scores.

6.3.6 Trapezius Surface Electromyography

Table 6.10 Spearman ranked correlations between the EMG variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
EMG Mean	Ch-B2	MBI Ex	-0.4291	0.0523
EMG CoefVar	(Ch-B2)/B2	MBI Pe	0.3773	0.0918
EMG CoefVar	Ch-B2	MBI Pe	0.372	0.0968
EMG Mean	Baseline 2	MBI Pe	0.4967	0.022
EMG Mean	Challenge	MBI Pe	0.5496	0.0099
EMG Mean	Ch-B2	MBI Pe	-0.3712	0.0976
EMG StdDev	Baseline 2	MBI Pe	0.4439	0.0438
EMG StdDev	Challenge	MBI Pe	0.508	0.0187
EMG Mean	(Ch-B2)/B2	STAI Y1	0.5109	0.0179
EMG Mean	Baseline 1	STAI Y1	-0.4248	0.0549
EMG Mean	Baseline 2	STAI Y1	-0.4974	0.0218
EMG Mean	Ch-B2	STAI Y1	0.5415	0.0112
EMG StdDev	(Ch-B2)/B2	STAI Y1	0.6042	0.0037
EMG StdDev	Baseline 1	STAI Y1	-0.4339	0.0494
EMG StdDev	Baseline 2	STAI Y1	-0.4972	0.0218
EMG StdDev	Ch-B2	STAI Y1	0.5031	0.0201
EMG CoefVar	Baseline 2	STAI Y1 Pr	-0.4696	0.0317
EMG Mean	(Ch-B2)/B2	STAI Y1 Pr	0.6015	0.0039
EMG Mean	Baseline 1	STAI Y1 Pr	-0.3724	0.0964
EMG Mean	Baseline 2	STAI Y1 Pr	-0.4841	0.0262
EMG Mean	Ch-B2	STAI Y1 Pr	0.5601	0.0083
EMG StdDev	(Ch-B2)/B2	STAI Y1 Pr	0.6353	0.002
EMG StdDev	Baseline 1	STAI Y1 Pr	-0.417	0.06
EMG StdDev	Baseline 2	STAI Y1 Pr	-0.5261	0.0143
EMG StdDev	Ch-B2	STAI Y1 Pr	0.5138	0.0172
EMG CoefVar	Baseline 2	STAI Y2	-0.4832	0.0265
EMG CoefVar	Challenge	STAI Y2	-0.4858	0.0256
EMG CoefVar	Baseline 2	STAI Y2 Pr	-0.5221	0.0152
EMG CoefVar	Challenge	STAI Y2 Pr	-0.5234	0.0149

EMG – Electromyography, StdDev – Standard deviation, CoefVar – Coefficient of variation, MBI – Maslach Burnout Inventory, Ex – Exhaustion subscale, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State anxiety, Y2 – Trait anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response.

EMG Mean

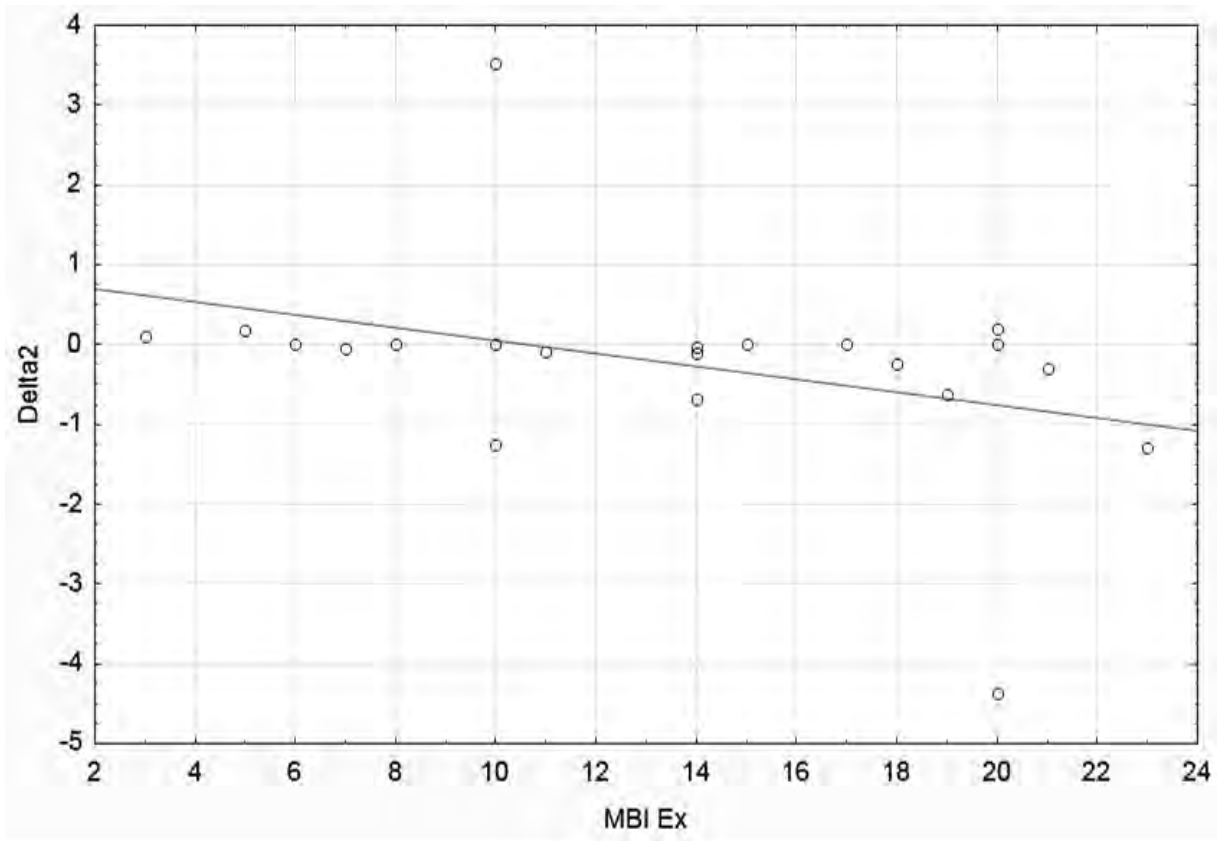
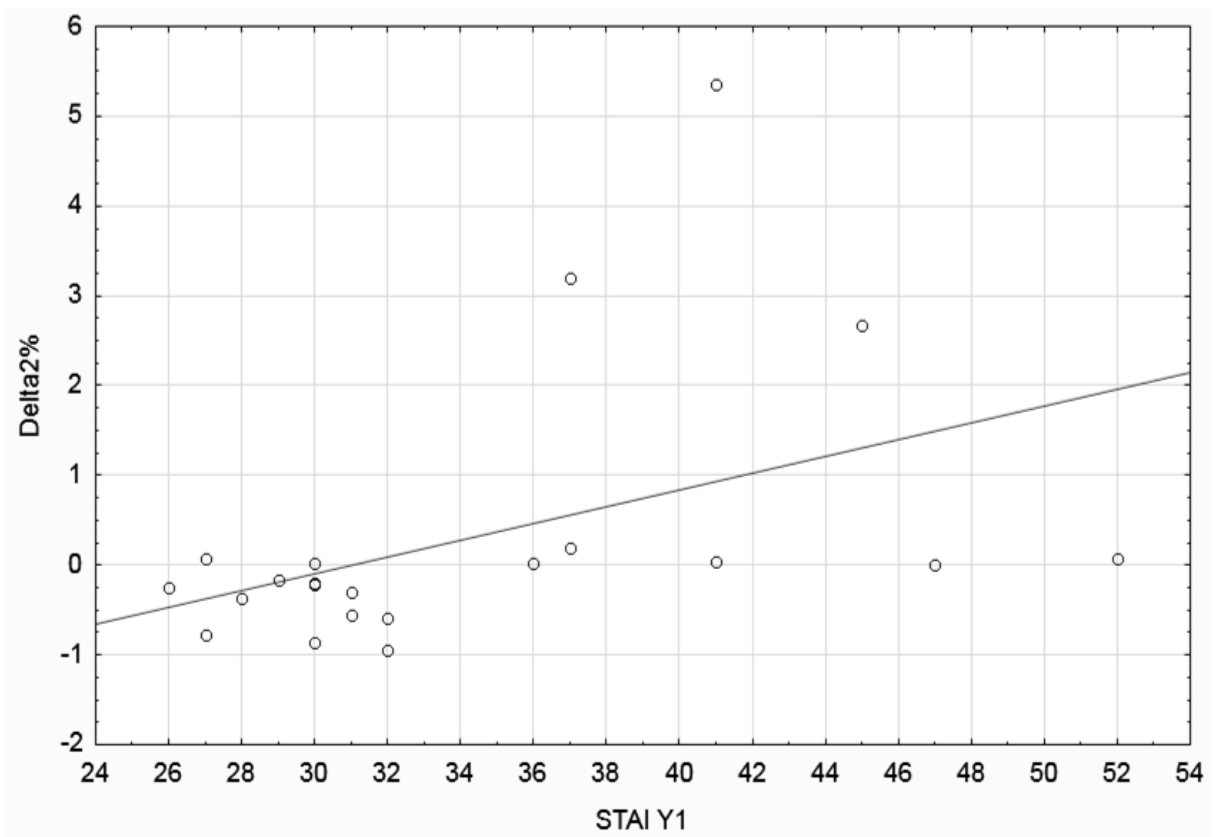
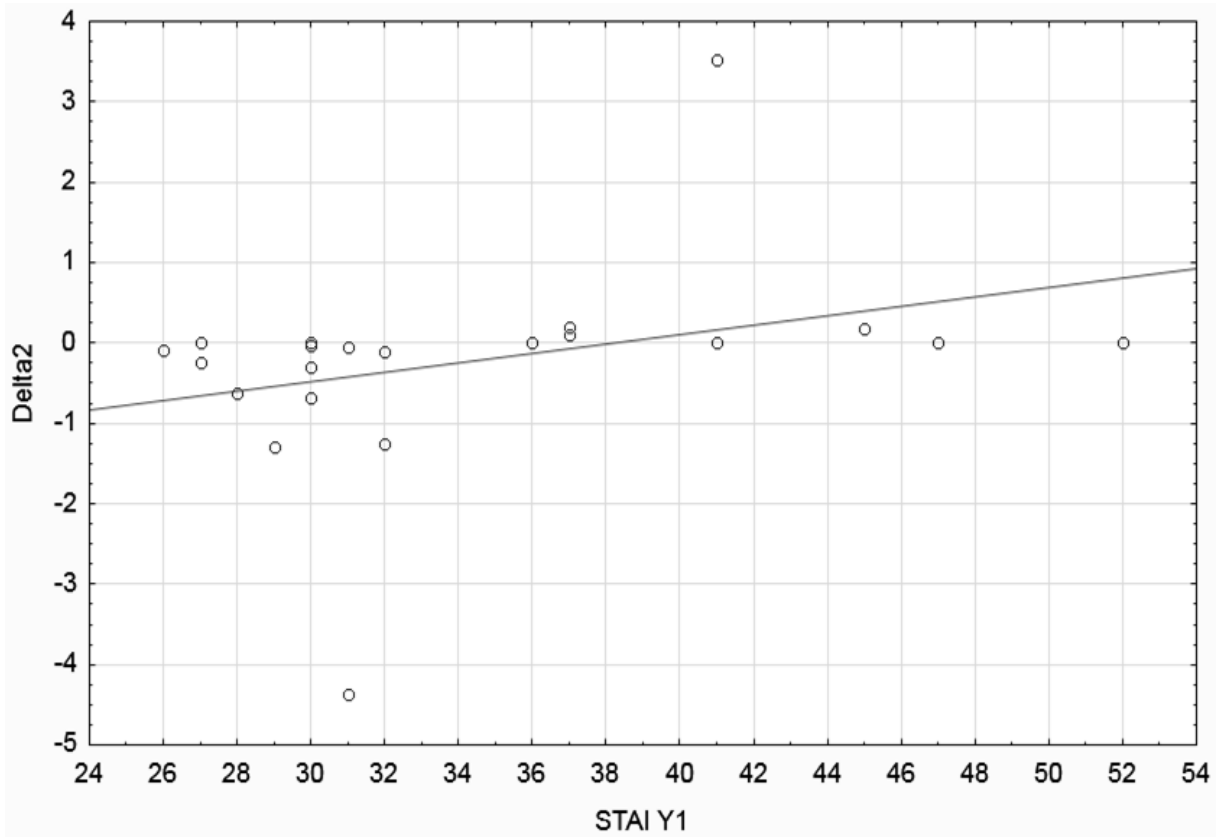


Figure 6.16 Scatterplot of EMG Mean response and MBI Exhaustion scores.



EMG Mean



EMG Mean

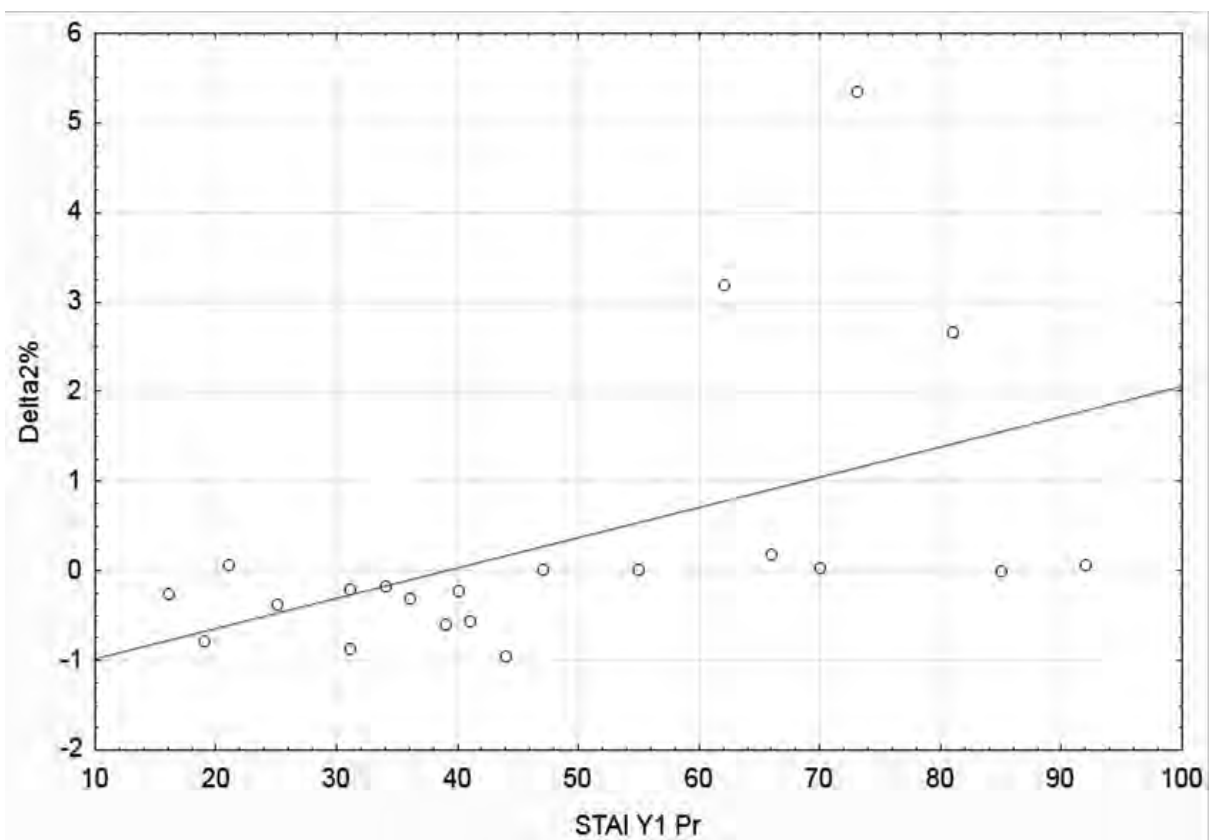
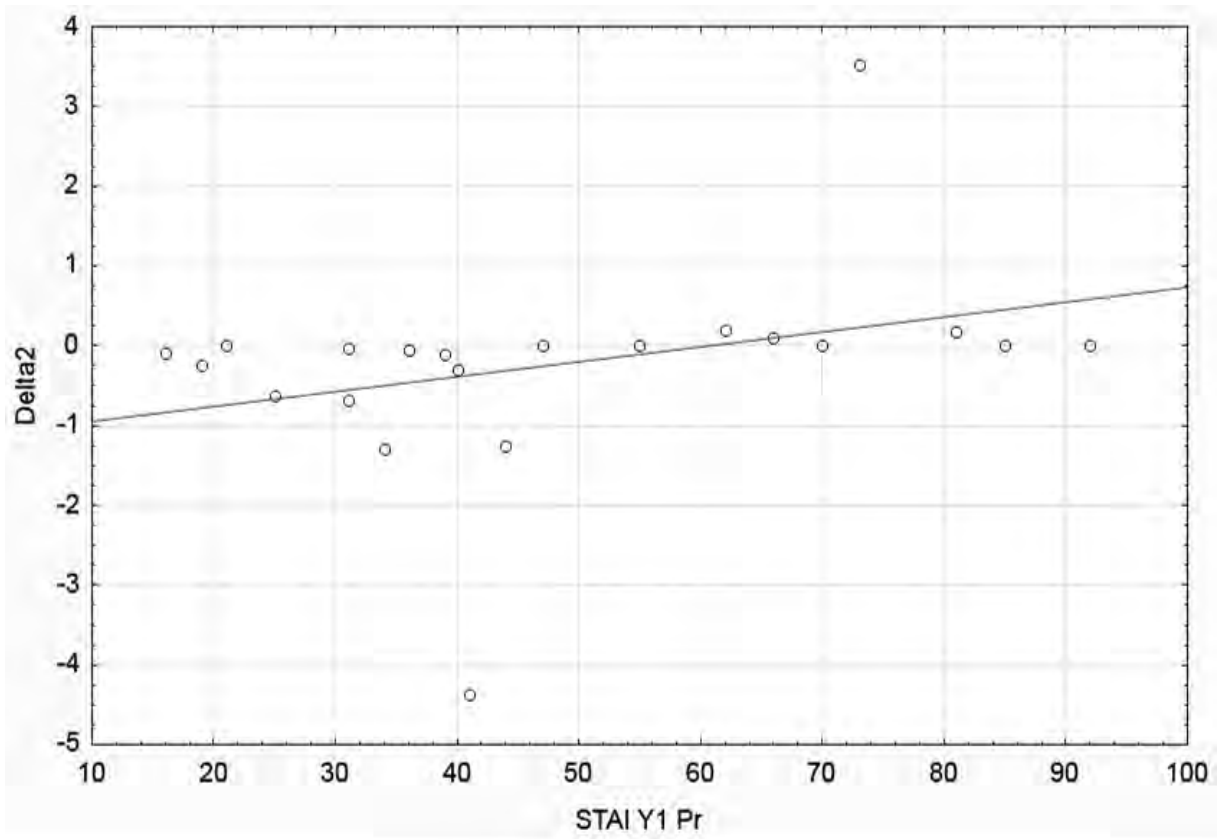
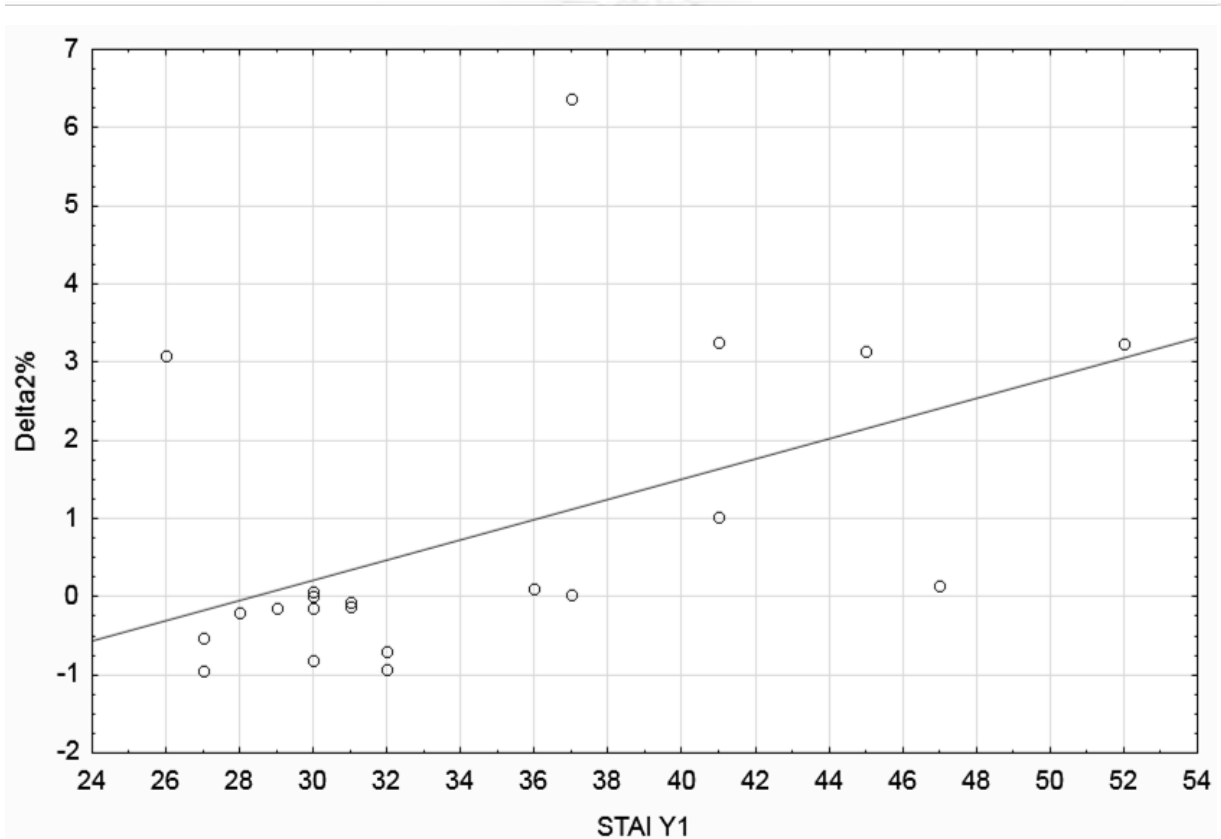
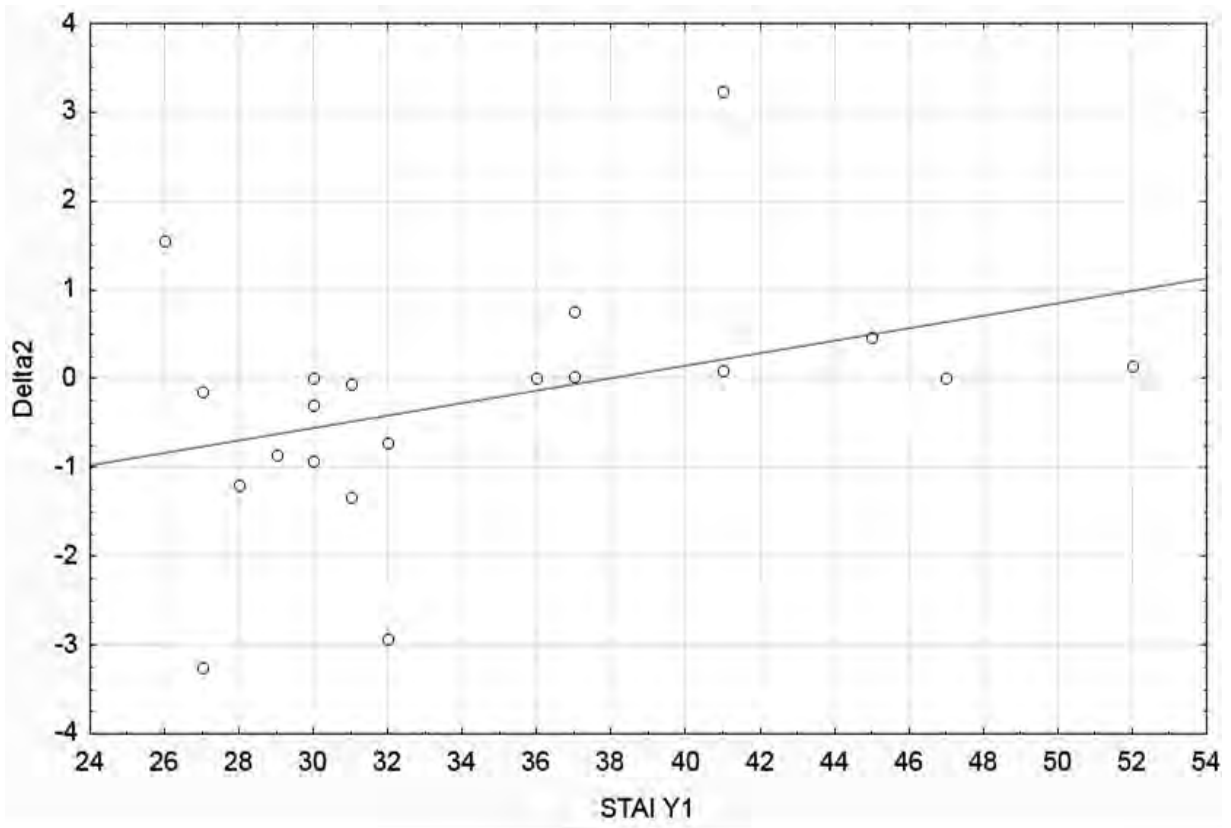


Figure 6.17 Scatterplots of EMG Mean response and State Anxiety scores.



EMG Standard Deviation



EMG Standard Deviation

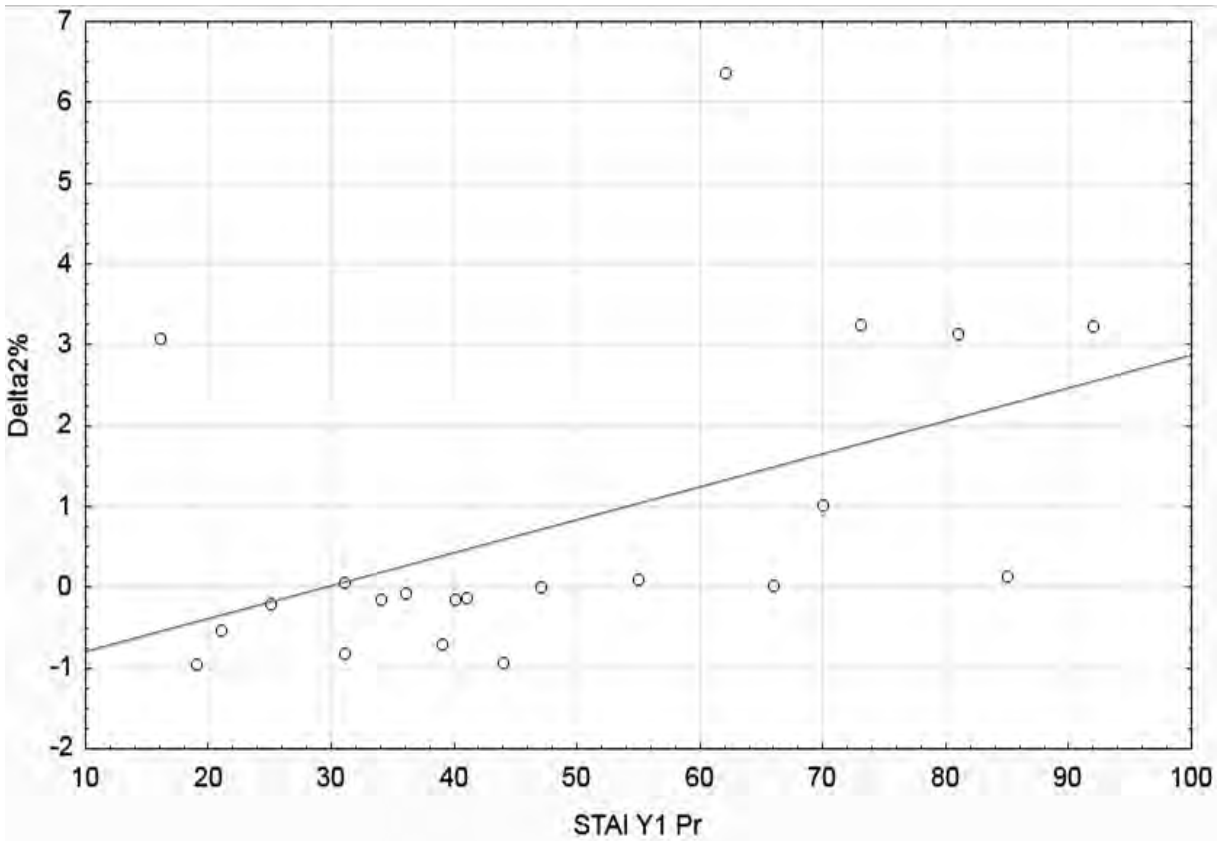
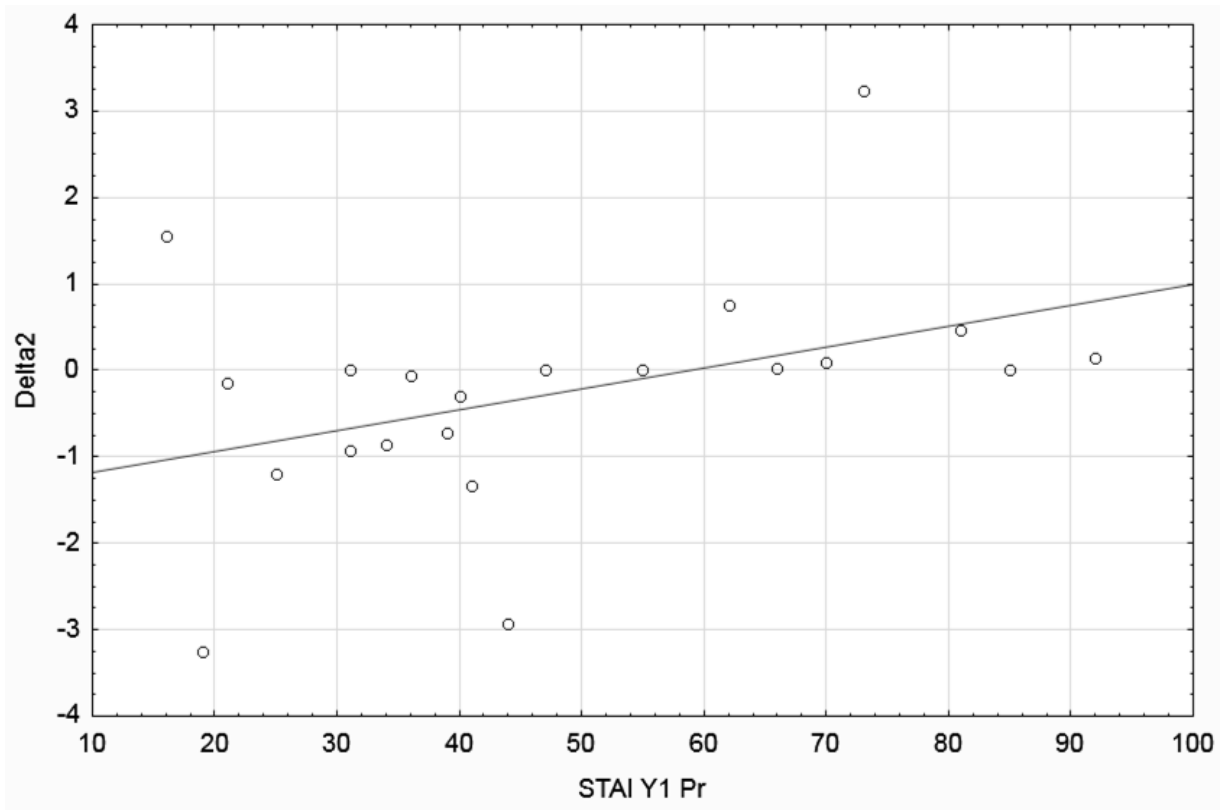


Figure 6.18 Scatterplots of EMG Standard Deviation response and State Anxiety scores.

6.3.7 Fingertip Temperature

Table 6.11 Spearman ranked correlations between the Fingertip Temperature variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Fingertip Temperature CoefVar	Baseline1	MBI Cy	-0.381	0.0883
Fingertip Temperature CoefVar	Baseline2	MBI Cy	-0.4478	0.0418
Fingertip Temperature StdDev	Baseline1	MBI Cy	-0.389	0.0814
Fingertip Temperature StdDev	Baseline2	MBI Cy	-0.458	0.0368
Fingertip Temperature Mean	(Ch-B2)/B2	MBI Pe	-0.6087	0.0034
Fingertip Temperature Mean	Ch-B2	MBI Pe	-0.5754	0.0064
Fingertip Temperature StdDev	Recovery	STAI Y1 Pr	-0.3762	0.0928
Fingertip Temperature CoefVar	(Ch-B2)/B2	STAI Y2	0.3997	0.0726
Fingertip Temperature CoefVar	Baseline2	STAI Y2	-0.4758	0.0293
Fingertip Temperature CoefVar	Ch-B2	STAI Y2	0.4113	0.064
Fingertip Temperature StdDev	(Ch-B2)/B2	STAI Y2	0.4337	0.0495
Fingertip Temperature StdDev	Baseline2	STAI Y2	-0.5219	0.0152
Fingertip Temperature StdDev	Ch-B2	STAI Y2	0.4514	0.04
Fingertip Temperature CoefVar	(Ch-B2)/B2	STAI Y2 Pr	0.4265	0.0539
Fingertip Temperature CoefVar	Baseline2	STAI Y2 Pr	-0.528	0.0139
Fingertip Temperature CoefVar	Ch-B2	STAI Y2 Pr	0.429	0.0523
Fingertip Temperature StdDev	(Ch-B2)/B2	STAI Y2 Pr	0.4596	0.0361
Fingertip Temperature StdDev	Baseline2	STAI Y2 Pr	-0.5705	0.0069
Fingertip Temperature StdDev	Ch-B2	STAI Y2 Pr	0.4712	0.0311

StdDev – Standard deviation, CoefVar – Coefficient of variation, MBI – Maslach Burnout Inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State anxiety, Y2 – Trait anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response.

Mean Temperature

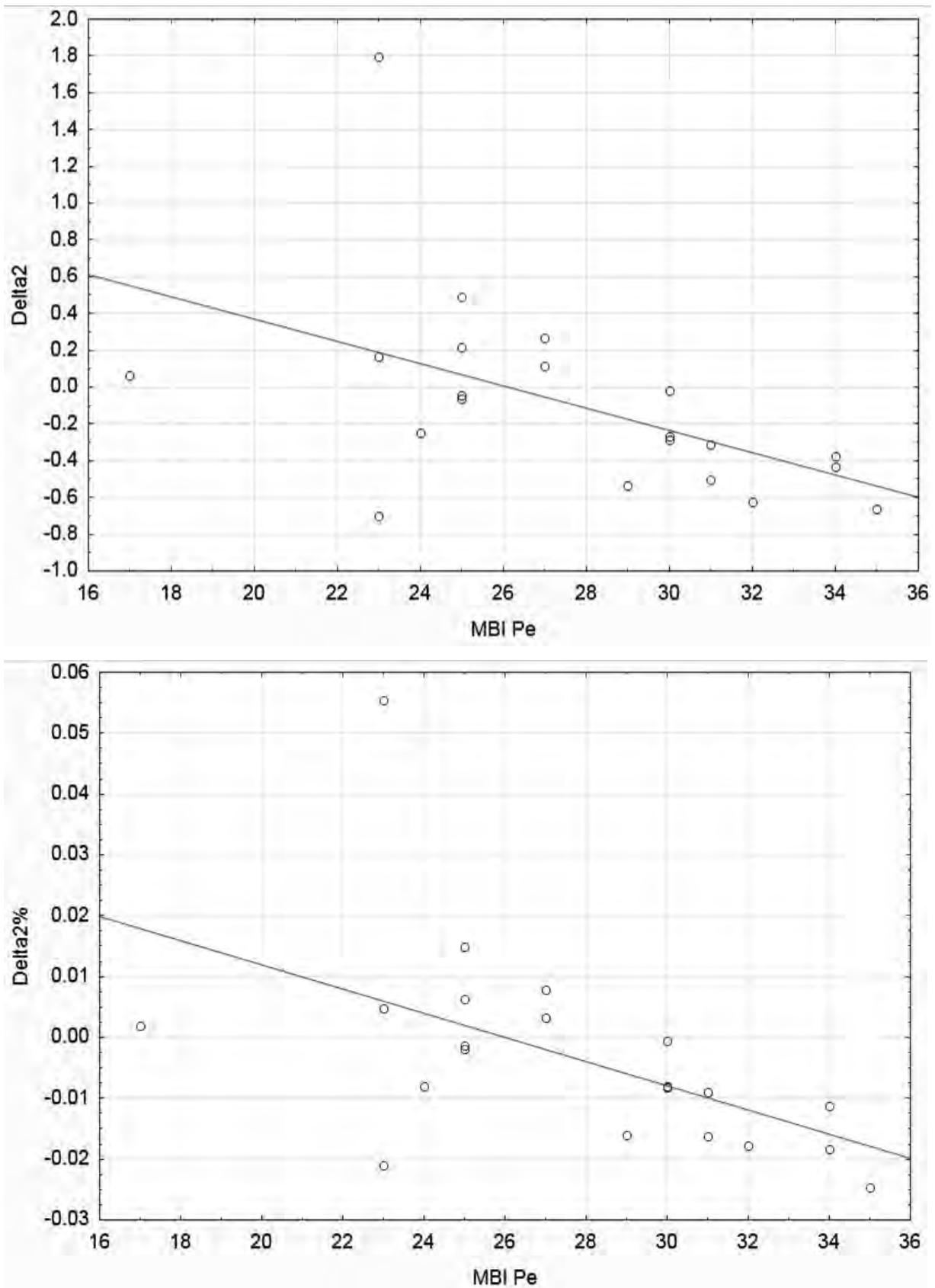
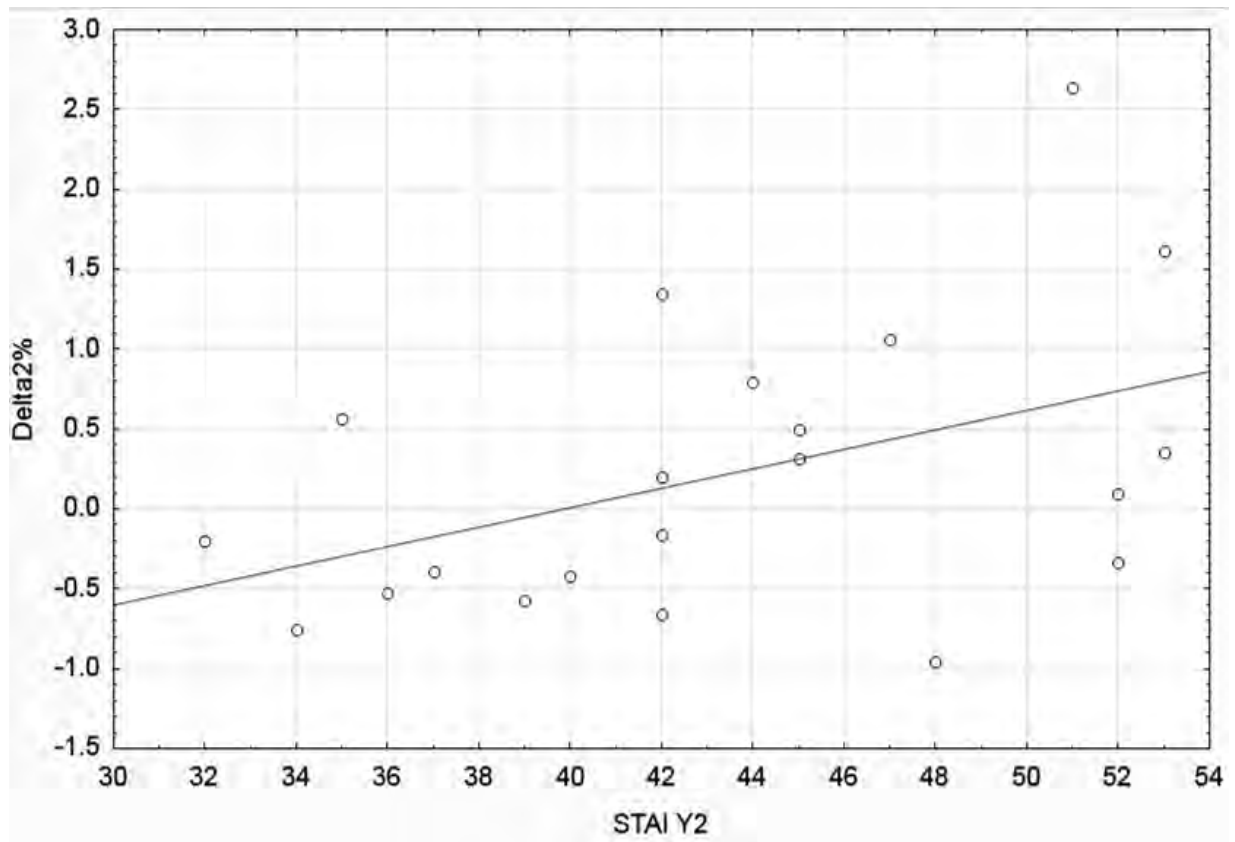
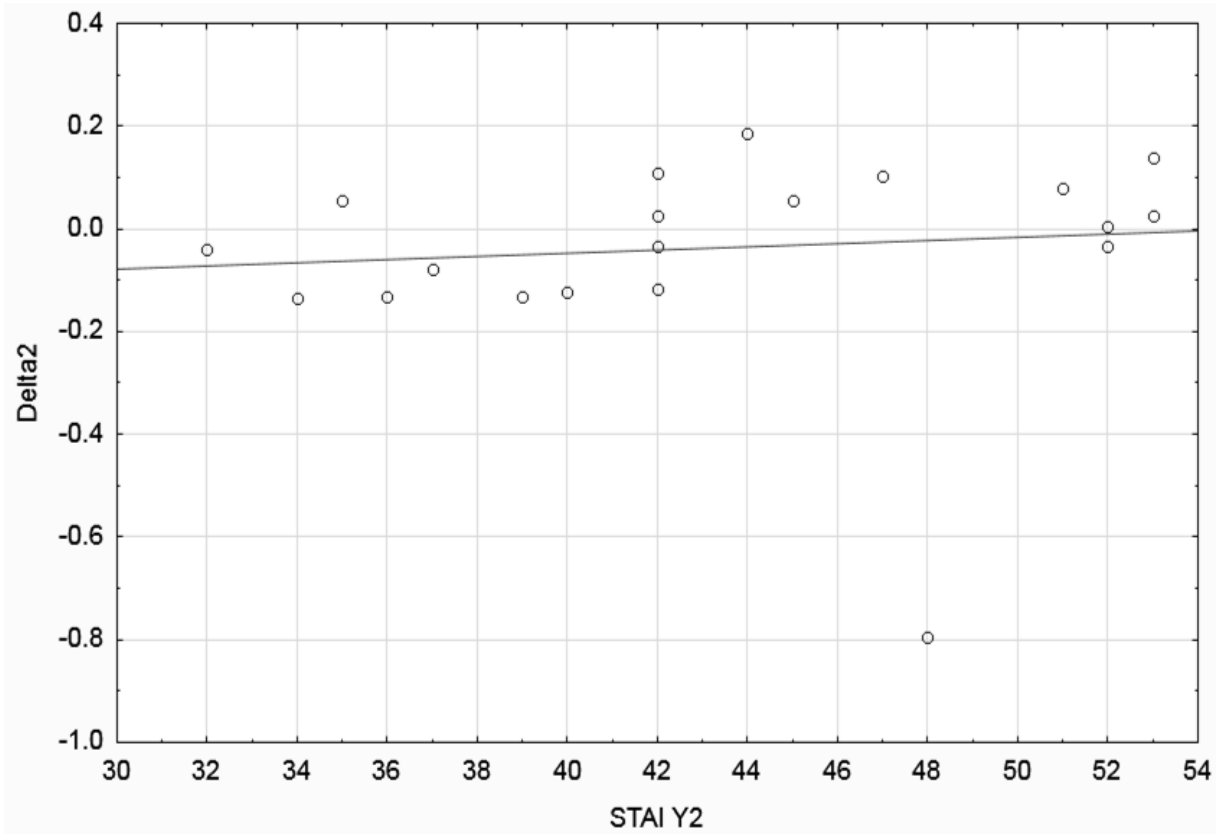


Figure 6.19 Scatterplots of Mean Temperature response and MBI Professional efficacy.



Temperature Standard Deviation



Temperature Standard Deviation

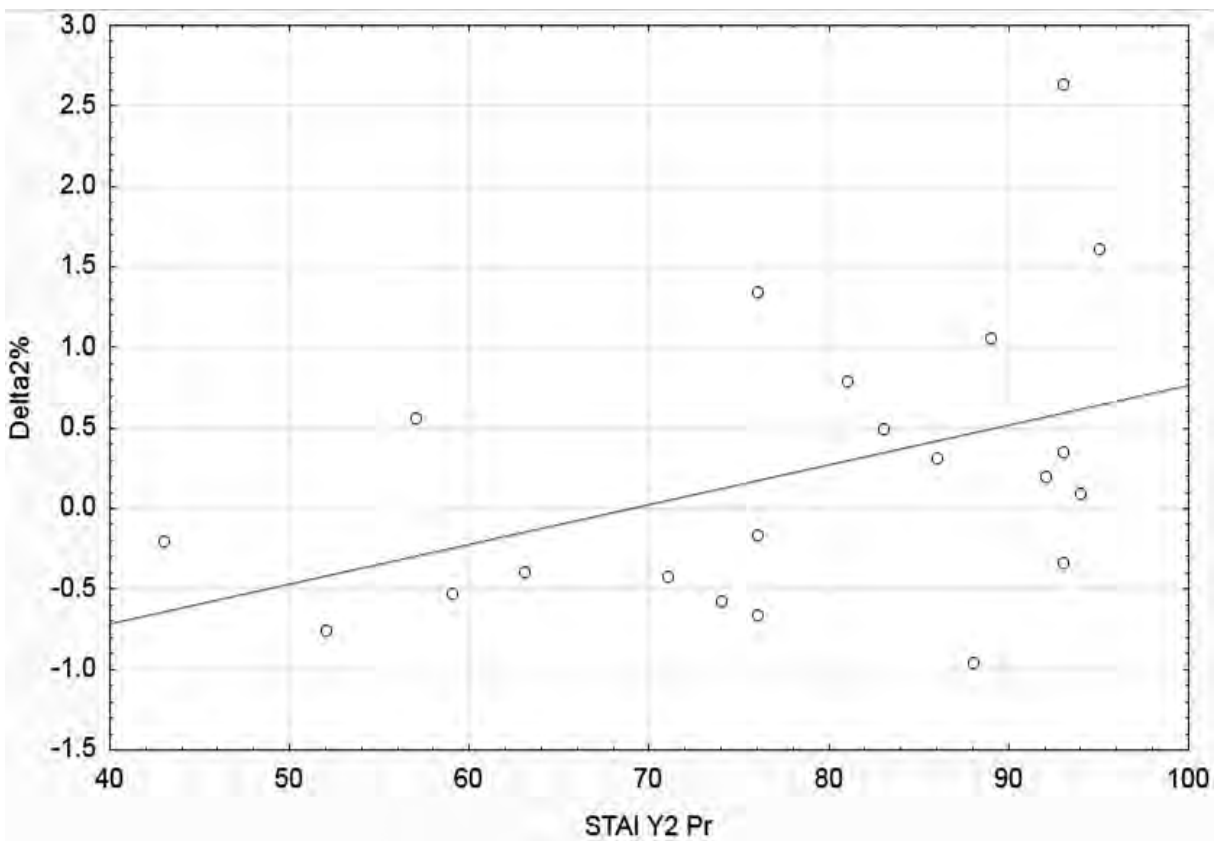
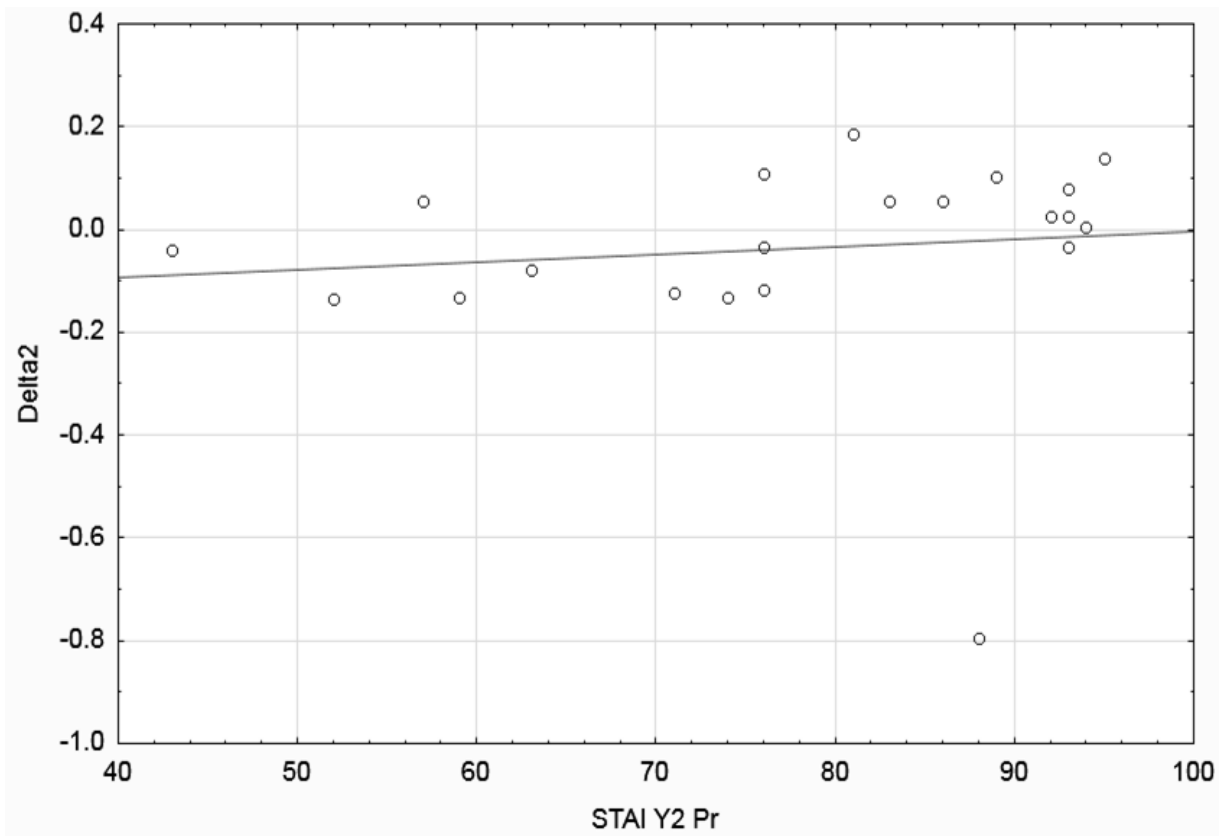


Figure 6.20 Scatterplots of Temperature Standard Deviation response and Trait Anxiety scores.

6.3.8 Pulse Transit Time

Table 6.12 Spearman ranked correlations between the Pulse Transit Time variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Pulse Transit Time CoefVar	Baseline 2	MBI Ex	-0.4044	0.069
Pulse Transit Time Mean	Baseline 1	MBI Ex	-0.3755	0.0935
Pulse Transit Time Mean	Recovery	MBI Ex	-0.4003	0.0722
Pulse Transit Time StdDev	Baseline 2	MBI Ex	-0.4263	0.054
Pulse Transit Time CoefVar	Baseline 1	MBI Pe	0.4879	0.0248
Pulse Transit Time StdDev	Baseline 1	MBI Pe	0.3694	0.0993
Pulse Transit Time CoefVar	Baseline 2	STAI Y1 Pr	-0.4082	0.0662
Pulse Transit Time CoefVar	Challenge	STAI Y1 Pr	-0.4094	0.0654
Pulse Transit Time StdDev	Baseline 2	STAI Y1 Pr	-0.3884	0.0818
Pulse Transit Time CoefVar	Baseline 2	STAI Y2	-0.46	0.0359
Pulse Transit Time Mean	Recovery	STAI Y2	-0.3711	0.0977
Pulse Transit Time StdDev	Baseline 2	STAI Y2	-0.5086	0.0185
Pulse Transit Time CoefVar	Baseline 2	STAI Y2 Pr	-0.4671	0.0328
Pulse Transit Time StdDev	Baseline 1	STAI Y2 Pr	-0.4206	0.0577
Pulse Transit Time StdDev	Baseline 2	STAI Y2 Pr	-0.5169	0.0164

StdDev – Standard deviation, CoefVar – Coefficient of variation, MBI – Maslach Burnout Inventory, Ex – Exhaustion subscale, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State anxiety, Y2 – Trait anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response.

6.3.9 Respiration Rate and Amplitude

Table 6.13 Spearman ranked correlations between the Respiration variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Respiration Amplitude CoefVar	Baseline 1	MBI Pe	0.4014	0.0713
Respiration Amplitude Mean	Baseline 1	MBI Pe	-0.4165	0.0604
Respiration Amplitude Mean	Challenge	MBI Pe	-0.4067	0.0673
Respiration Amplitude CoefVar	Challenge	STAI Y1	0.5259	0.0143
Respiration Amplitude CoefVar	Challenge	STAI Y1 Pr	0.4807	0.0274
Respiration Amplitude CoefVar	Baseline 1	STAI Y2	-0.3737	0.0952
Respiration Amplitude CoefVar	Baseline 2	STAI Y2	-0.4923	0.0234
Respiration Amplitude CoefVar	Ch-B2	STAI Y2	0.4513	0.04
Respiration Amplitude CoefVar	Recovery	STAI Y2	-0.439	0.0465
Respiration Amplitude CoefVar	Baseline 2	STAI Y2 Pr	-0.3984	0.0736
Respiration Rate CoefVar	Recovery	MBI Cy	0.4306	0.0513
Respiration Rate StdDev	Baseline 2	MBI Cy	0.3735	0.0954
Respiration Rate StdDev	Recovery	MBI Cy	0.5756	0.0063
Respiration Rate CoefVar	Baseline 2	MBI Ex	-0.4226	0.0563
Respiration Rate Mean	Baseline 2	MBI Ex	0.5124	0.0176
Respiration Rate Mean	Recovery	MBI Ex	0.4172	0.0599
Respiration Rate CoefVar	Challenge	STAI Y1	0.3711	0.0977
Respiration Rate StdDev	Challenge	STAI Y1	0.432	0.0505
Respiration Rate StdDev	Challenge	STAI Y1 Pr	0.4027	0.0703

StdDev – Standard deviation, CoefVar – Coefficient of variation, MBI – Maslach Burnout Inventory, Cy – Cynicism subscale, Ex – Exhaustion subscale, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State anxiety, Y2 – Trait anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

Respiration Amplitude Coefficient of Variation

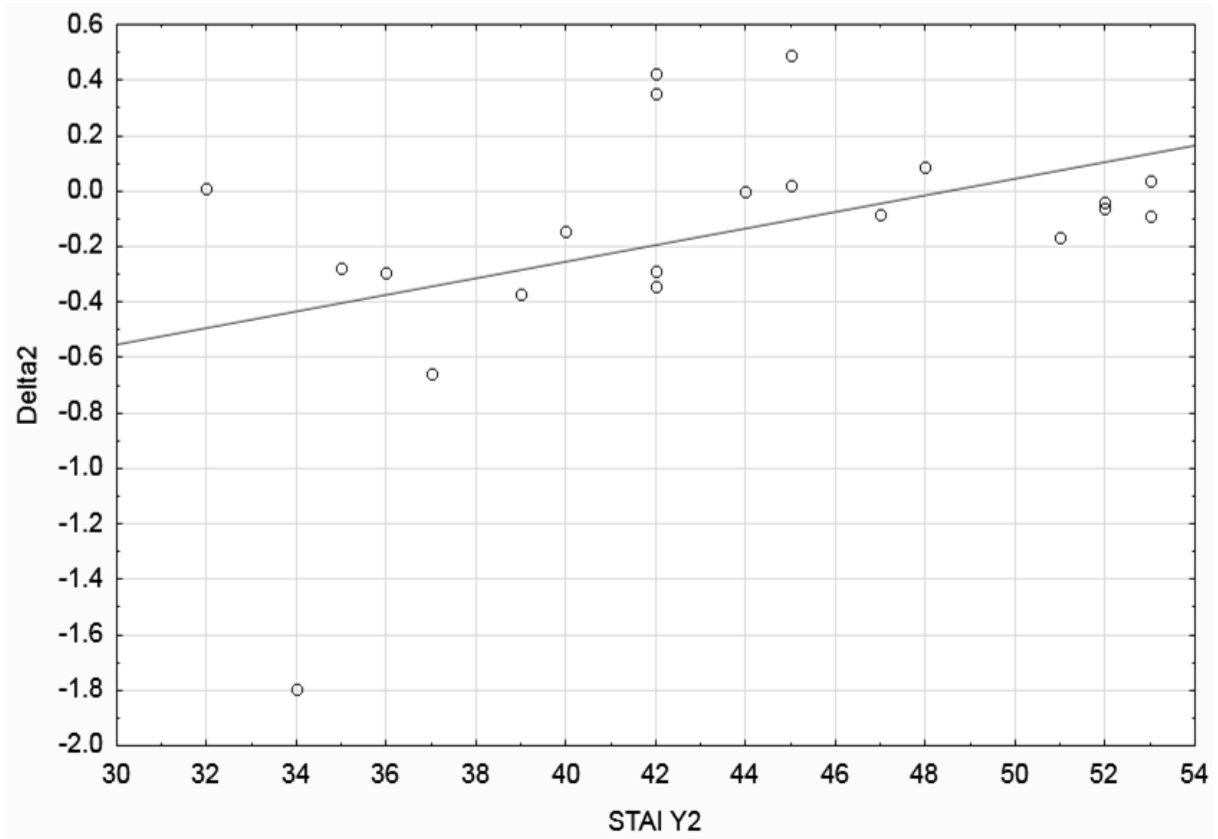


Figure 6.21 Scatterplot of Respiration Amplitude Coefficient of Variation response and Trait Anxiety scores.

6.3.10 Skin Conductivity

Table 6.14 Spearman ranked correlations between the Skin Conductivity variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Skin Conductivity CoefVar	Baseline 1	MBI Ex	0.5797	0.0059
Skin Conductivity Mean	Baseline 1	MBI Ex	0.3859	0.084
Skin Conductivity StdDev	Baseline 1	MBI Ex	0.6363	0.0019
Skin Conductivity CoefVar	Recovery	MBI Pe	-0.3967	0.075
Skin Conductivity Mean	Baseline 2	MBI Pe	-0.3759	0.093
Skin Conductivity Mean	Challenge	MBI Pe	-0.4152	0.0613
Skin Conductivity Mean	Recovery	MBI Pe	-0.5257	0.0144
Skin Conductivity StdDev	Challenge	MBI Pe	-0.5597	0.0083
Skin Conductivity StdDev	Recovery	MBI Pe	-0.5664	0.0074
Skin Conductivity CoefVar	(Ch-B2)/B2	STAI Y1	-0.4078	0.0665
Skin Conductivity CoefVar	Ch-B2	STAI Y1	-0.3738	0.0951
Skin Conductivity Mean	(Ch-B2)/B2	STAI Y1	-0.4796	0.0278
Skin Conductivity StdDev	Baseline 2	STAI Y1	0.4662	0.0331
Skin Conductivity CoefVar	(Ch-B2)/B2	STAI Y1 Pr	-0.467	0.0328
Skin Conductivity CoefVar	Baseline 2	STAI Y1 Pr	0.3697	0.099
Skin Conductivity CoefVar	Ch-B2	STAI Y1 Pr	-0.4296	0.0519
Skin Conductivity Mean	(Ch-B2)/B2	STAI Y1 Pr	-0.545	0.0106
Skin Conductivity StdDev	(Ch-B2)/B2	STAI Y1 Pr	-0.4261	0.0541
Skin Conductivity StdDev	Baseline 2	STAI Y1 Pr	0.4888	0.0245
Skin Conductivity CoefVar	(Ch-B2)/B2	STAI Y2	-0.5269	0.0141
Skin Conductivity CoefVar	Baseline 1	STAI Y2	0.3725	0.0963
Skin Conductivity CoefVar	Ch-B2	STAI Y2	-0.4783	0.0283
Skin Conductivity Mean	Baseline 1	STAI Y2	0.5739	0.0065
Skin Conductivity Mean	Baseline 2	STAI Y2	0.5145	0.017
Skin Conductivity Mean	Challenge	STAI Y2	0.4591	0.0363
Skin Conductivity Mean	Recovery	STAI Y2	0.4571	0.0372
Skin Conductivity StdDev	(Ch-B2)/B2	STAI Y2	-0.448	0.0417
Skin Conductivity StdDev	Baseline 1	STAI Y2	0.6788	0.0007
Skin Conductivity StdDev	Baseline 2	STAI Y2	0.5374	0.012
Skin Conductivity CoefVar	(Ch-B2)/B2	STAI Y2 Pr	-0.513	0.0174
Skin Conductivity CoefVar	Ch-B2	STAI Y2 Pr	-0.4951	0.0225
Skin Conductivity Mean	Baseline 1	STAI Y2 Pr	0.5664	0.0074
Skin Conductivity Mean	Baseline 2	STAI Y2 Pr	0.5104	0.0181
Skin Conductivity Mean	Challenge	STAI Y2 Pr	0.4609	0.0355
Skin Conductivity Mean	Recovery	STAI Y2 Pr	0.4766	0.029
Skin Conductivity StdDev	(Ch-B2)/B2	STAI Y2 Pr	-0.4492	0.0411
Skin Conductivity StdDev	Baseline 1	STAI Y2 Pr	0.6042	0.0037
Skin Conductivity StdDev	Baseline 2	STAI Y2 Pr	0.4912	0.0237
Skin Conductivity StdDev	Recovery	STAI Y2 Pr	0.3706	0.0982

StdDev – Standard deviation, CoefVar – Coefficient of variation, MBI – Maslach Burnout Inventory, Cy – Cynicism subscale, Ex – Exhaustion subscale, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State anxiety, Y2 – Trait anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

Skin Conductivity Standard Deviation

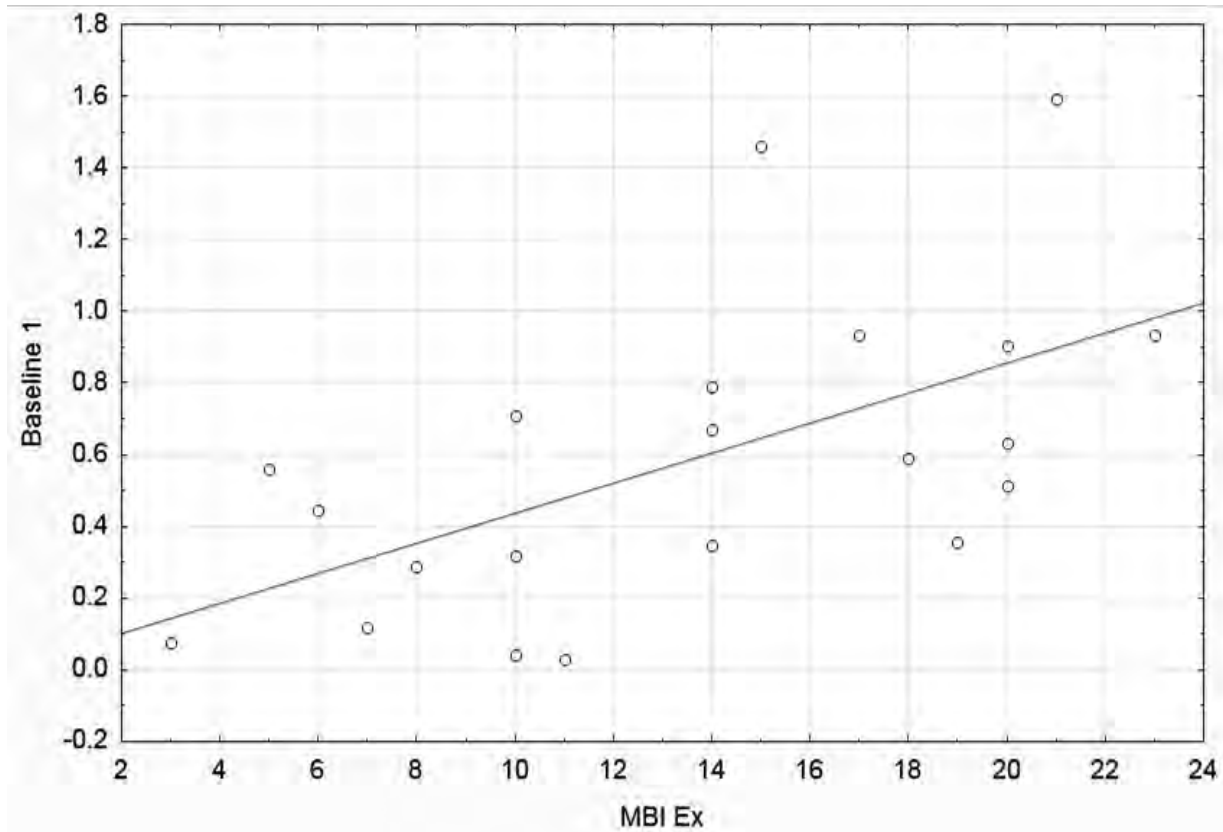


Figure 6.22 Scatterplot of Skin Conductivity Standard Deviation at Baseline 1 and MBI Exhaustion scores.

Mean Skin Conductivity

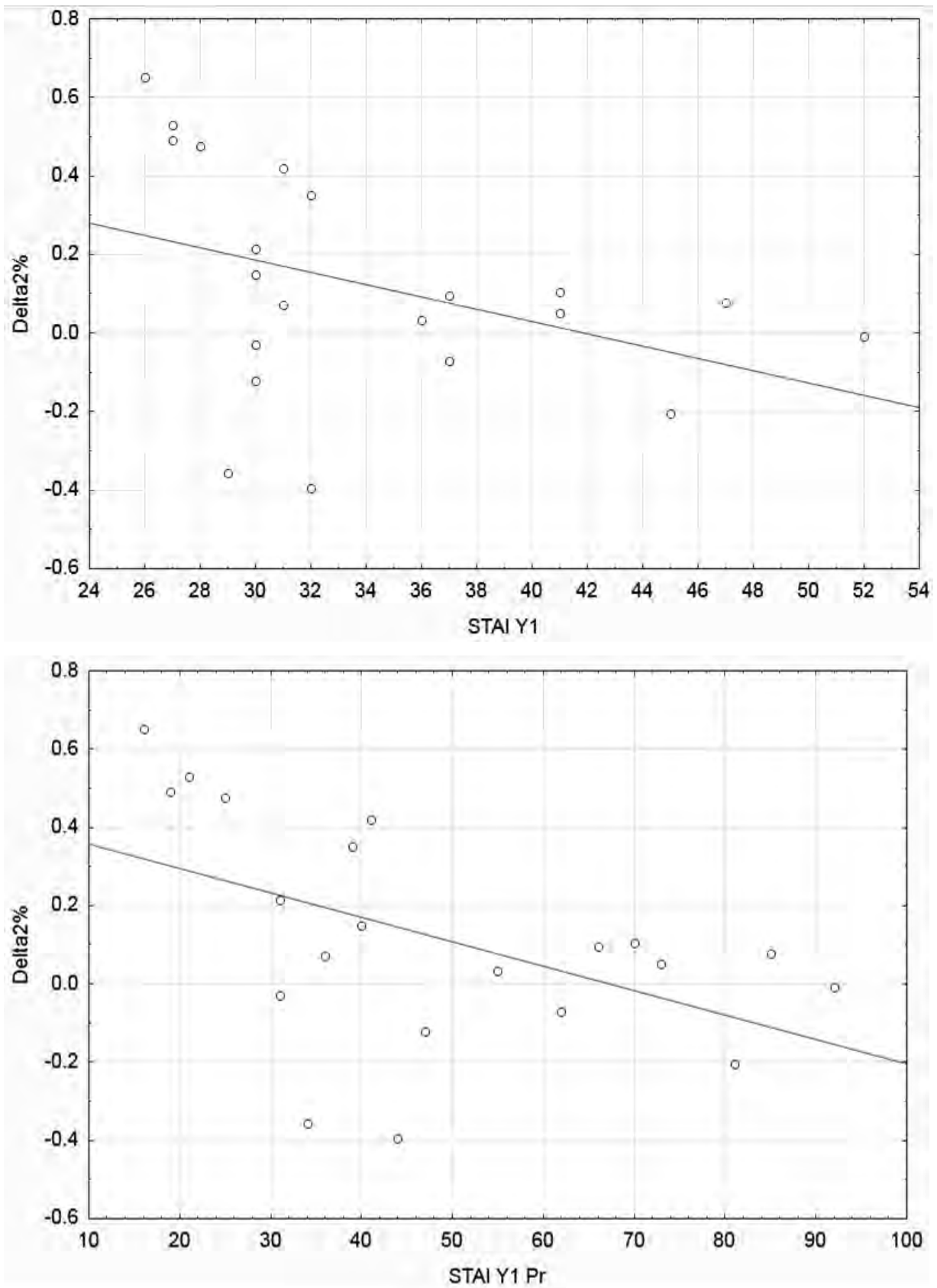


Figure 6.23 Scatterplots of Mean Skin Conductivity response and State Anxiety scores.

Skin Conductivity Coefficient of Variation

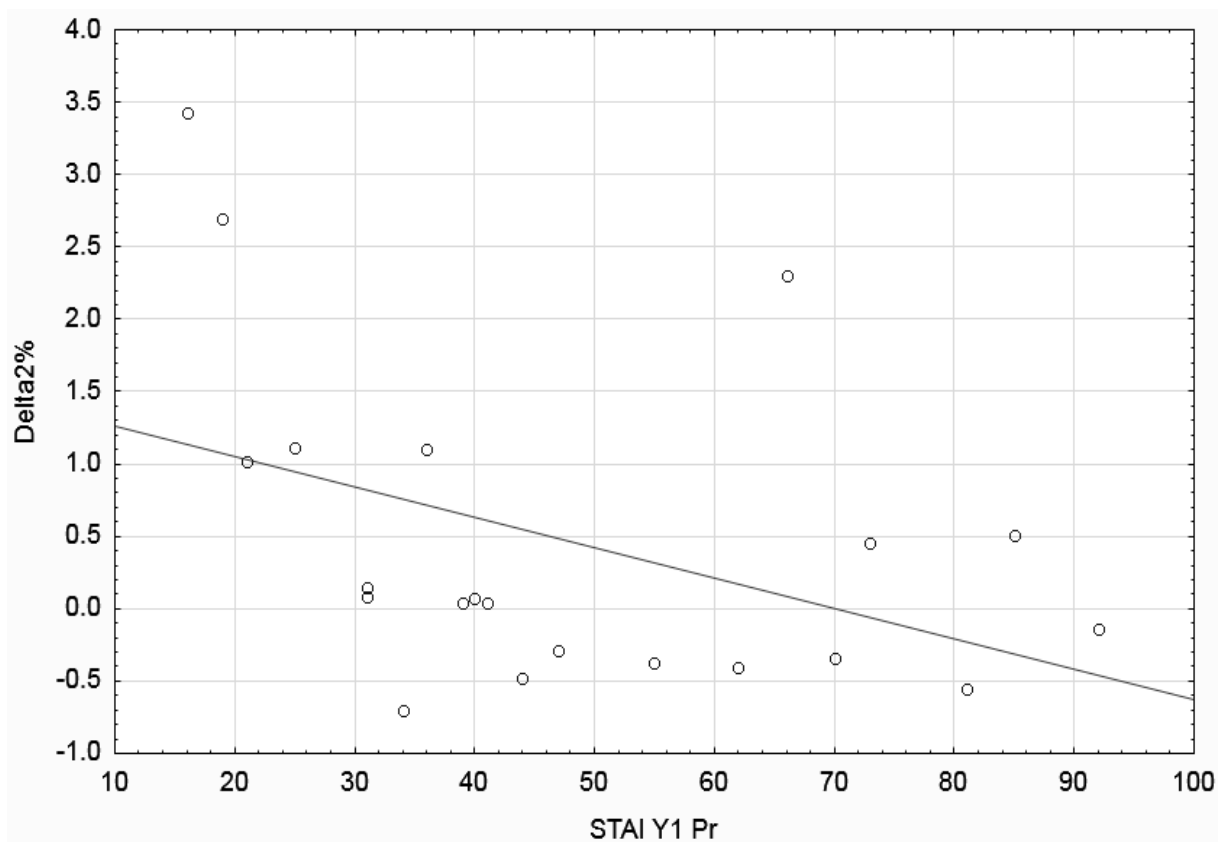
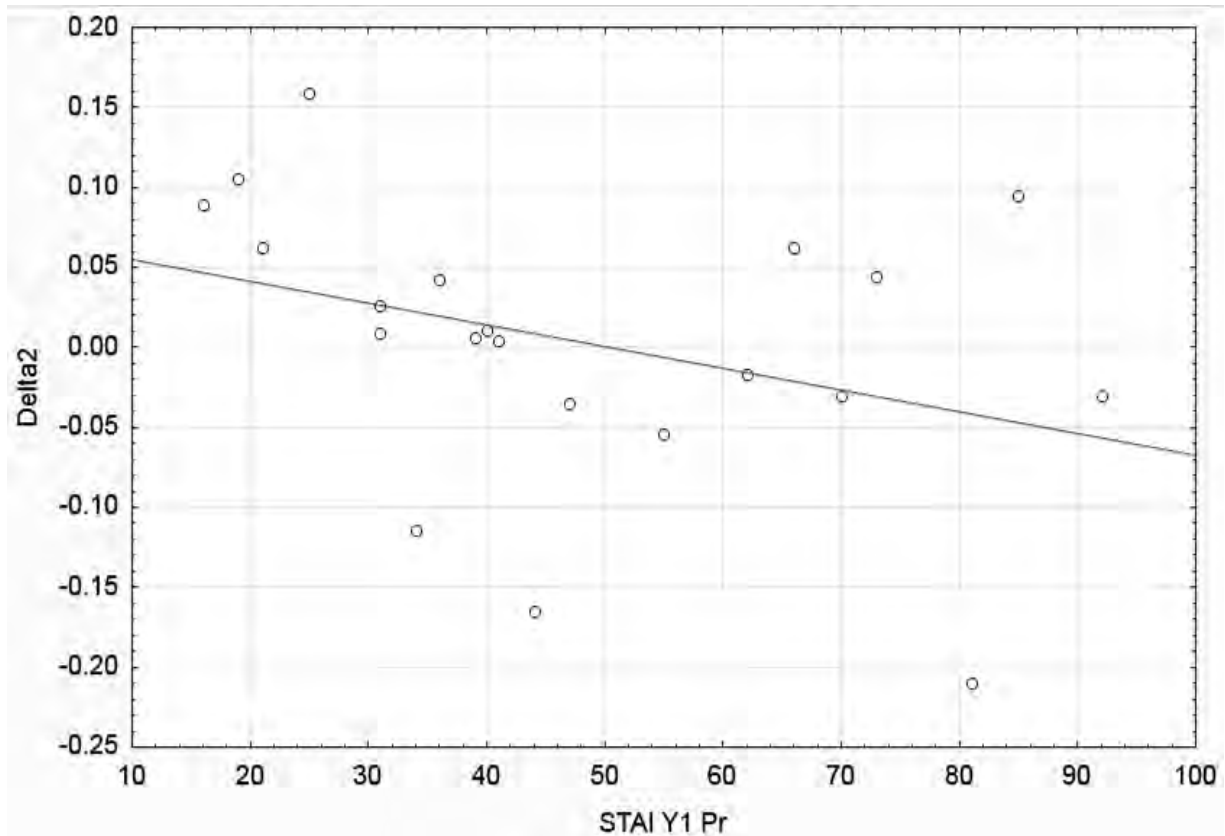


Figure 6.24 Scatterplots of Skin Conductivity Coefficient of Variation response and State Anxiety scores.

Skin Conductivity Standard Deviation

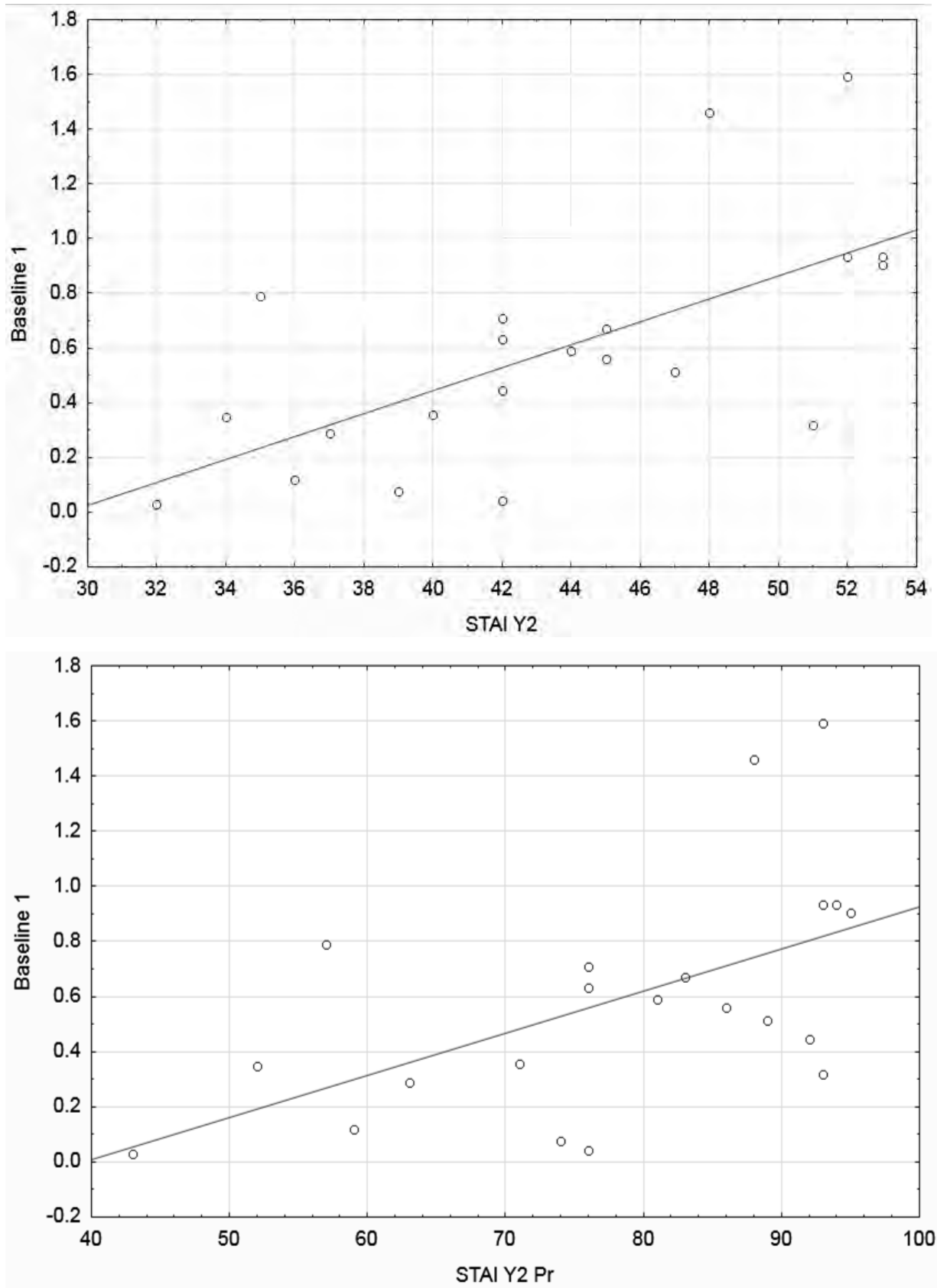
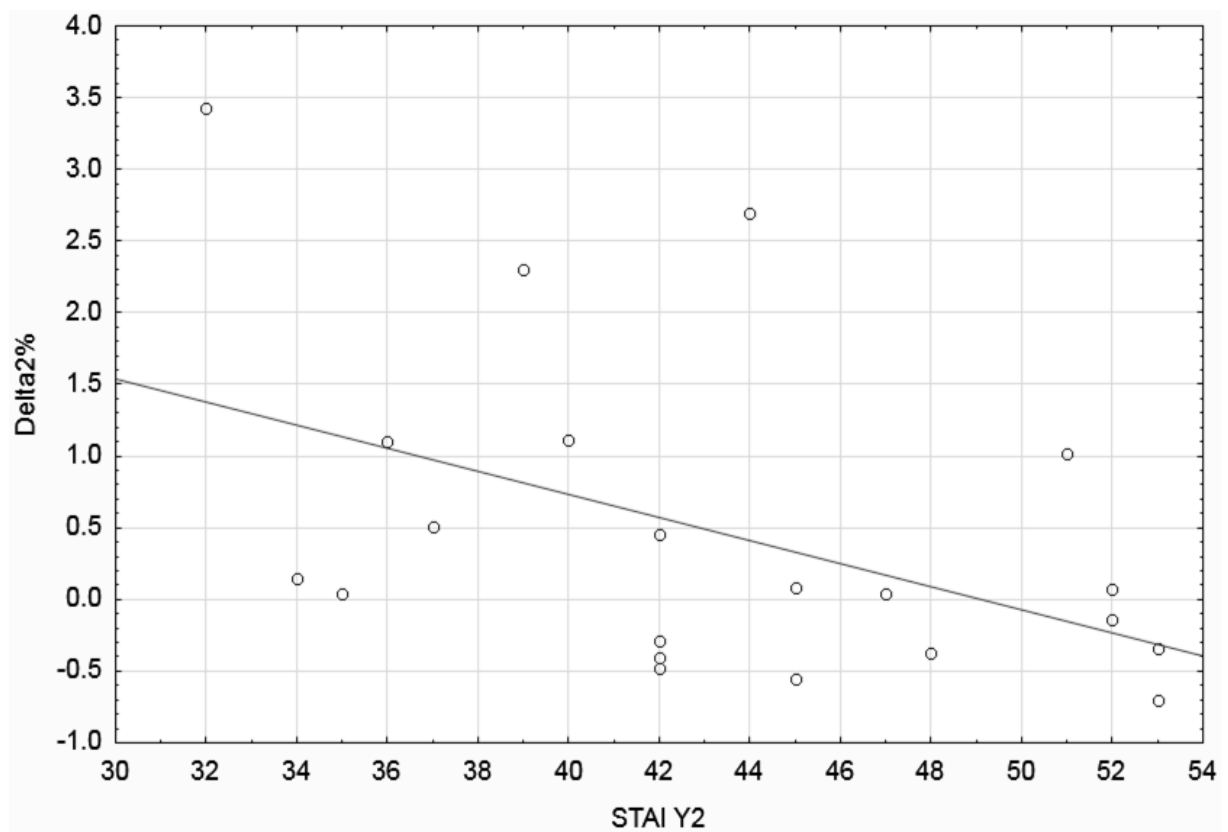
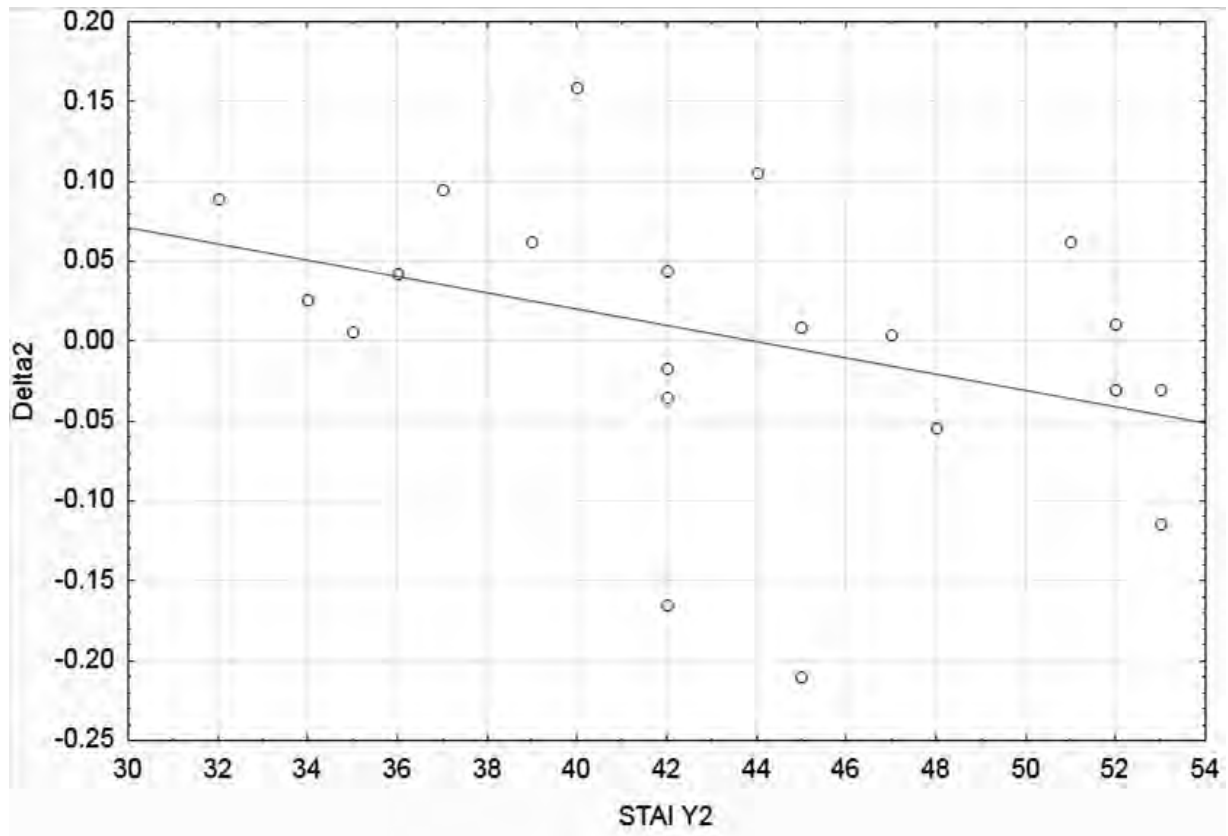


Figure 6.25 Scatterplots of Skin Conductivity Standard Deviation at Baseline 1 and Trait Anxiety scores.

Skin Conductivity Coefficient of Variation



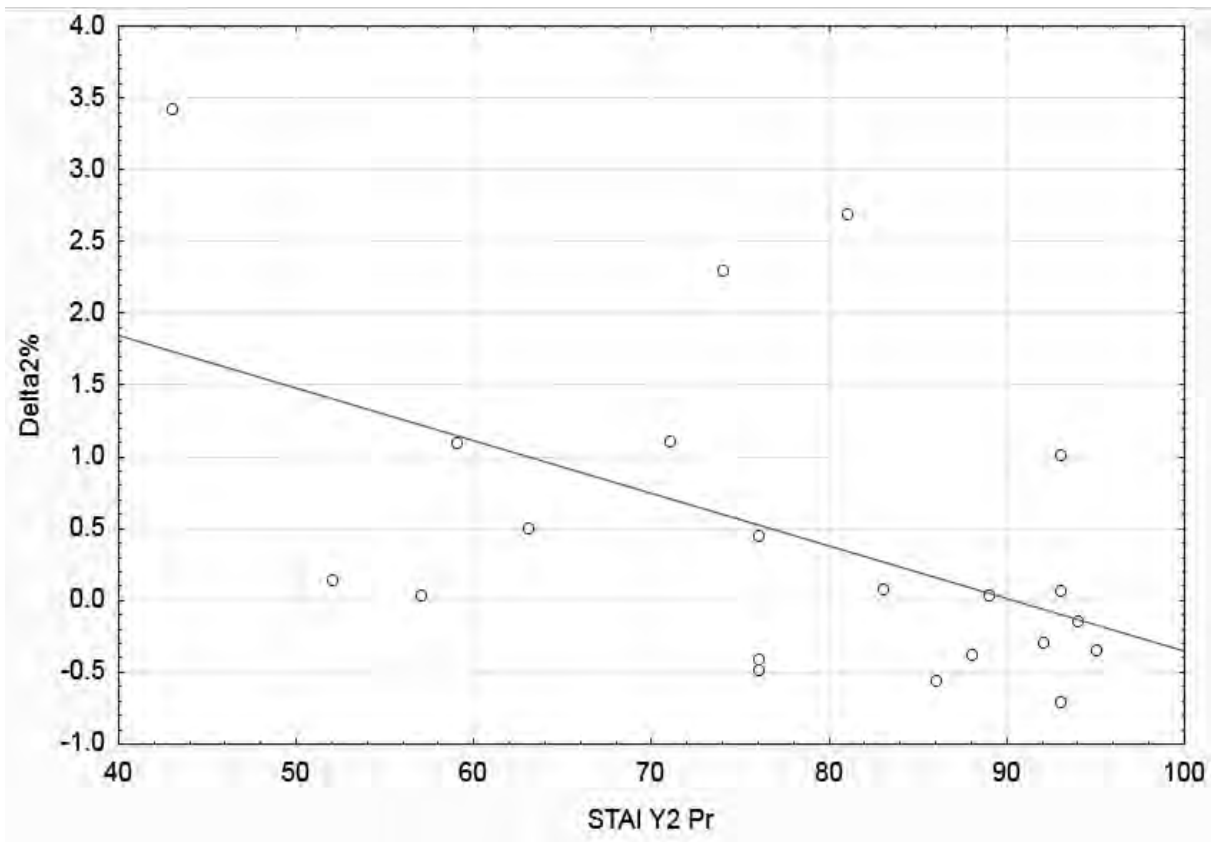
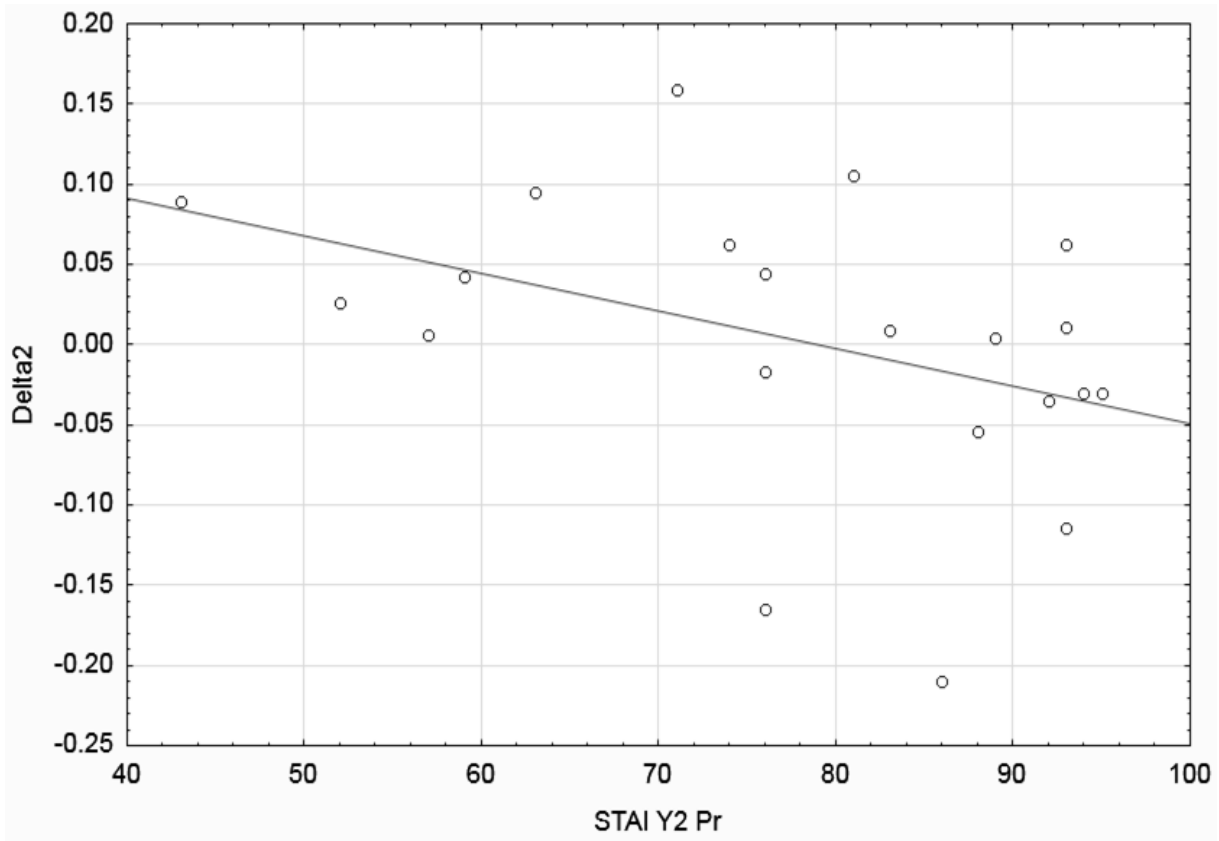


Figure 6.26 Scatterplots of Skin Conductivity Coefficient of Variation response and Trait Anxiety scores.

Skin Conductivity Standard Deviation

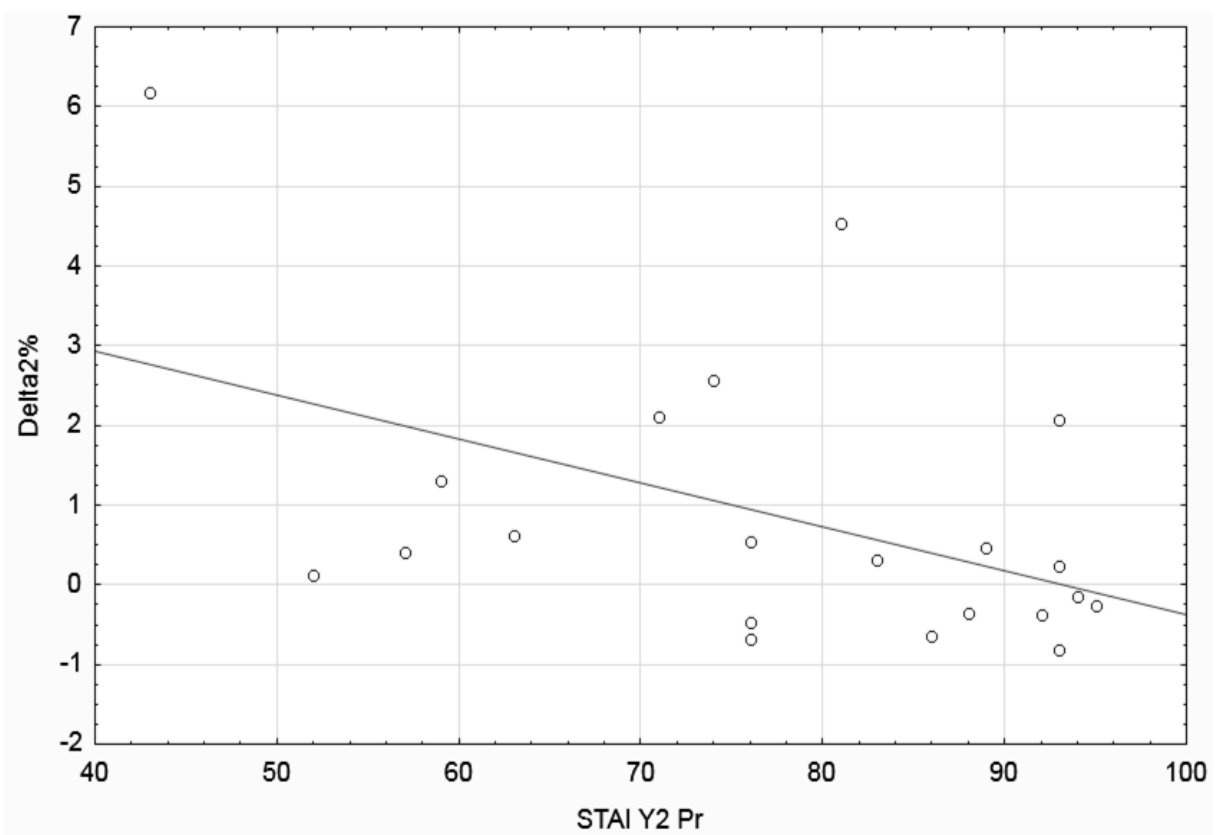
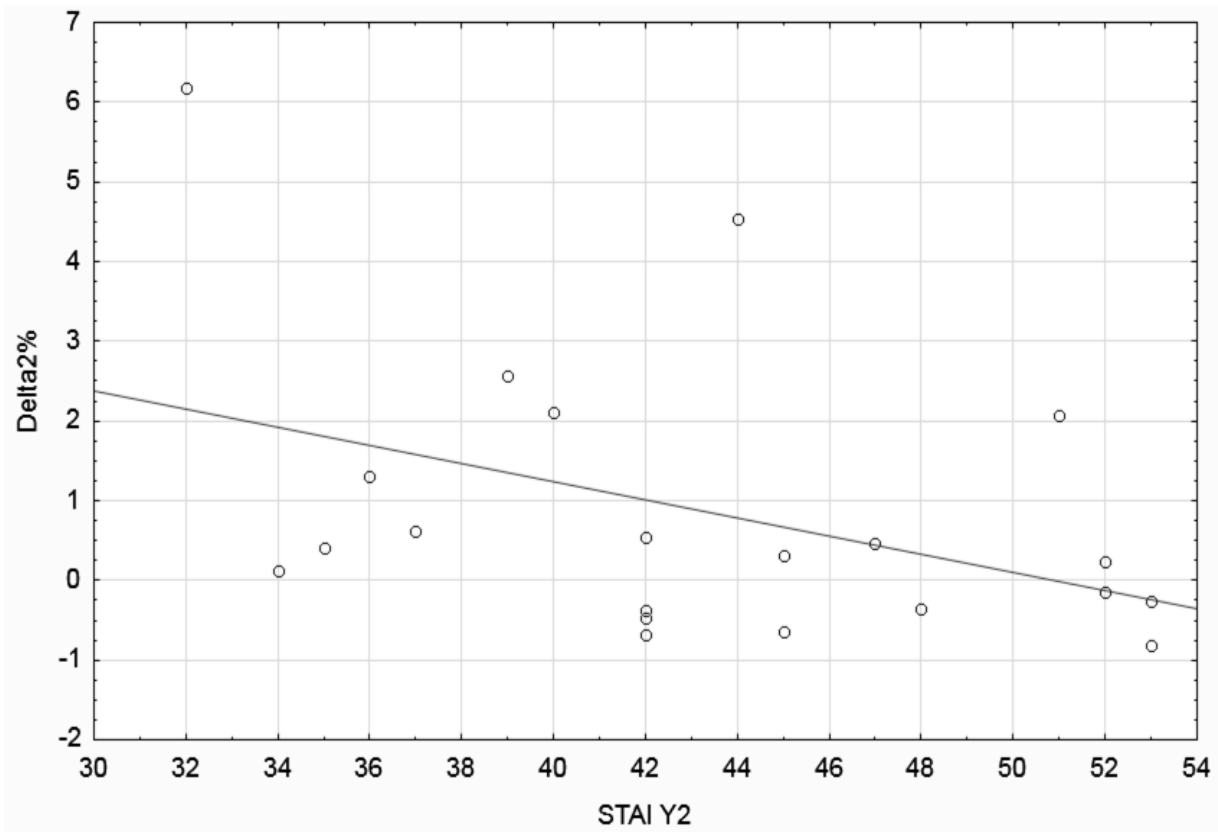


Figure 6.27 Scatterplots of Skin Conductivity Standard Deviation response and Trait Anxiety.

6.3.11 EEG – Delta Rhythm

Table 6.15 Spearman ranked correlations between the EEG Delta % Power variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Left Delta%Power StdDev	Baseline 1	MBI Cy	-0.3774	0.0917
Right Delta%PowerCoefVar	Baseline 1	MBI Cy	0.4022	0.0707
Left Delta%Power Mean	(Ch-B2)/B2	MBI Ex	0.4668	0.0329
Left Delta%Power Mean	Challenge	MBI Ex	0.412	0.0635
Left Delta%Power Mean	Ch-B2	MBI Ex	0.4628	0.0346
Right Delta%Power Mean	(Ch-B2)/B2	MBI Ex	0.5072	0.0189
Right Delta%Power Mean	Ch-B2	MBI Ex	0.485	0.0258
Left Delta%Power StdDev	Challenge	STAI Y1	-0.3746	0.0944
Right Delta%Power Mean	Challenge	STAI Y1	-0.4561	0.0377
Right Delta%Power StdDev	Challenge	STAI Y1	-0.4118	0.0637
Right Delta%Power Mean	Challenge	STAI Y1 Pr	-0.369	0.0998
Left Delta%Power Mean	Baseline 2	STAI Y2	0.4004	0.0721
Left Delta%Power StdDev	Recovery	STAI Y2	0.4376	0.0473
Left Delta%Power StdDev	Recovery	STAI Y2 Pr	0.5065	0.0191

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

Mean Left Delta % power

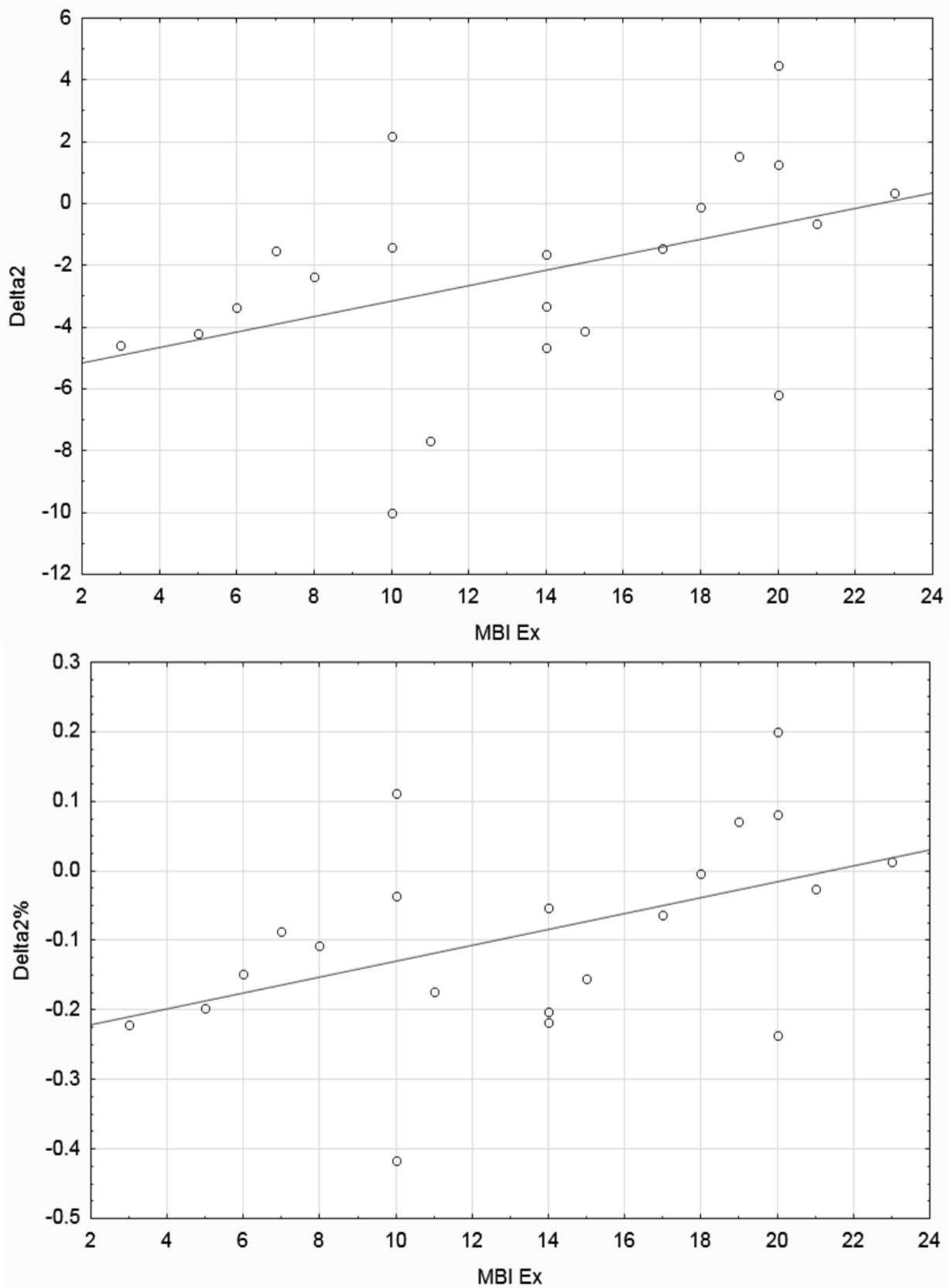


Figure 6.28 Scatterplots of Mean Left Delta% power response and MBI Exhaustion scores.

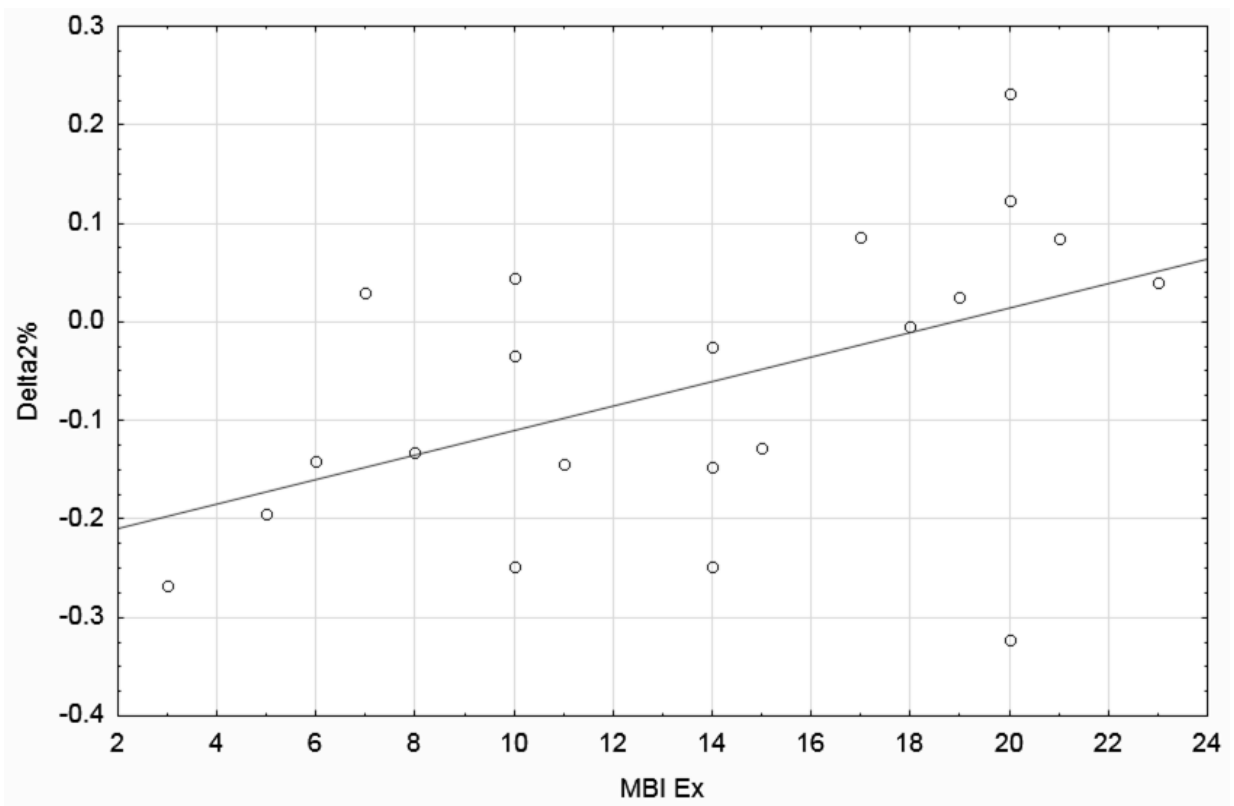
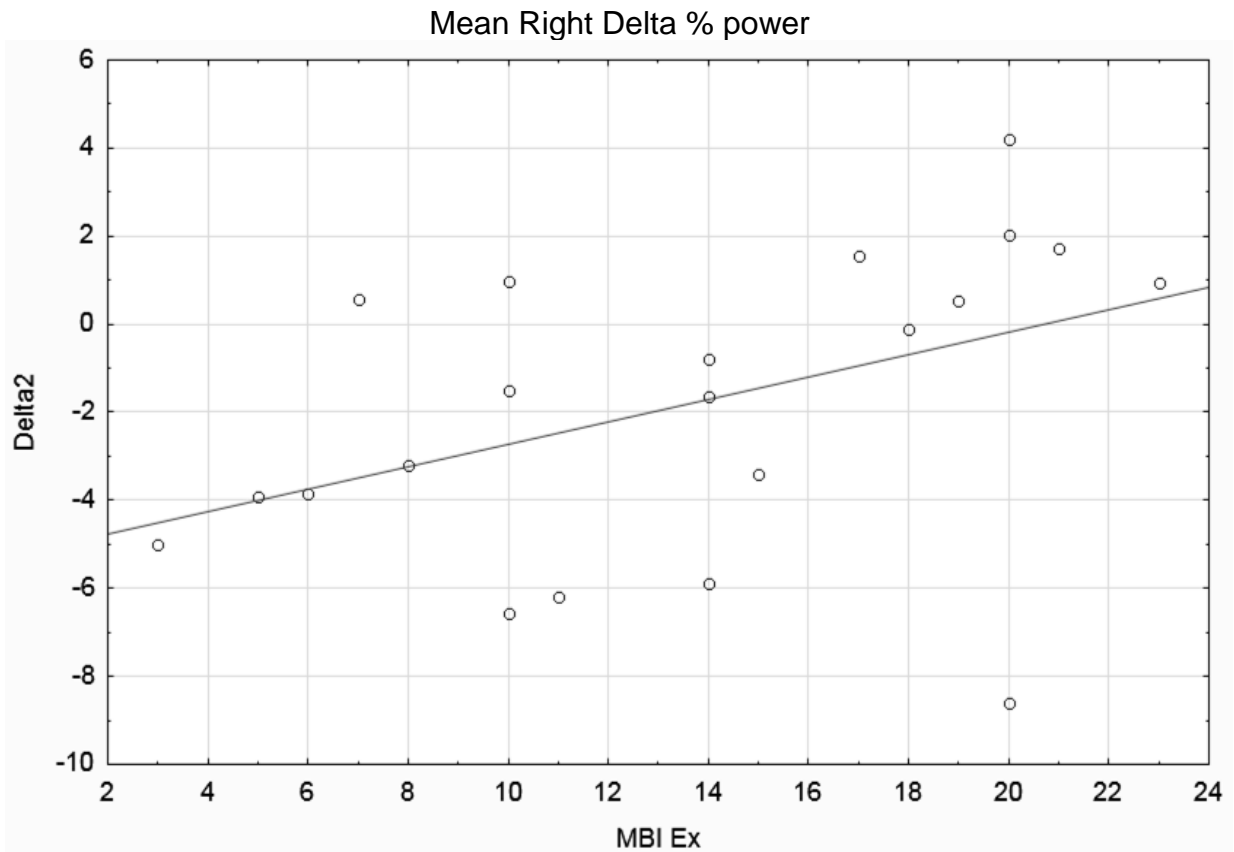


Figure 6.29 Scatterplots of Mean Right Delta% power response and MBI Exhaustion scores.

Table 6.16 Spearman ranked correlations between the EEG Delta Amplitude Asymmetry variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Delta Amplitude Asymmetry StdDev	Challenge	MBI Cy	0.4546	0.0384
Delta Amplitude Asymmetry StdDev	Recovery	MBI Cy	0.5075	0.0188
Delta Amplitude Asymmetry Mean	Ch-B2	MBI Pe	-0.4453	0.0431
Delta Amplitude Asymmetry StdDev	Baseline 1	MBI Pe	-0.4341	0.0493
Delta Amplitude Asymmetry StdDev	Challenge	MBI Pe	-0.4132	0.0626
Delta Amplitude Asymmetry StdDev	Recovery	MBI Pe	-0.4472	0.0421
Delta Amplitude Asymmetry Mean	Challenge	STAI Y1	0.3798	0.0895
Delta Amplitude Asymmetry Mean	Ch-B2	STAI Y1	0.3863	0.0837
Delta Amplitude Asymmetry StdDev	Ch-B2	STAI Y2	0.4121	0.0634
Delta Amplitude Asymmetry StdDev	(Ch-B2)/B2	STAI Y2	0.4024	0.0706
Delta Amplitude Asymmetry StdDev	Ch-B2	STAI Y2 Pr	0.4596	0.0361
Delta Amplitude Asymmetry StdDev	(Ch-B2)/B2	STAI Y2 Pr	0.4505	0.0404

StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response,

Mean Delta Amplitude Asymmetry

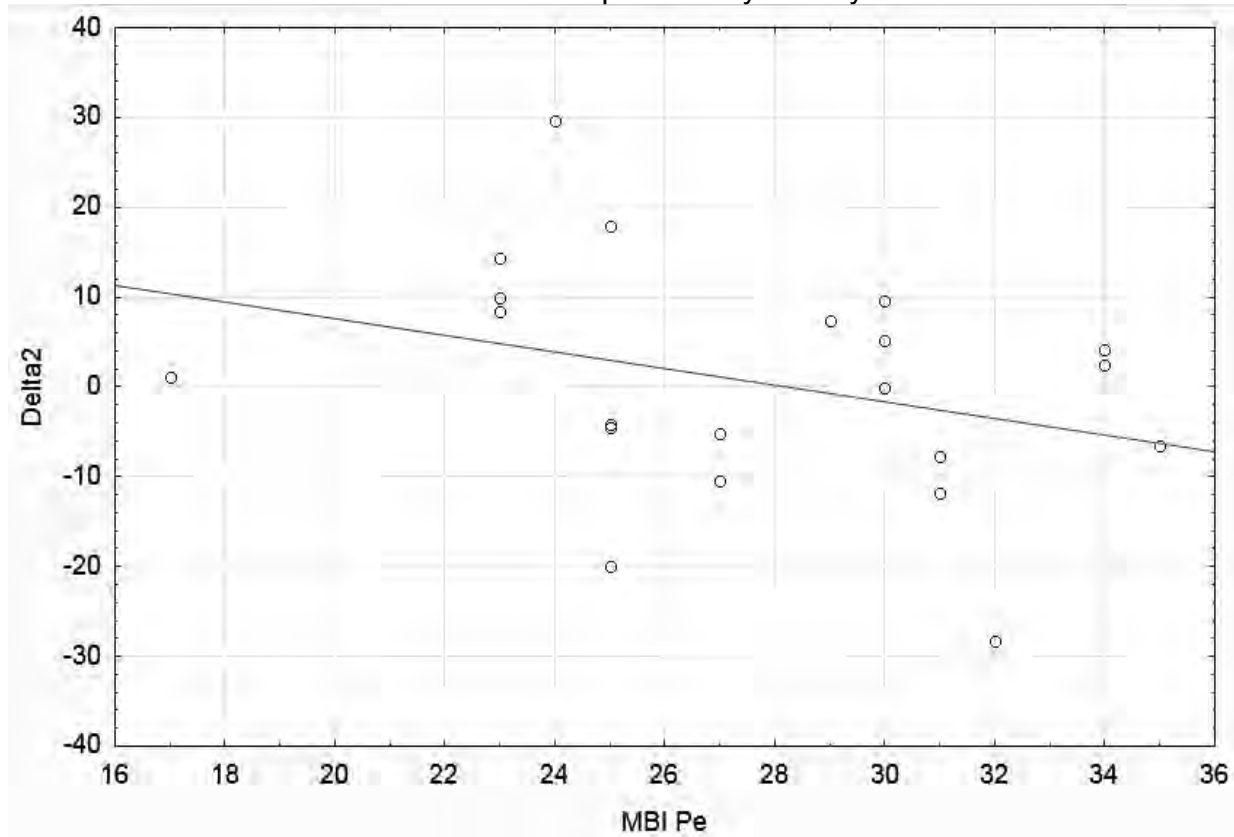


Figure 6.30 Scatterplot of Mean Delta Amplitude Asymmetry response and MBI Professional Efficacy scores.

Table 6.17 Spearman ranked correlations between the EEG Delta Coherence variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Delta Coherence CoefVar	Recovery	MBI Cy	0.373	0.0958
Delta Coherence Mean	Baseline 2	MBI Cy	-0.4035	0.0697
Delta Coherence Mean	Recovery	MBI Cy	-0.4703	0.0315
Delta Coherence StdDev	Recovery	MBI Cy	0.3931	0.0779
Delta Coherence CoefVar	Challenge	MBI Ex	-0.4068	0.0672
Delta Coherence CoefVar	Baseline 2	MBI Pe	-0.3753	0.0937
Delta Coherence CoefVar	Challenge	MBI Pe	-0.4368	0.0477
Delta Coherence CoefVar	Ch-B2	MBI Pe	-0.381	0.0884
Delta Coherence CoefVar	(Ch-B2)/B2	MBI Pe	-0.4283	0.0528
Delta Coherence CoefVar	Recovery	MBI Pe	-0.4361	0.0481
Delta Coherence Mean	Challenge	MBI Pe	0.3779	0.0912
Delta Coherence Mean	Ch-B2	MBI Pe	0.5211	0.0154
Delta Coherence Mean	(Ch-B2)/B2	MBI Pe	0.5133	0.0173
Delta Coherence StdDev	Baseline 2	MBI Pe	-0.5002	0.0209
Delta Coherence StdDev	Challenge	MBI Pe	-0.4662	0.0332
Delta Coherence StdDev	Recovery	MBI Pe	-0.4322	0.0504

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response,

Mean Delta Coherence

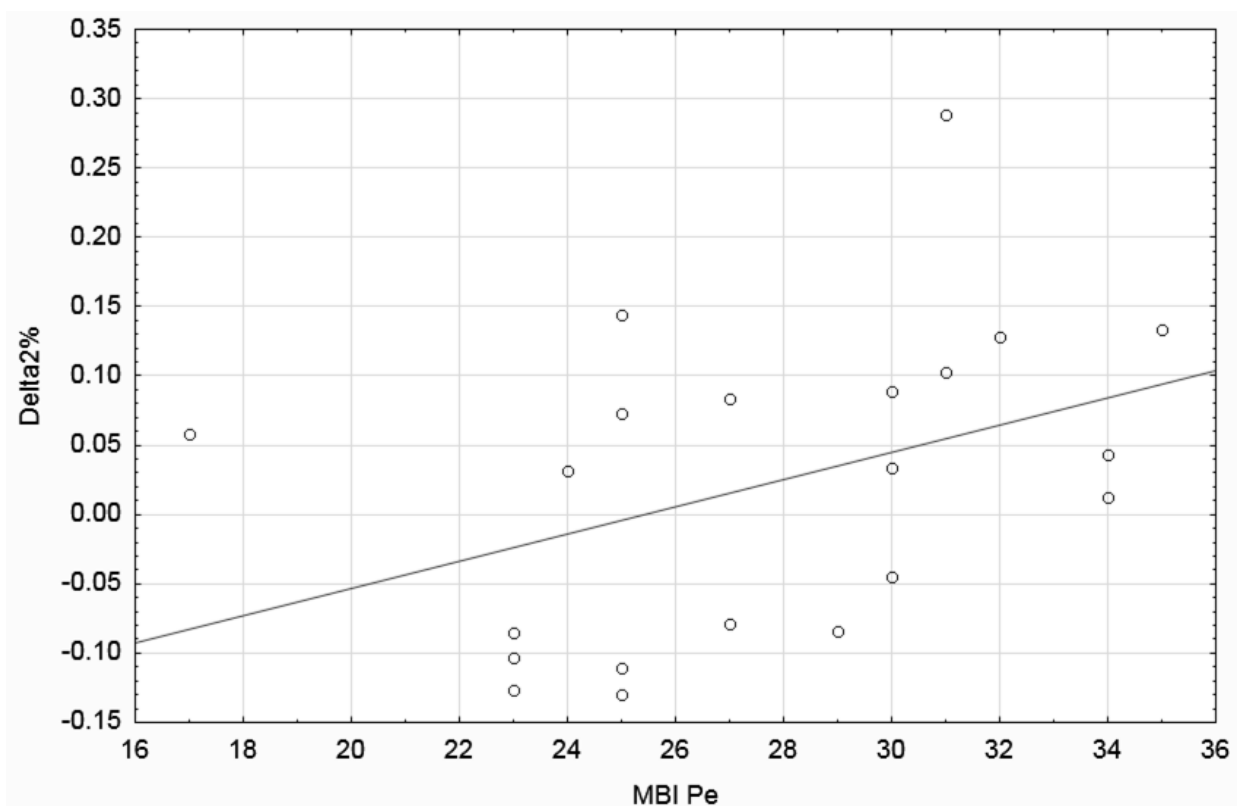
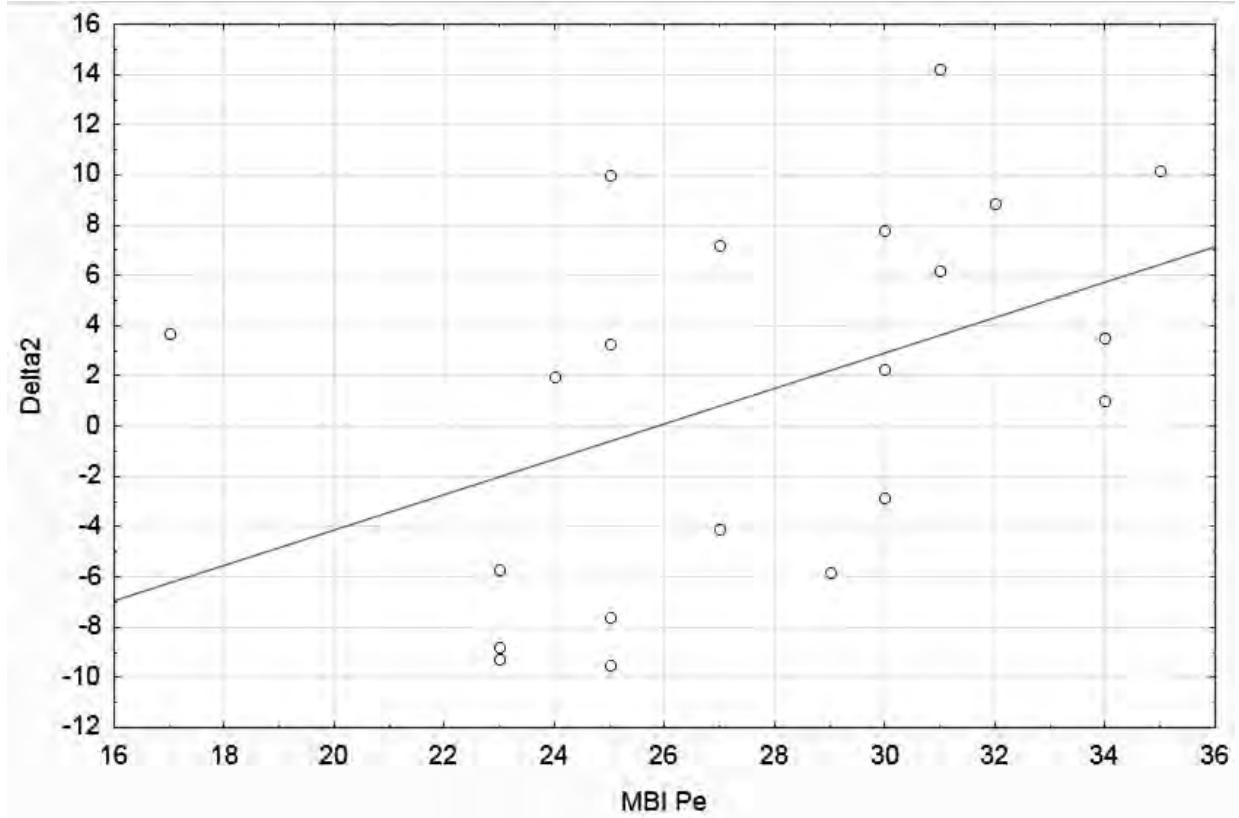


Figure 6.32 Scatterplots of the Mean Delta Coherence response and MBI Professional Efficacy scores.

Table 6.18 Spearman ranked correlations between the EEG Delta Phase variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Delta Phase Mean	Baseline 1	MBI Ex	0.4081	0.0663
Delta Phase StdDev	Challenge	MBI Ex	-0.4198	0.0581
Delta Phase StdDev	(Ch-B2)/B2	MBI Pe	-0.3949	0.0764
Delta Phase StdDev	Challenge	MBI Pe	-0.4041	0.0693
Delta Phase StdDev	Recovery	MBI Pe	-0.3929	0.078
Delta Phase Mean	Baseline 1	STAI Y1	-0.4	0.0724
Delta Phase Mean	Baseline 2	STAI Y1	-0.5605	0.0082
Delta Phase Mean	Challenge	STAI Y1	-0.402	0.0709
Delta Phase Mean	Baseline 1	STAI Y1 Pr	-0.4313	0.0509
Delta Phase Mean	Baseline 2	STAI Y1 Pr	-0.6132	0.0031
Delta Phase Mean	Challenge	STAI Y1 Pr	-0.4644	0.0339
Delta Phase Mean	(Ch-B2)/B2	STAI Y2	0.4343	0.0492
Delta Phase Mean	(Ch-B2)/B2	STAI Y2 Pr	0.4961	0.0222

StdDev – Standard deviation, MBI – Maslach Burnout inventory, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response,

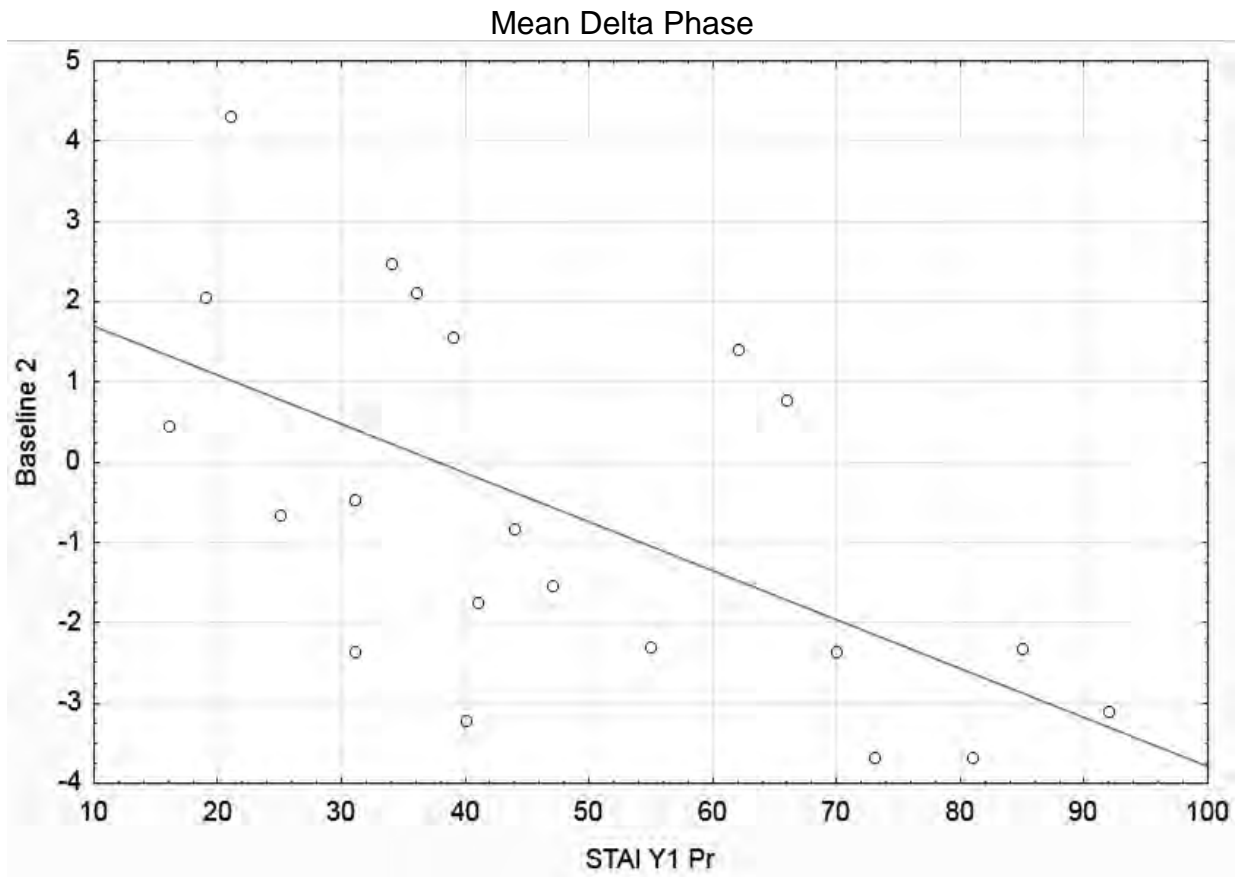


Figure 6.33 Scatterplot of Mean Delta Phase at Baseline 2 and State Anxiety scores.

Mean Delta Phase

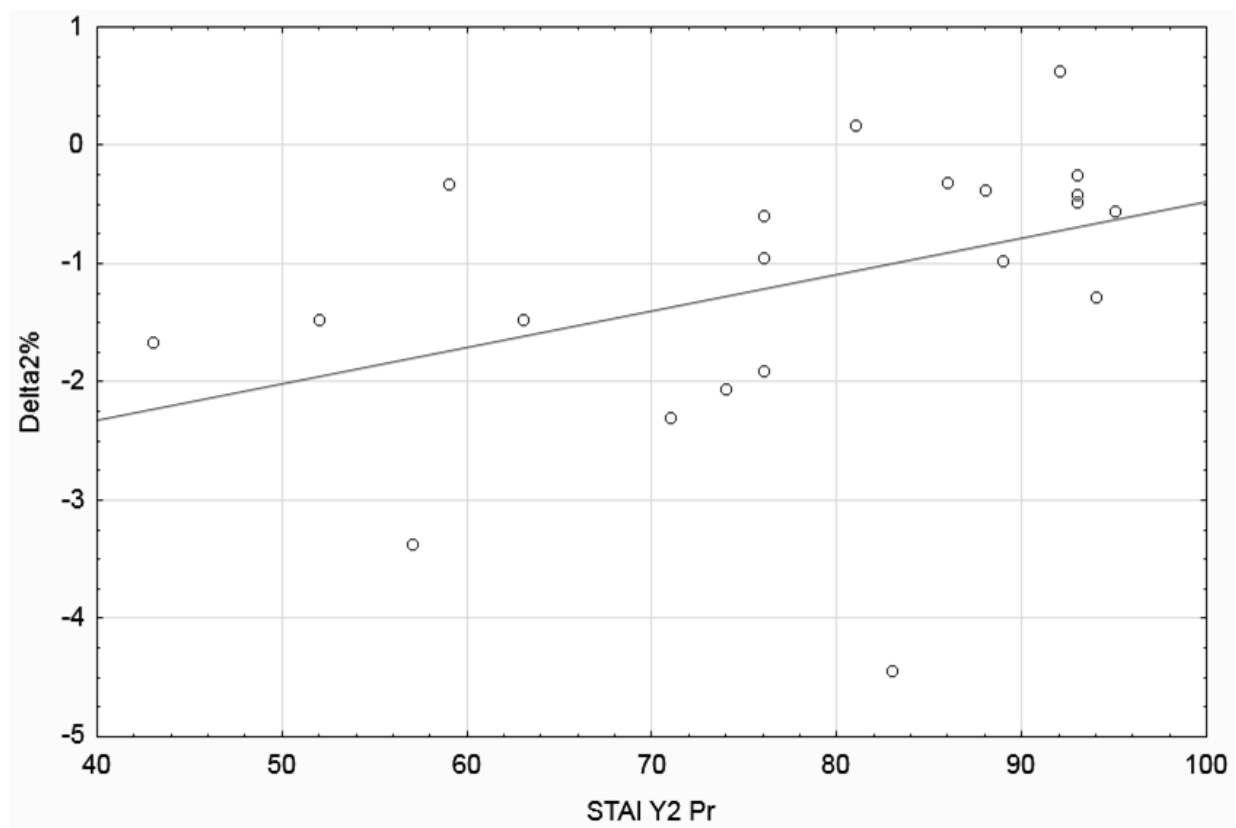
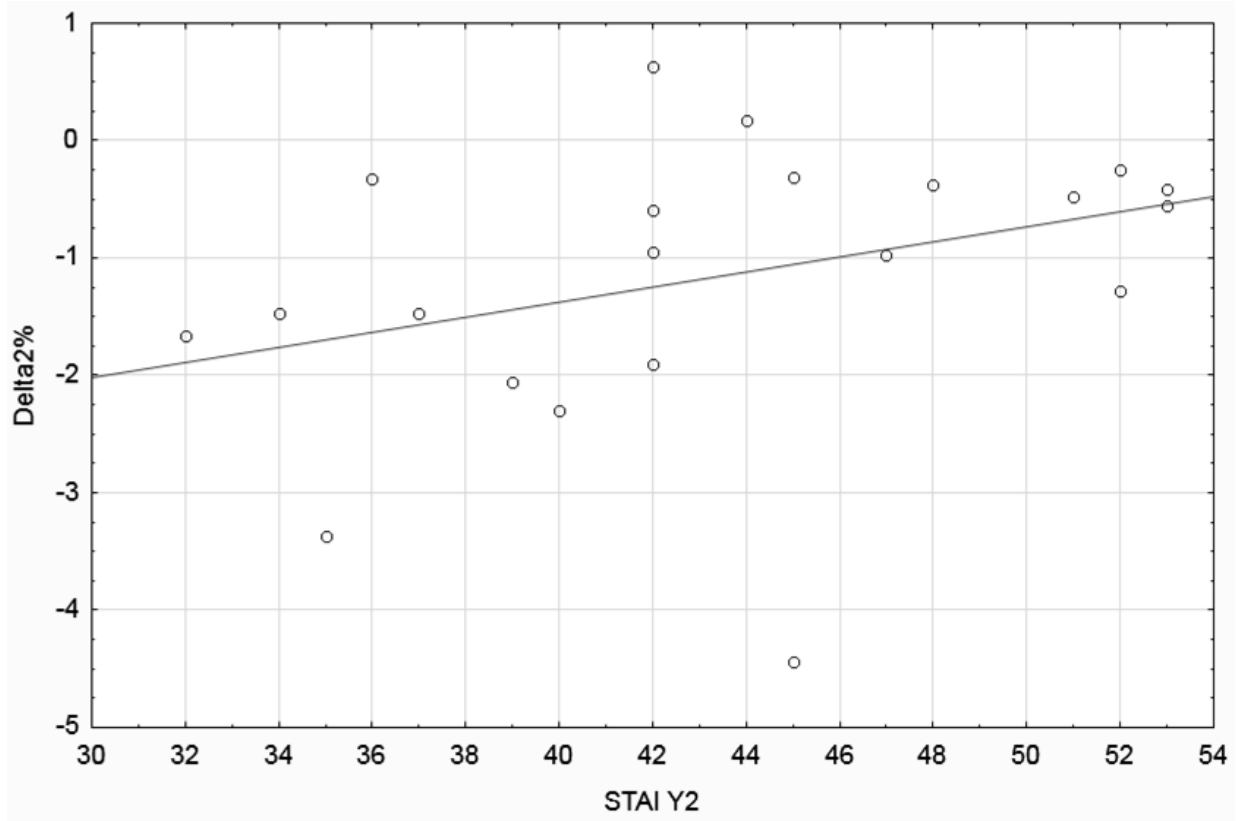


Figure 6.34 Scatterplots of Mean Delta Phase response and Trait Anxiety scores.

6.3.12 EEG – Theta Rhythm

Table 6.19 Spearman ranked correlations between the EEG Theta % Power variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Left Theta%Power Mean	(Ch-B2)/B2	MBI Ex	0.4459	0.0428
Left Theta%Power Mean	Ch-B2	MBI Ex	0.4303	0.0516
Right Theta%PowerCoefVar	Ch-B2	MBI Ex	-0.4081	0.0663
Right Theta%Power Mean	(Ch-B2)/B2	MBI Ex	0.6363	0.0019
Right Theta%Power Mean	Ch-B2	MBI Ex	0.6219	0.0026
Left Theta%PowerCoefVar	(Ch-B2)/B2	STAI Y1	0.4261	0.0541
Left Theta%Power StdDev	Baseline 2	STAI Y1	-0.4235	0.0557
Right Theta%PowerCoefVar	Ch-B2	STAI Y1	0.4255	0.0545
Left Theta%PowerCoefVar	(Ch-B2)/B2	STAI Y1 Pr	0.4878	0.0249
Left Theta%PowerCoefVar	Ch-B2	STAI Y1 Pr	0.4166	0.0603
Left Theta%Power StdDev	(Ch-B2)/B2	STAI Y1 Pr	0.4177	0.0596
Left Theta%Power StdDev	Baseline 2	STAI Y1 Pr	-0.4443	0.0436
Left Theta%Power StdDev	Ch-B2	STAI Y1 Pr	0.4229	0.0562
Right Theta%PowerCoefVar	(Ch-B2)/B2	STAI Y1 Pr	0.4281	0.0529
Right Theta%PowerCoefVar	Ch-B2	STAI Y1 Pr	0.4716	0.0309
Right Theta%Power StdDev	(Ch-B2)/B2	STAI Y1 Pr	0.3774	0.0917
Right Theta%Power StdDev	Ch-B2	STAI Y1 Pr	0.3741	0.0947

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

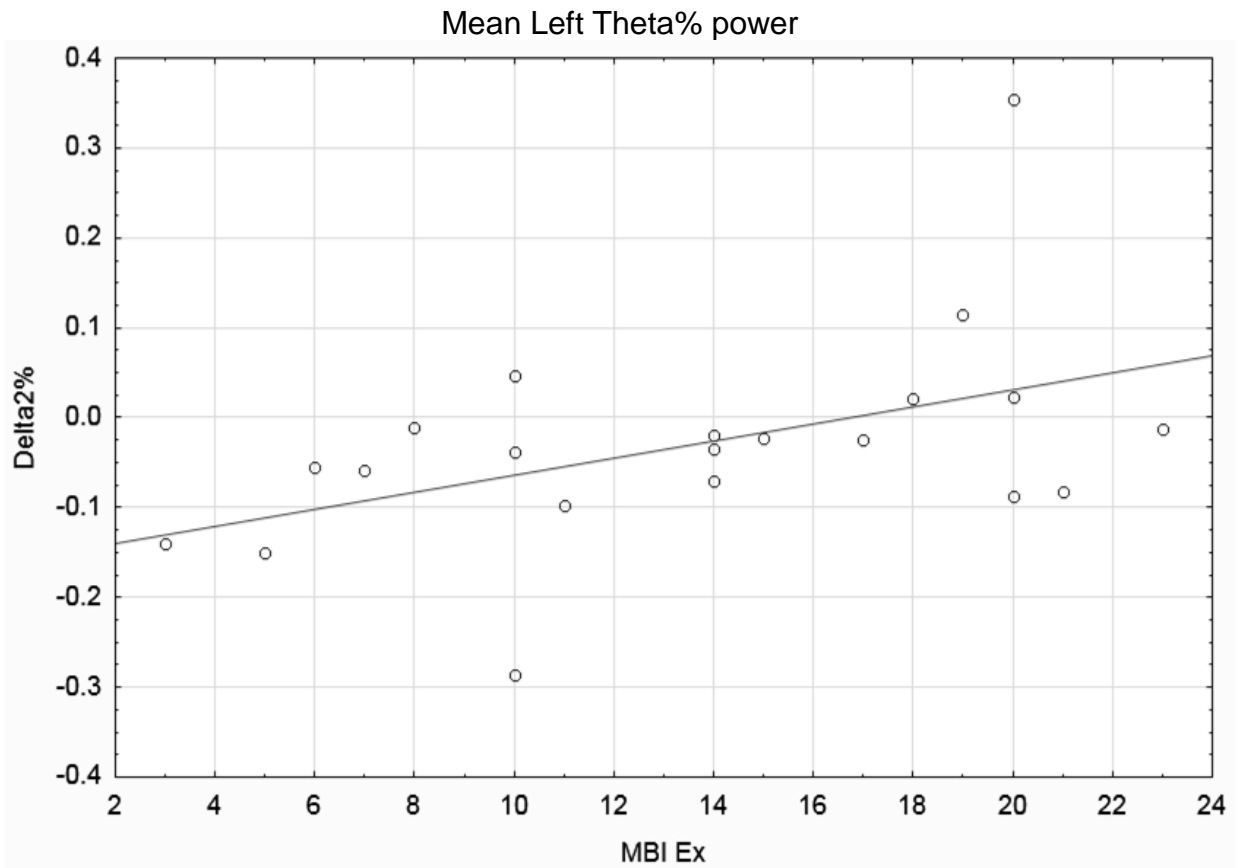


Figure 6.35 Scatterplot of Mean Left Theta% power response and MBI Exhaustion scores.

Mean Right Theta% power

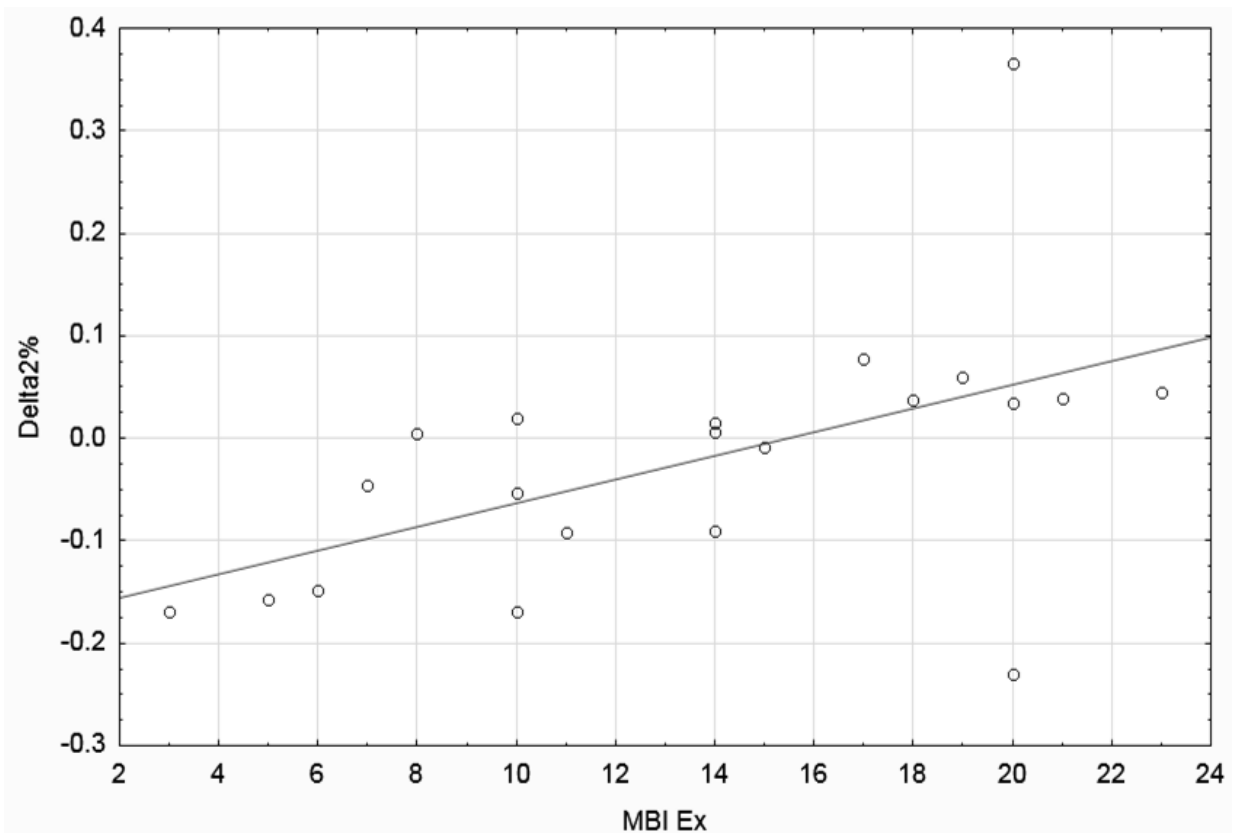
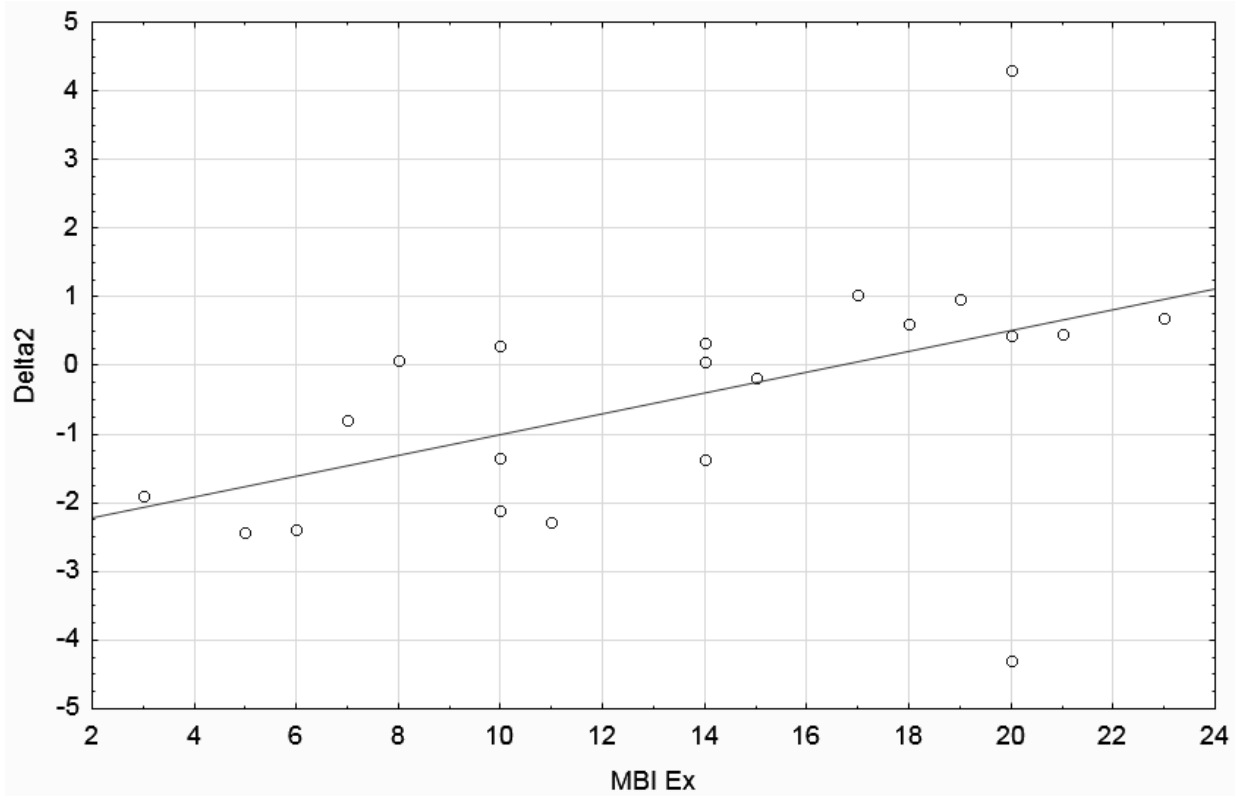


Figure 6.36 Scatterplots of Mean Right Theta% power response and MBI Exhaustion scores.

Coefficient of Variation of Left Theta% power

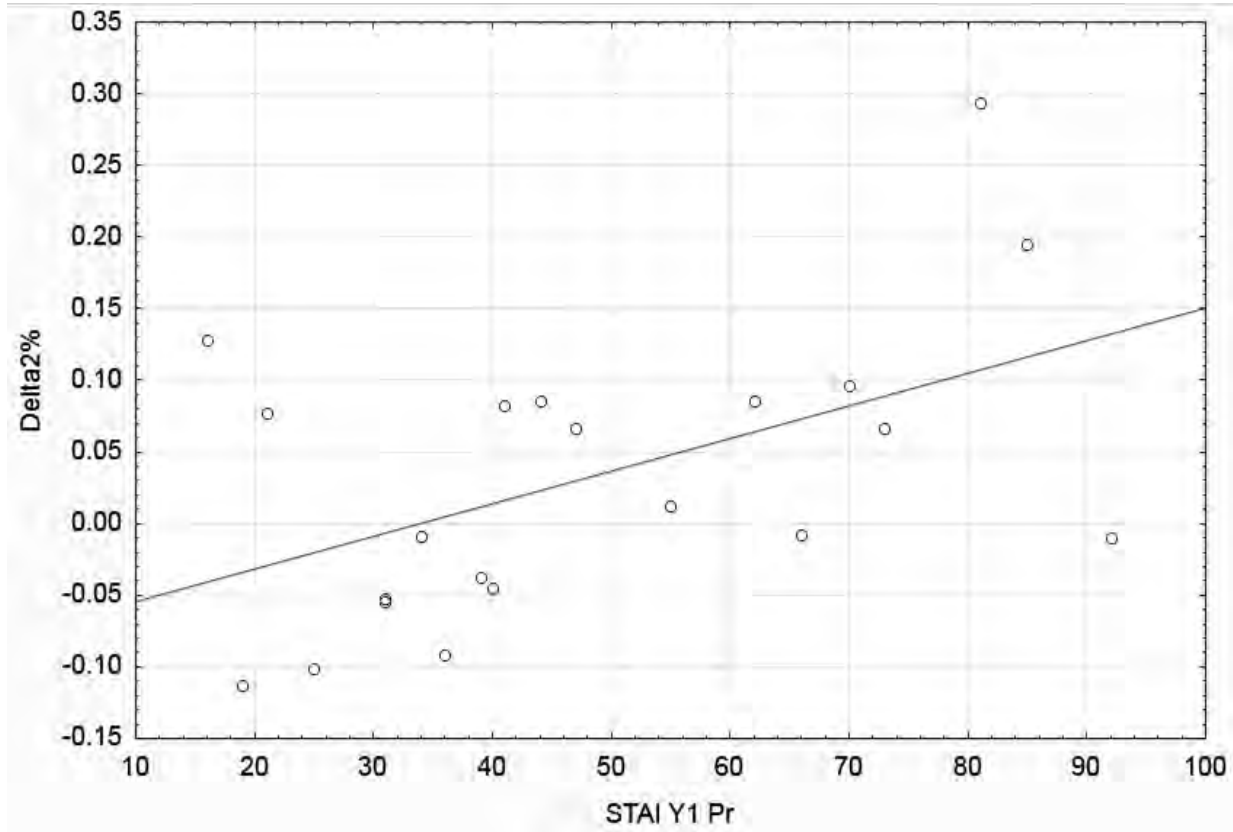


Figure 6.37 Scatterplot of the Coefficient of Variation of Left Theta% power response and State Anxiety scores.

Coefficient of Variation of Right Theta% power

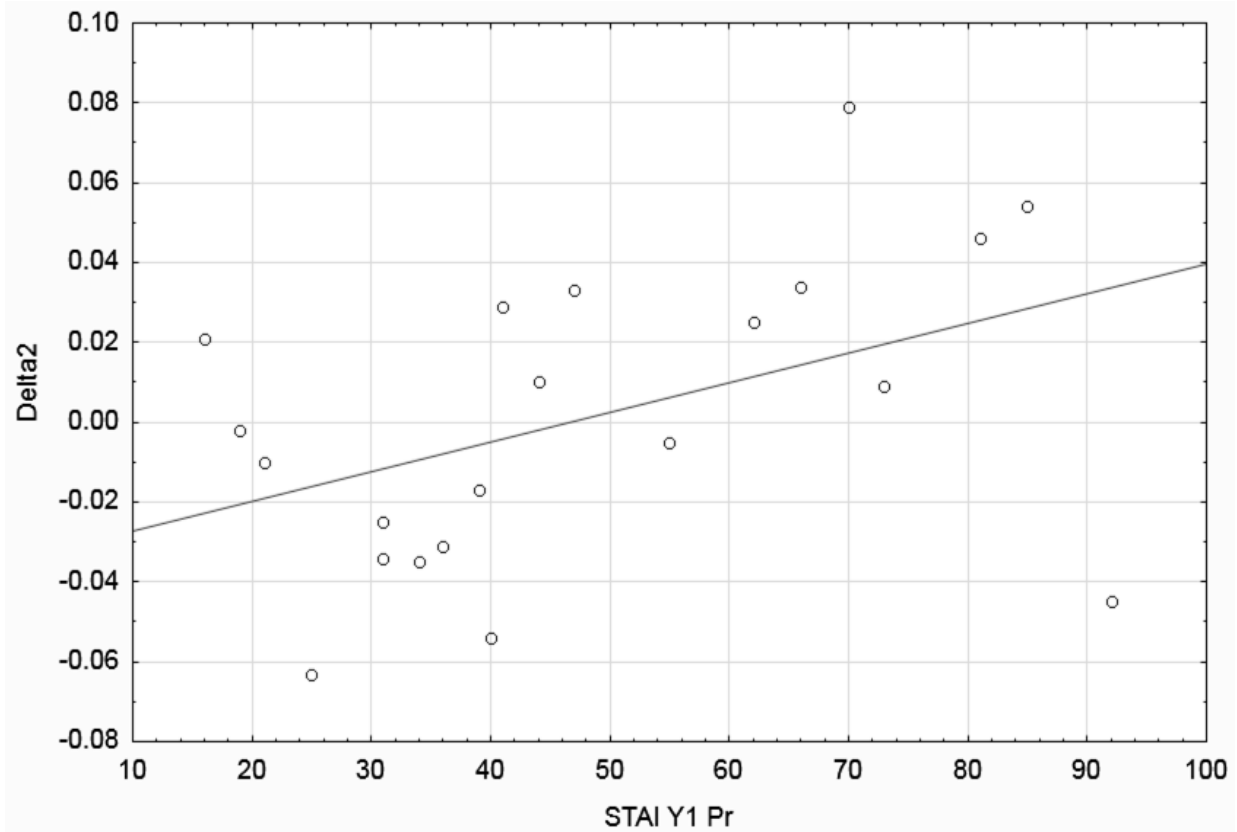


Figure 6.38 Scatterplot of the Coefficient of Variation of Right Theta% power response and State Anxiety scores.

Table 6.20 Spearman ranked correlations between the EEG Theta Amplitude Asymmetry variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Theta Amplitude Asymmetry StdDev	Baseline 1	MBI Cy	0.4114	0.0639
Theta Amplitude Asymmetry StdDev	Baseline 2	MBI Cy	0.4781	0.0284
Theta Amplitude Asymmetry StdDev	Challenge	MBI Cy	0.4376	0.0473
Theta Amplitude Asymmetry StdDev	Recovery	MBI Cy	0.5121	0.0176
Theta Amplitude Asymmetry Mean	Ch-B2	MBI Pe	-0.5237	0.0148
Theta Amplitude Asymmetry Mean	Challenge	STAI Y1	0.3876	0.0825
Theta Amplitude Asymmetry Mean	Ch-B2	STAI Y1	0.5677	0.0073
Theta Amplitude Asymmetry Mean	(Ch-B2)/B2	STAI Y1	0.6662	0.001
Theta Amplitude Asymmetry Mean	Challenge	STAI Y1 Pr	0.4177	0.0596
Theta Amplitude Asymmetry Mean	Ch-B2	STAI Y1 Pr	0.5261	0.0143
Theta Amplitude Asymmetry Mean	(Ch-B2)/B2	STAI Y1 Pr	0.5099	0.0182
Theta Amplitude Asymmetry Mean	Recovery	STAI Y2	0.4004	0.0721
Theta Amplitude Asymmetry StdDev	Ch-B2	STAI Y2 Pr	0.4128	0.0629
Theta Amplitude Asymmetry StdDev	(Ch-B2)/B2	STAI Y2 Pr	0.4049	0.0686

StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

Mean Theta Amplitude Asymmetry

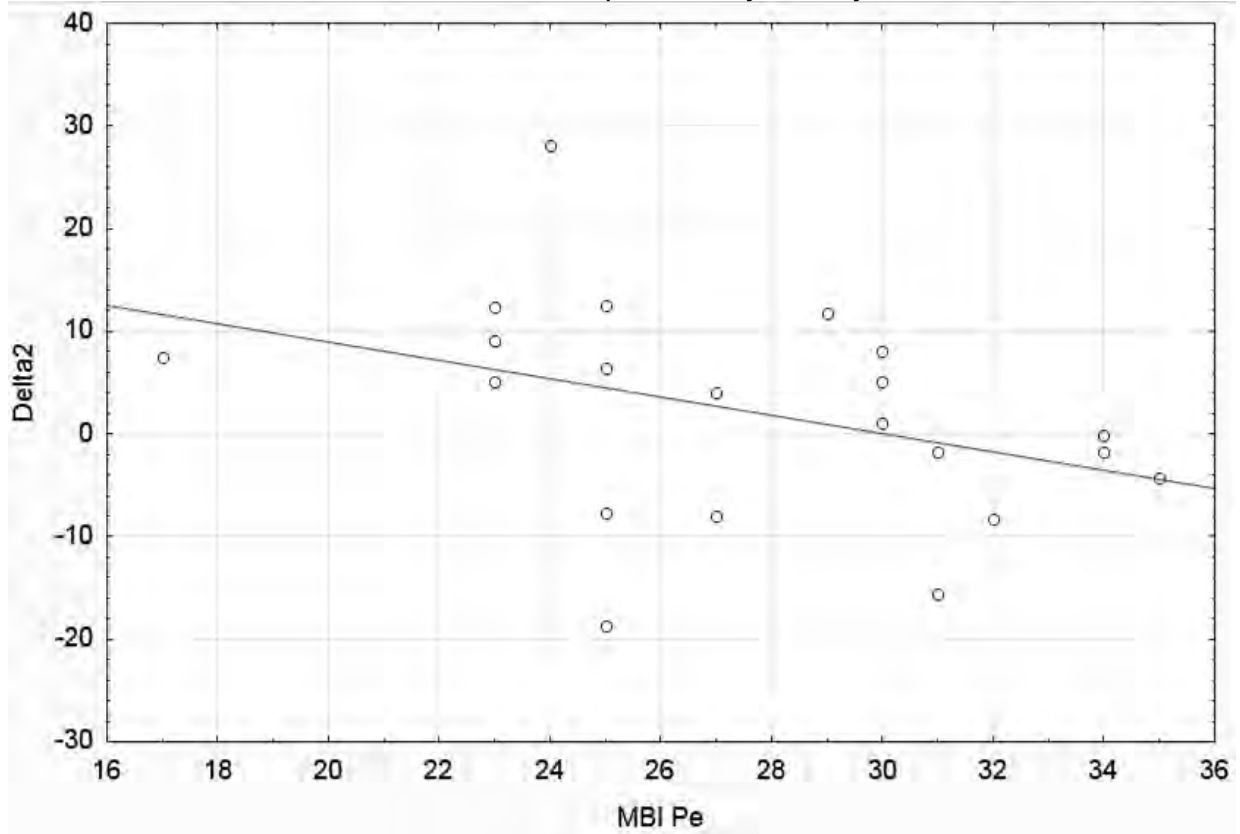
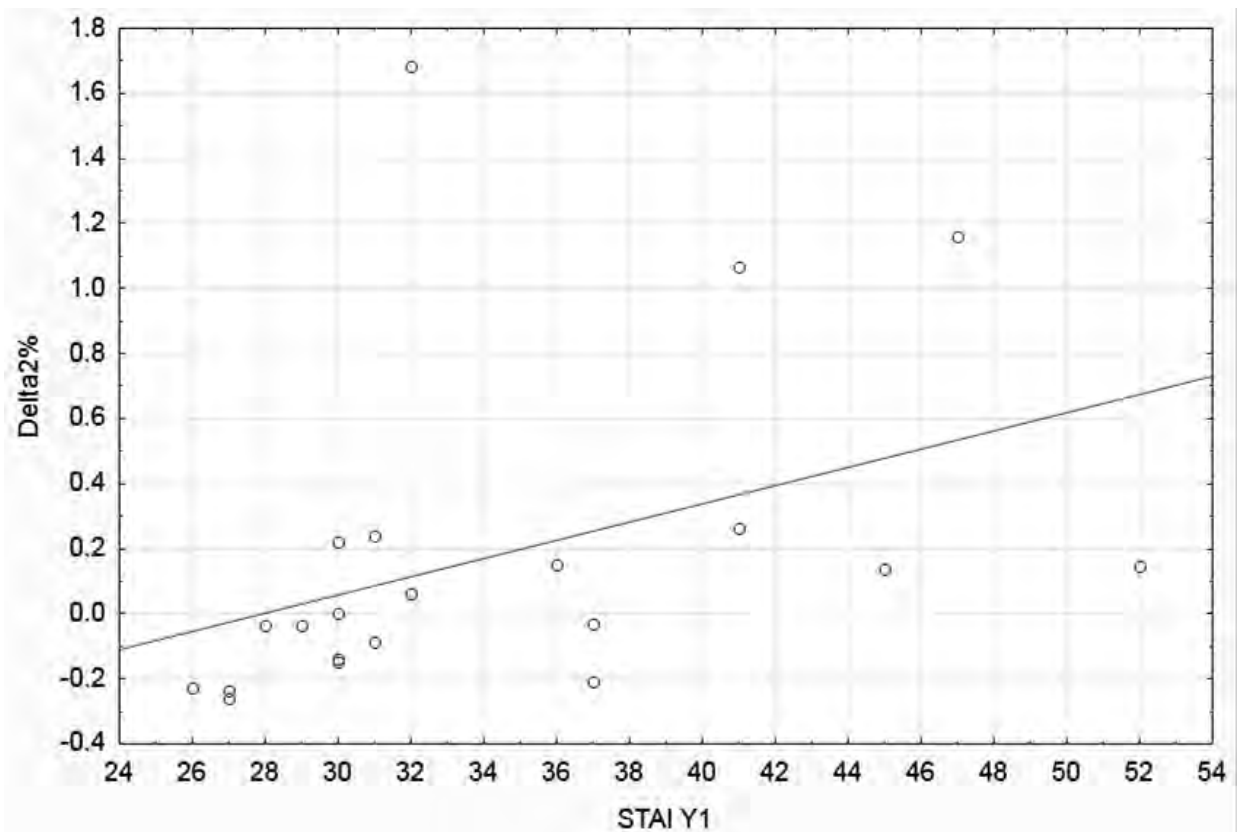
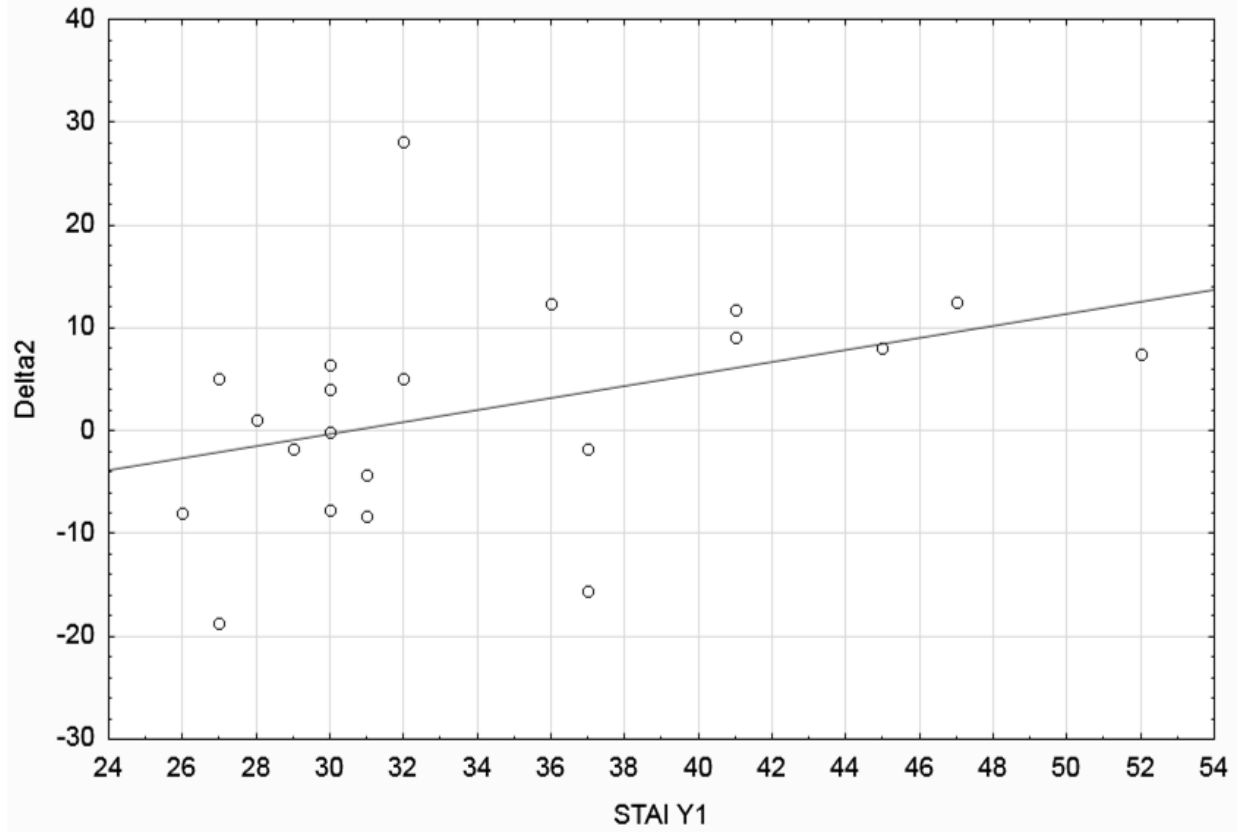


Figure 6.39 Scatterplot of the response of Mean Theta Amplitude Asymmetry and MBI Professional Efficacy scores.

Mean Theta Amplitude Asymmetry



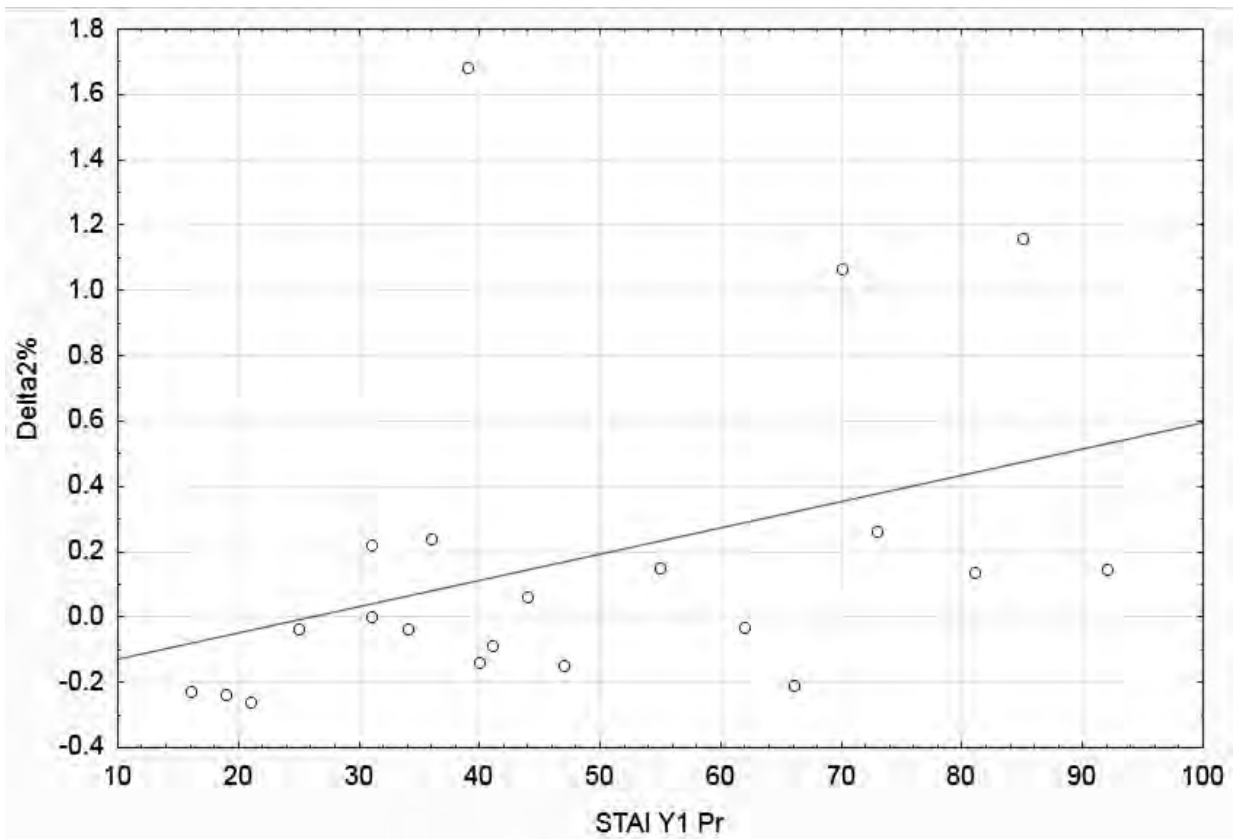
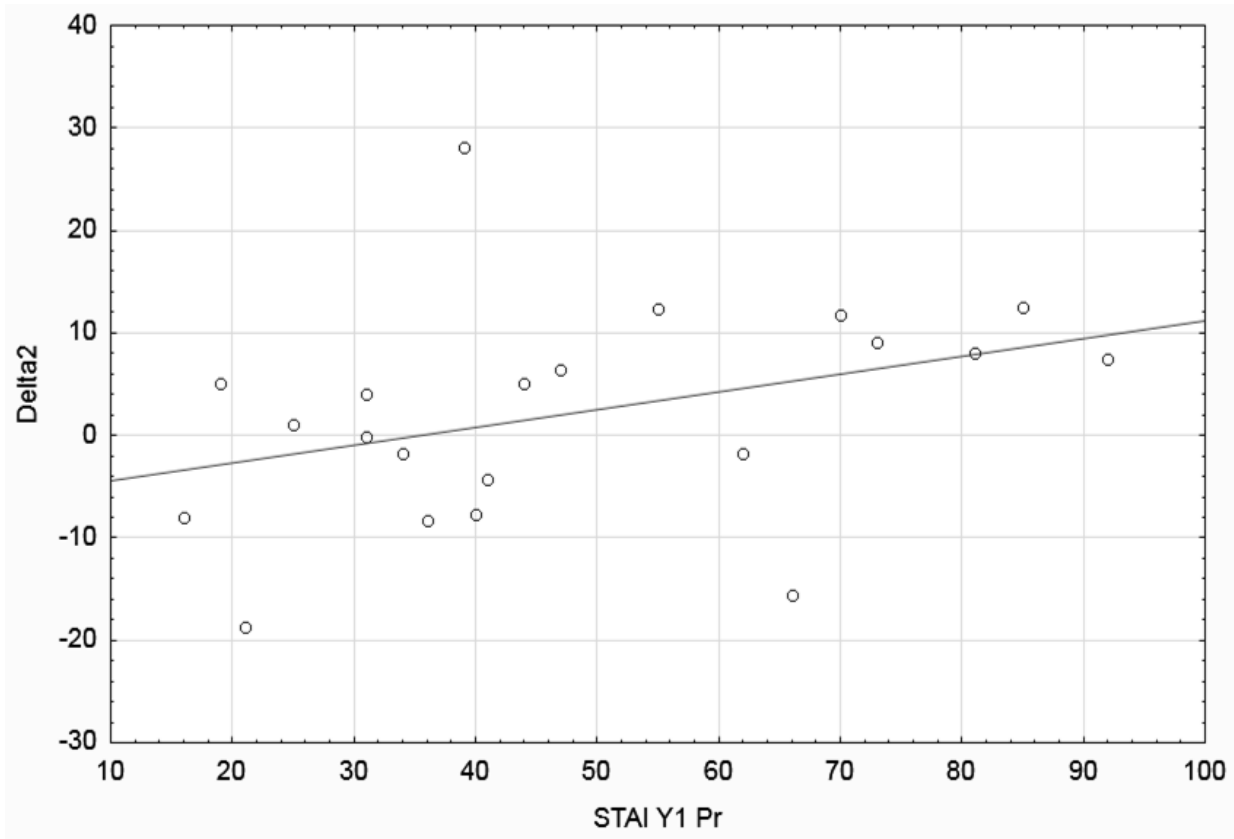


Figure 6.40 Scatterplot of the response of Mean Theta Amplitude Asymmetry and State Anxiety scores.

Table 6.21 Spearman ranked correlations between the EEG Theta Coherence variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Theta Coherence CoefVar	Baseline 2	MBI Cy	0.4033	0.0698
Theta Coherence Mean	Baseline 2	MBI Cy	-0.4814	0.0271
Theta Coherence Mean	Recovery	MBI Cy	-0.4447	0.0434
Theta Coherence CoefVar	Baseline 2	MBI Pe	-0.3767	0.0923
Theta Coherence Mean	Baseline 1	MBI Pe	0.3975	0.0743
Theta Coherence Mean	Ch-B2	MBI Pe	0.3688	0.1
Theta Coherence StdDev	Baseline 2	MBI Pe	-0.4394	0.0463
Theta Coherence StdDev	Recovery	MBI Pe	-0.3956	0.0759

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, Ch-B2 – Response.

Table 6.22 Spearman ranked correlations between the EEG Theta Phase variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Theta Phase StdDev	Baseline 2	MBI Cy	0.5651	0.0076
Theta Phase StdDev	Recovery	MBI Cy	0.4297	0.0519
Theta Phase Mean	Challenge	MBI Ex	0.3794	0.0898
Theta Phase Mean	(Ch-B2)/B2	MBI Pe	-0.4662	0.0332
Theta Phase StdDev	Challenge	MBI Pe	-0.3916	0.0791

StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, (Ch-B2)/B2 – Relative response,

Standard Deviation of Theta Phase

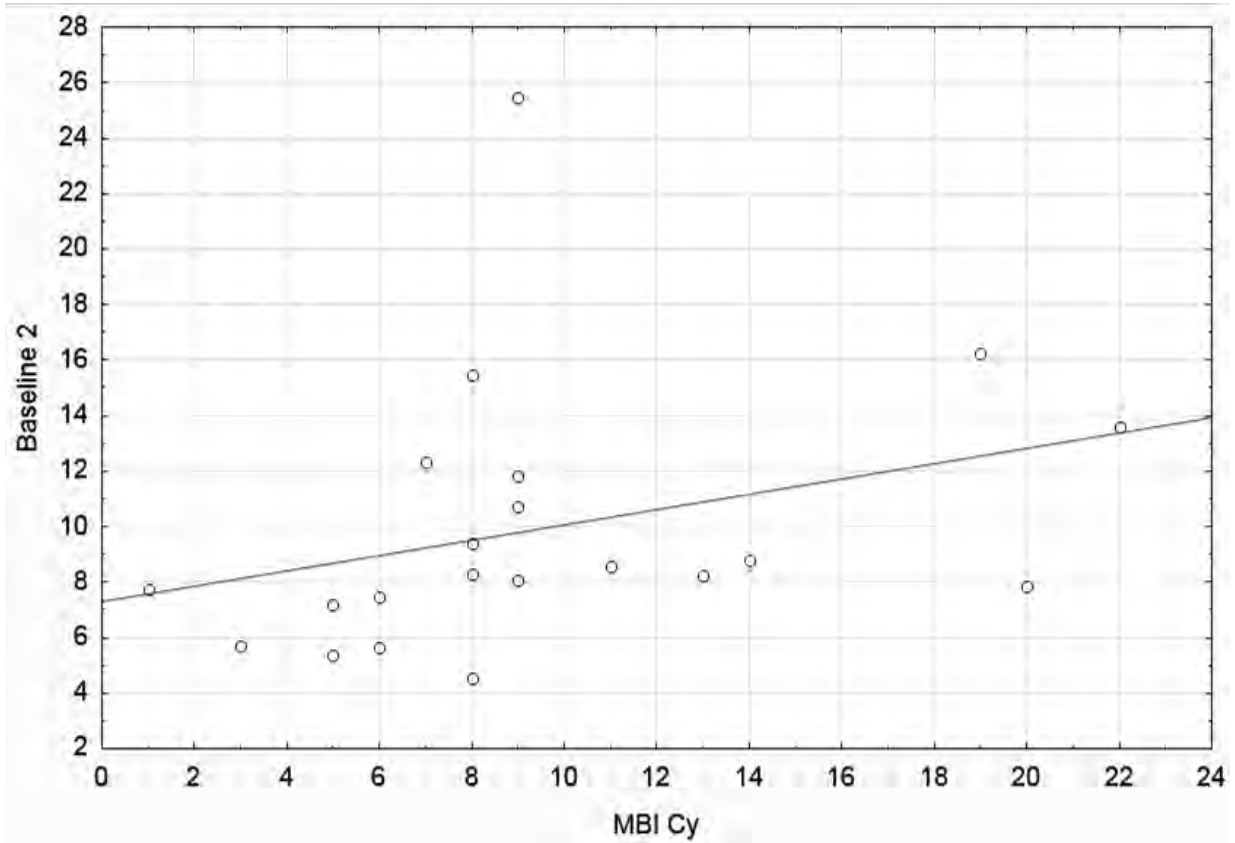


Figure 6.41 Scatterplot of the Standard Deviation of Theta Phase at baseline 2 and MBI Cynicism scores.

Mean Theta Phase

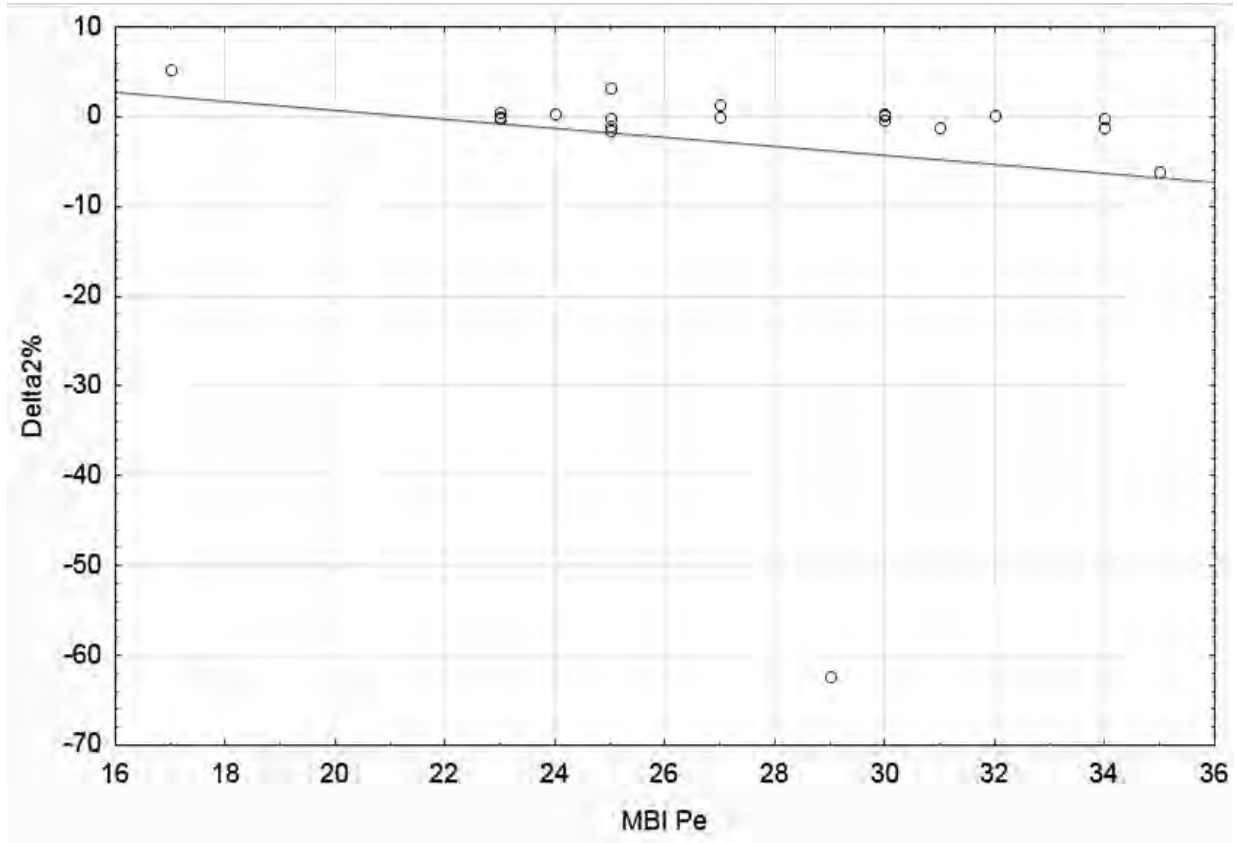


Figure 6.42 Scatterplot of the response of Mean Theta Phase and MBI Professional Efficacy scores.

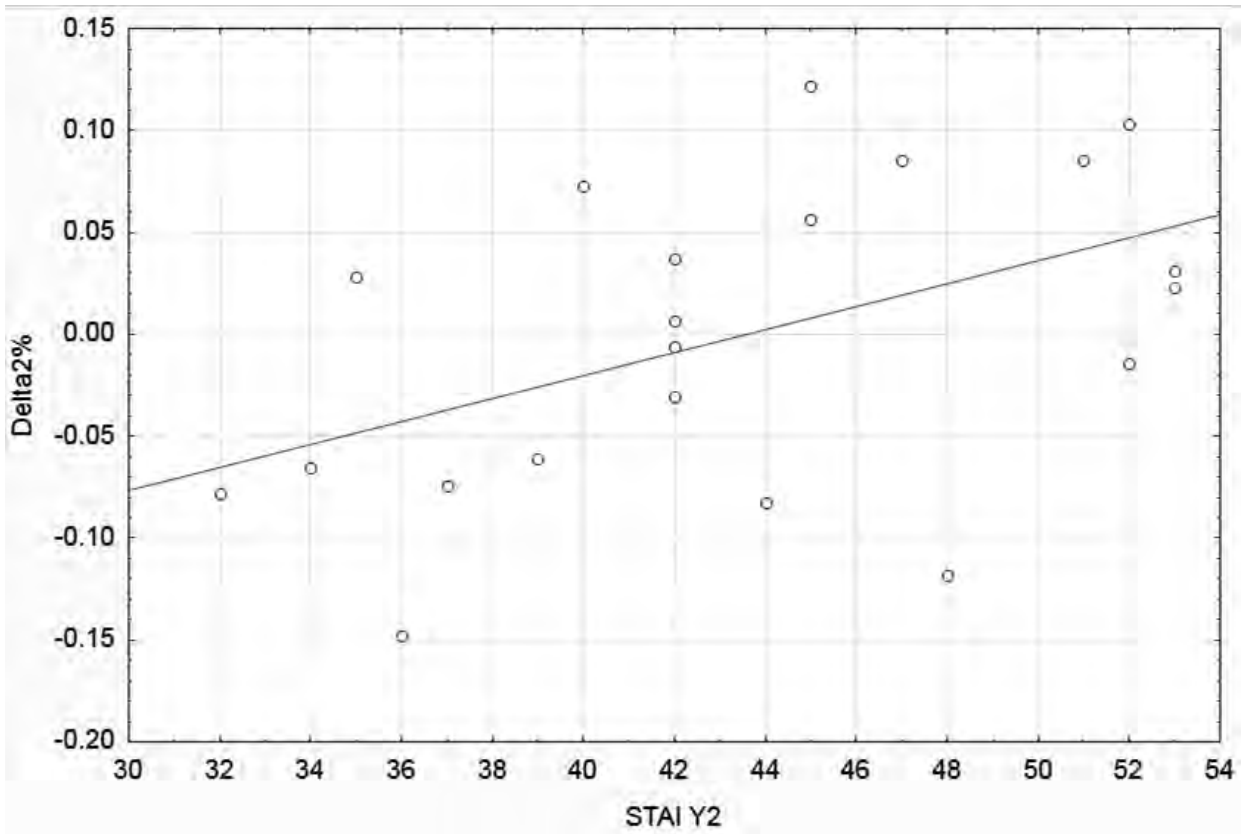
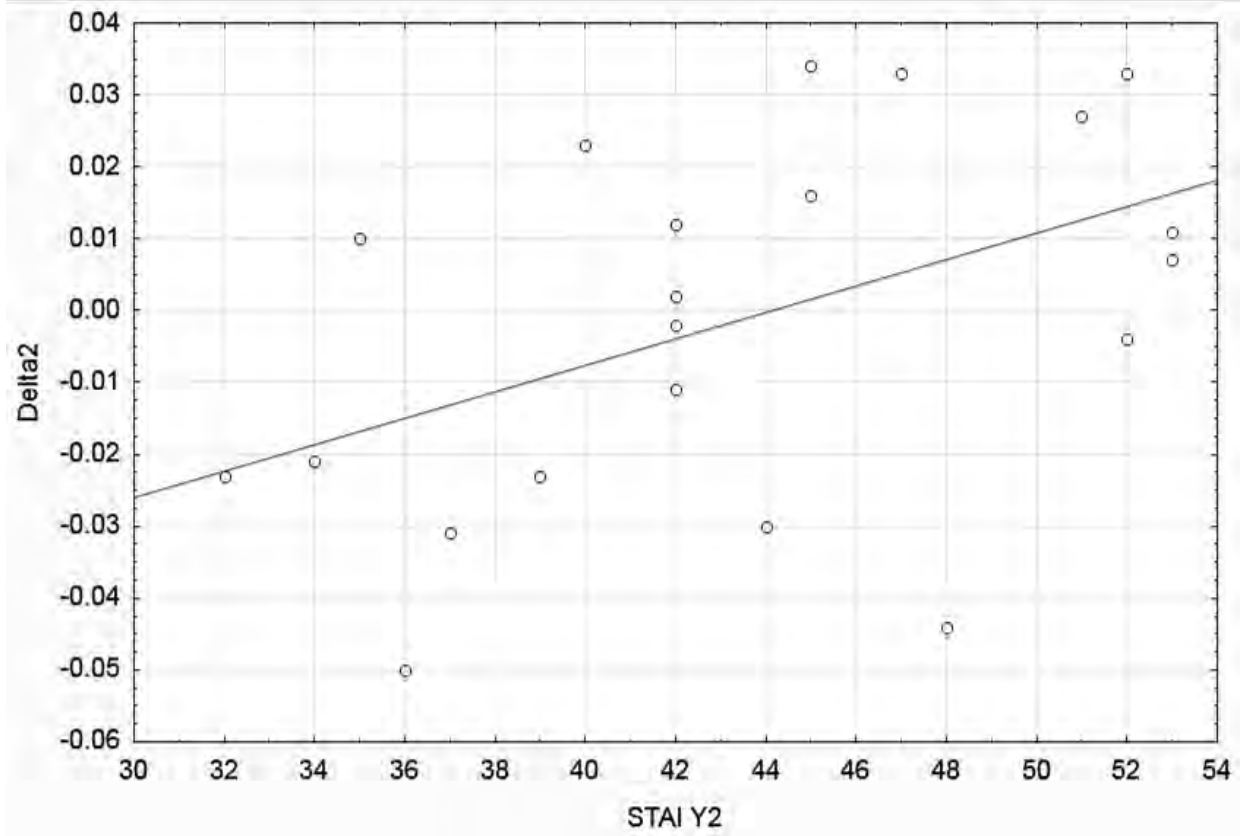
6.3.13 EEG – Alpha Rhythm

Table 6.23 Spearman ranked correlations between the EEG Low Alpha % Power variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Left Low Alpha%Power StdDev	(Ch-B2)/B2	MBI Ex	0.3898	0.0806
Left Low Alpha%Power StdDev	Ch-B2	MBI Ex	0.4211	0.0573
Right Low Alpha%Power Mean	Ch-B2	MBI Ex	0.3794	0.0898
Left Low Alpha%Power Mean	Recovery	STAI Y1	0.464	0.0341
Left Low Alpha%Power StdDev	Recovery	STAI Y1	0.4462	0.0426
Left Low Alpha%Power Mean	Recovery	STAI Y1 Pr	0.4755	0.0294
Left Low Alpha%Power StdDev	Recovery	STAI Y1 Pr	0.4753	0.0294
Right Low Alpha%Power Mean	(Ch-B2)/B2	STAI Y1 Pr	-0.3793	0.0899
Left Low Alpha%PowerCoefVar	(Ch-B2)/B2	STAI Y2	0.4591	0.0363
Left Low Alpha%PowerCoefVar	Ch-B2	STAI Y2	0.4465	0.0424
Left Low Alpha%Power StdDev	(Ch-B2)/B2	STAI Y2	0.3763	0.0927
Left Low Alpha%Power StdDev	Ch-B2	STAI Y2	0.3965	0.0752
Left Low Alpha%PowerCoefVar	(Ch-B2)/B2	STAI Y2 Pr	0.4349	0.0488
Left Low Alpha%PowerCoefVar	Ch-B2	STAI Y2 Pr	0.4175	0.0597

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response,

Coefficient of Variation of Left Low Alpha% power



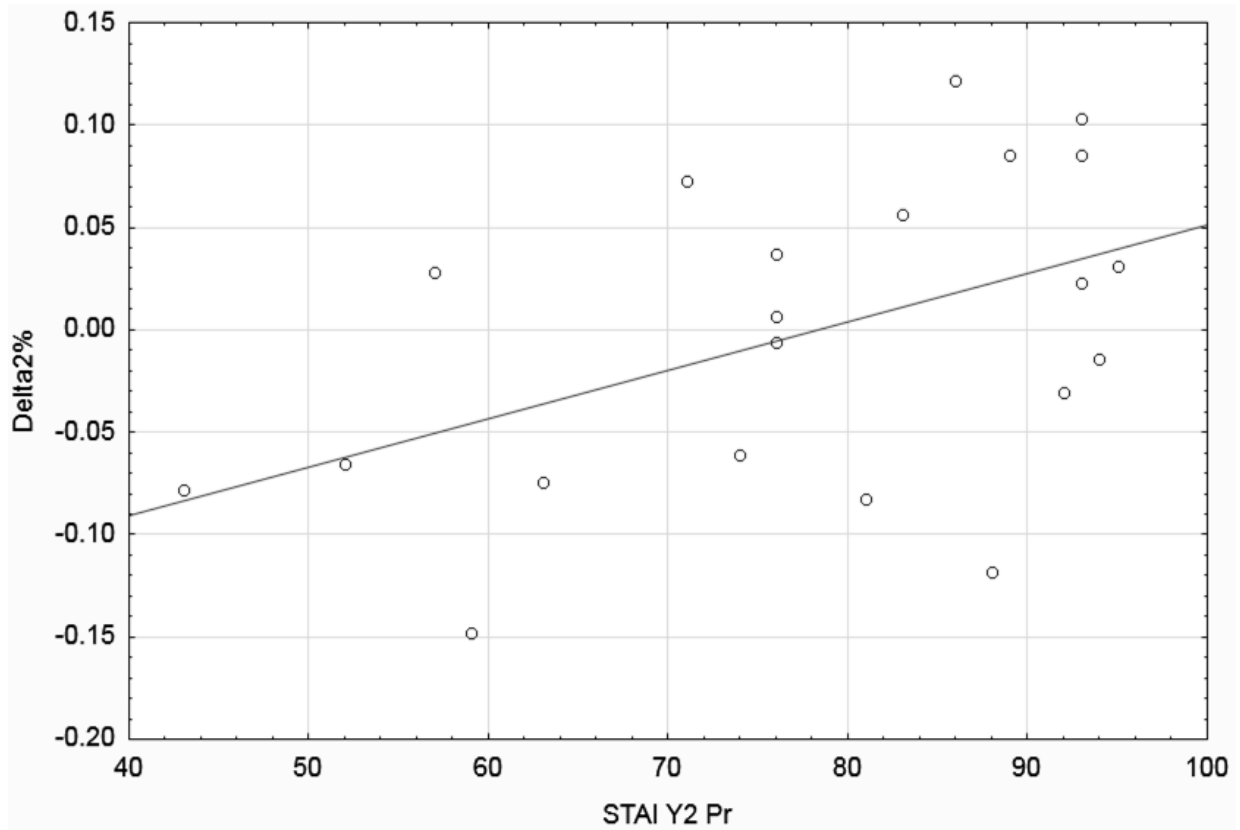


Figure 6.43 Scatterplots of the response of the Coefficient of Variation of Left Low Alpha% power and Trait Anxiety scores.

Table 6.24 Spearman ranked correlations between the EEG High Alpha % Power variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Left High Alpha%PowerCoefVar	(Ch-B2)/B2	MBI Ex	0.3937	0.0774
Left High Alpha%PowerCoefVar	Ch-B2	MBI Ex	0.3887	0.0816
Right High Alpha%PowerCoefVar	(Ch-B2)/B2	MBI Ex	0.3703	0.0985
Left High Alpha%PowerCoefVar	(Ch-B2)/B2	MBI Pe	0.4165	0.0604
Left High Alpha%PowerCoefVar	Ch-B2	MBI Pe	0.4251	0.0547
Right High Alpha%PowerCoefVar	(Ch-B2)/B2	MBI Pe	0.4766	0.0289
Right High Alpha%PowerCoefVar	Ch-B2	MBI Pe	0.4813	0.0272
Left High Alpha%Power Mean	Baseline 1	STAI Y1	0.3876	0.0825
Left High Alpha%Power Mean	Baseline 2	STAI Y1	0.5272	0.014
Left High Alpha%Power Mean	Recovery	STAI Y1	0.5814	0.0057
Left High Alpha%Power StdDev	(Ch-B2)/B2	STAI Y1	-0.3883	0.082
Left High Alpha%Power StdDev	Baseline 2	STAI Y1	0.4444	0.0436
Left High Alpha%Power StdDev	Recovery	STAI Y1	0.4855	0.0257
Right High Alpha%Power Mean	Baseline 1	STAI Y1	0.432	0.0505
Right High Alpha%Power Mean	Baseline 2	STAI Y1	0.4998	0.021
Right High Alpha%Power Mean	Recovery	STAI Y1	0.5416	0.0112
Right High Alpha%Power StdDev	Baseline 1	STAI Y1	0.4529	0.0393
Right High Alpha%Power StdDev	Baseline 2	STAI Y1	0.4731	0.0303
Right High Alpha%Power StdDev	Challenge	STAI Y1	0.3759	0.0931
Right High Alpha%Power StdDev	Recovery	STAI Y1	0.4281	0.0529
Left High Alpha%Power Mean	Baseline 2	STAI Y1 Pr	0.4644	0.0339
Left High Alpha%Power Mean	Recovery	STAI Y1 Pr	0.5255	0.0144
Left High Alpha%Power StdDev	(Ch-B2)/B2	STAI Y1 Pr	-0.4021	0.0708
Left High Alpha%Power StdDev	Baseline 2	STAI Y1 Pr	0.419	0.0587
Left High Alpha%Power StdDev	Ch-B2	STAI Y1 Pr	-0.3741	0.0947
Left High Alpha%Power StdDev	Recovery	STAI Y1 Pr	0.456	0.0378
Right High Alpha%Power Mean	Baseline 1	STAI Y1 Pr	0.3871	0.083
Right High Alpha%Power Mean	Baseline 2	STAI Y1 Pr	0.4339	0.0494
Right High Alpha%Power Mean	Recovery	STAI Y1 Pr	0.5054	0.0194
Right High Alpha%Power StdDev	Baseline 1	STAI Y1 Pr	0.4053	0.0683
Right High Alpha%Power StdDev	Baseline 2	STAI Y1 Pr	0.4307	0.0513
Right High Alpha%Power StdDev	Recovery	STAI Y1 Pr	0.4216	0.057

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response,

Coefficient of Variation of Right High Alpha% power

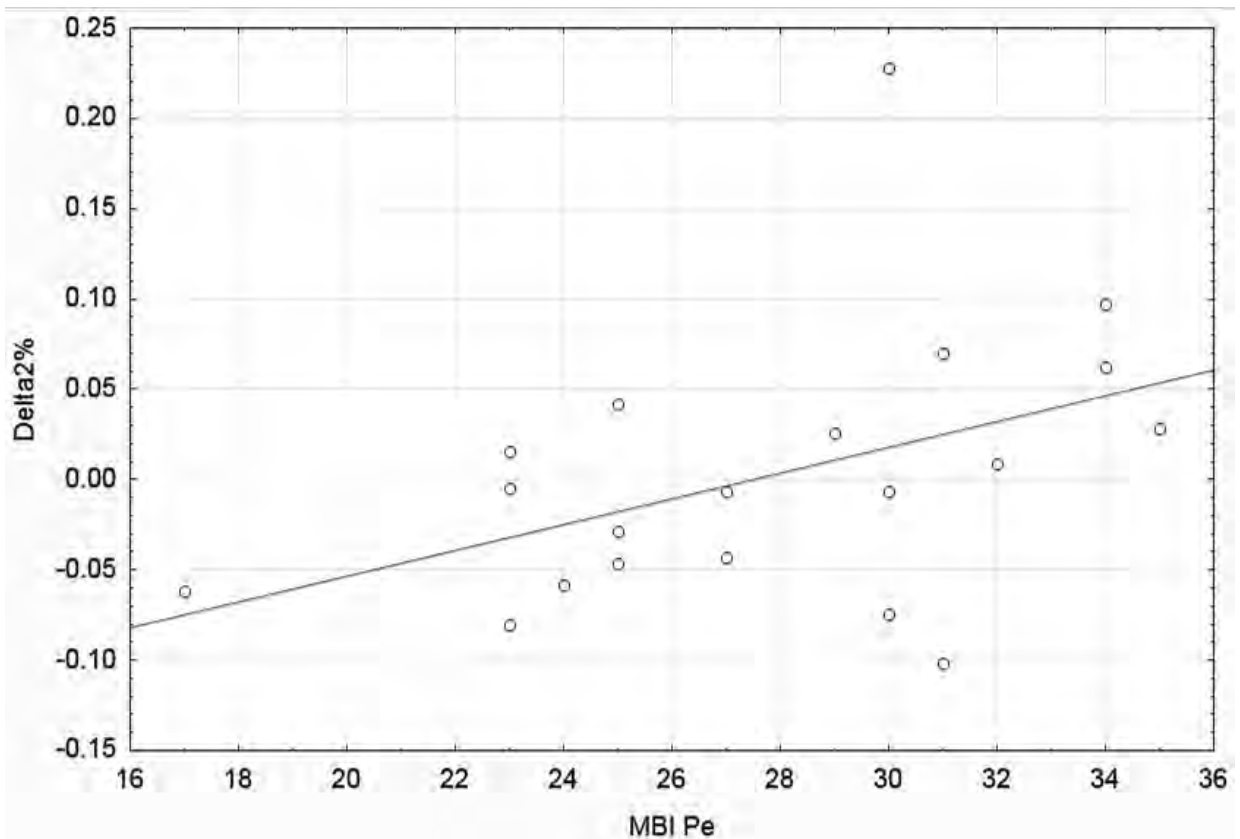
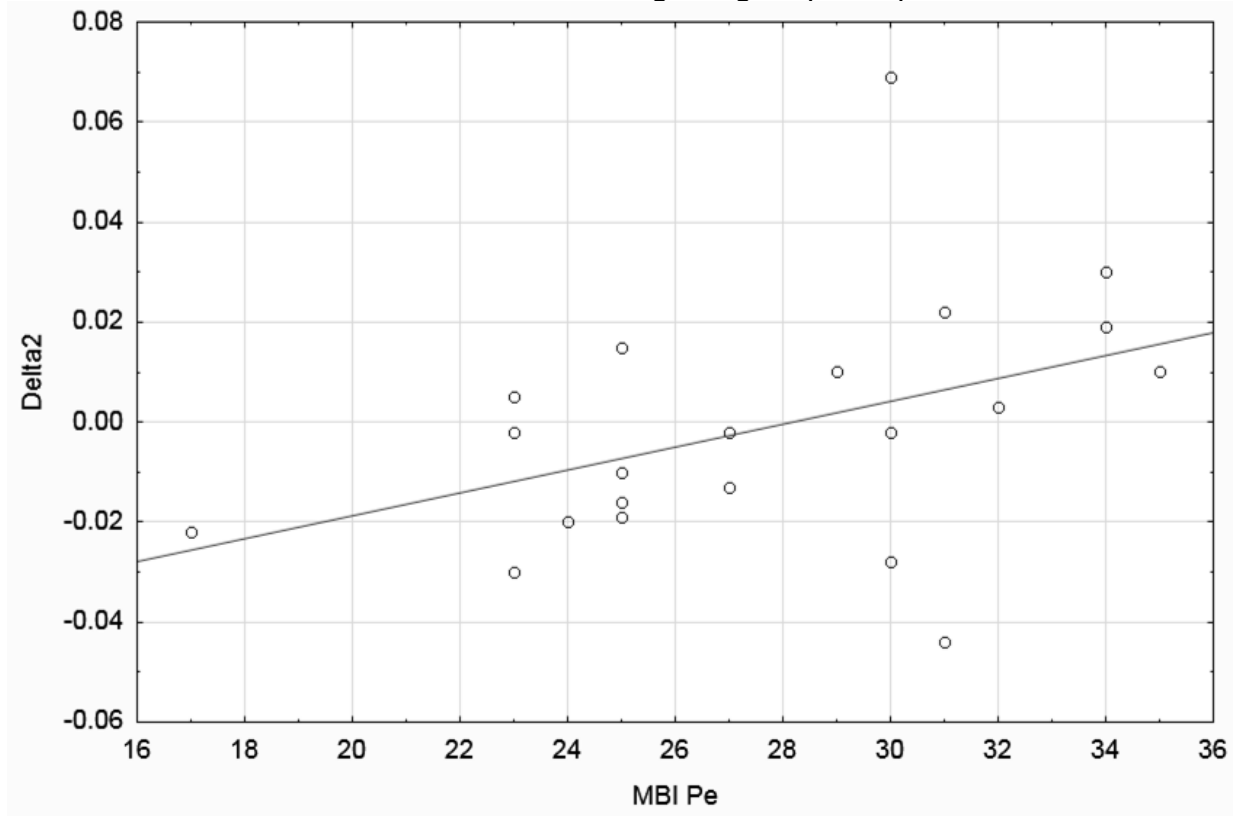


Figure 6.44 Scatterplots of the response of Coefficient of Variation of Right High Alpha% power and MBI Professional efficacy scores.

Table 6.25 Spearman ranked correlations between the EEG Whole Alpha % Power variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Left Whole Alpha%PowerCoefVar	Ch-B2	MBI Ex	0.4017	0.0711
Left Whole Alpha%Power StdDev	(Ch-B2)/B2	MBI Ex	0.4289	0.0523
Left Whole Alpha%Power StdDev	Ch-B2	MBI Ex	0.4563	0.0376
Right Whole Alpha%Power StdDev	(Ch-B2)/B2	MBI Ex	0.4694	0.0318
Right Whole Alpha%Power StdDev	Ch-B2	MBI Ex	0.4563	0.0376
Right Whole Alpha%PowerCoefVar	(Ch-B2)/B2	MBI Pe	0.5695	0.007
Right Whole Alpha%PowerCoefVar	Ch-B2	MBI Pe	0.5538	0.0092
Left Whole Alpha%Power Mean	Recovery	STAI Y1	0.5096	0.0183
Left Whole Alpha%Power StdDev	Baseline 2	STAI Y1	0.4476	0.0419
Left Whole Alpha%Power StdDev	Recovery	STAI Y1	0.4503	0.0405
Right Whole Alpha%Power Mean	Recovery	STAI Y1	0.4509	0.0402
Right Whole Alpha%Power StdDev	Baseline 2	STAI Y1	0.3778	0.0913
Right Whole Alpha%Power StdDev	Recovery	STAI Y1	0.4176	0.0596
Left Whole Alpha%Power Mean	Recovery	STAI Y1 Pr	0.4995	0.0211
Left Whole Alpha%Power StdDev	Baseline 2	STAI Y1 Pr	0.432	0.0505
Left Whole Alpha%Power StdDev	Recovery	STAI Y1 Pr	0.469	0.032
Right Whole Alpha%Power Mean	(Ch-B2)/B2	STAI Y1 Pr	-0.4014	0.0713
Right Whole Alpha%Power Mean	Ch-B2	STAI Y1 Pr	-0.3982	0.0738
Right Whole Alpha%Power Mean	Recovery	STAI Y1 Pr	0.4339	0.0494
Right Whole Alpha%Power StdDev	Baseline 1	STAI Y1 Pr	0.3735	0.0954
Right Whole Alpha%Power StdDev	Recovery	STAI Y1 Pr	0.4183	0.0591
Left Whole Alpha%PowerCoefVar	(Ch-B2)/B2	STAI Y2	0.4408	0.0455
Left Whole Alpha%PowerCoefVar	Ch-B2	STAI Y2	0.4416	0.045
Right Whole Alpha%Power StdDev	(Ch-B2)/B2	STAI Y2	0.4884	0.0247
Right Whole Alpha%Power StdDev	Ch-B2	STAI Y2	0.4819	0.027
Right Whole Alpha%Power StdDev	(Ch-B2)/B2	STAI Y2 Pr	0.3854	0.0844
Right Whole Alpha%Power StdDev	Ch-B2	STAI Y2 Pr	0.3828	0.0867

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

Standard Deviation of Left Whole Alpha% power

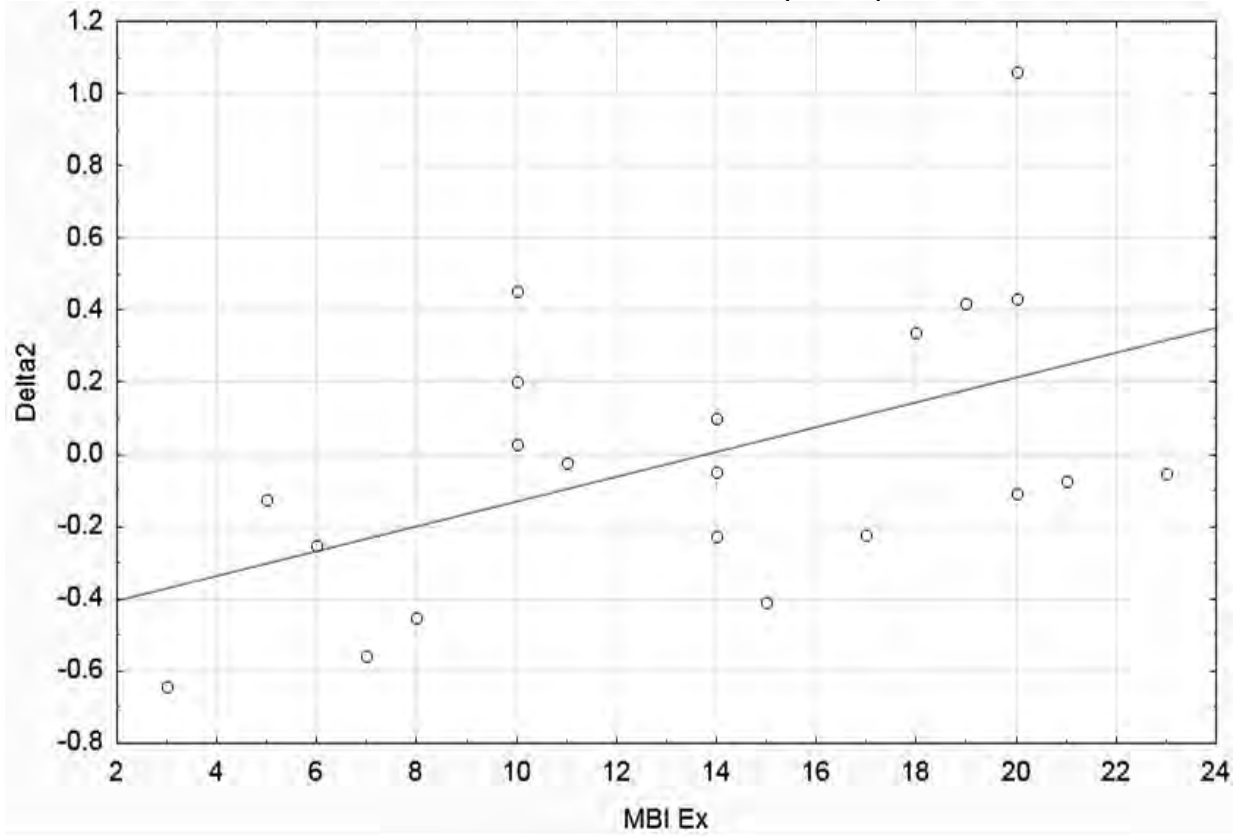


Figure 6.45 Scatterplot of the response of the Standard Deviation of Left Whole Alpha% power and MBI Exhaustion scores.

Standard Deviation of Right Whole Alpha% power

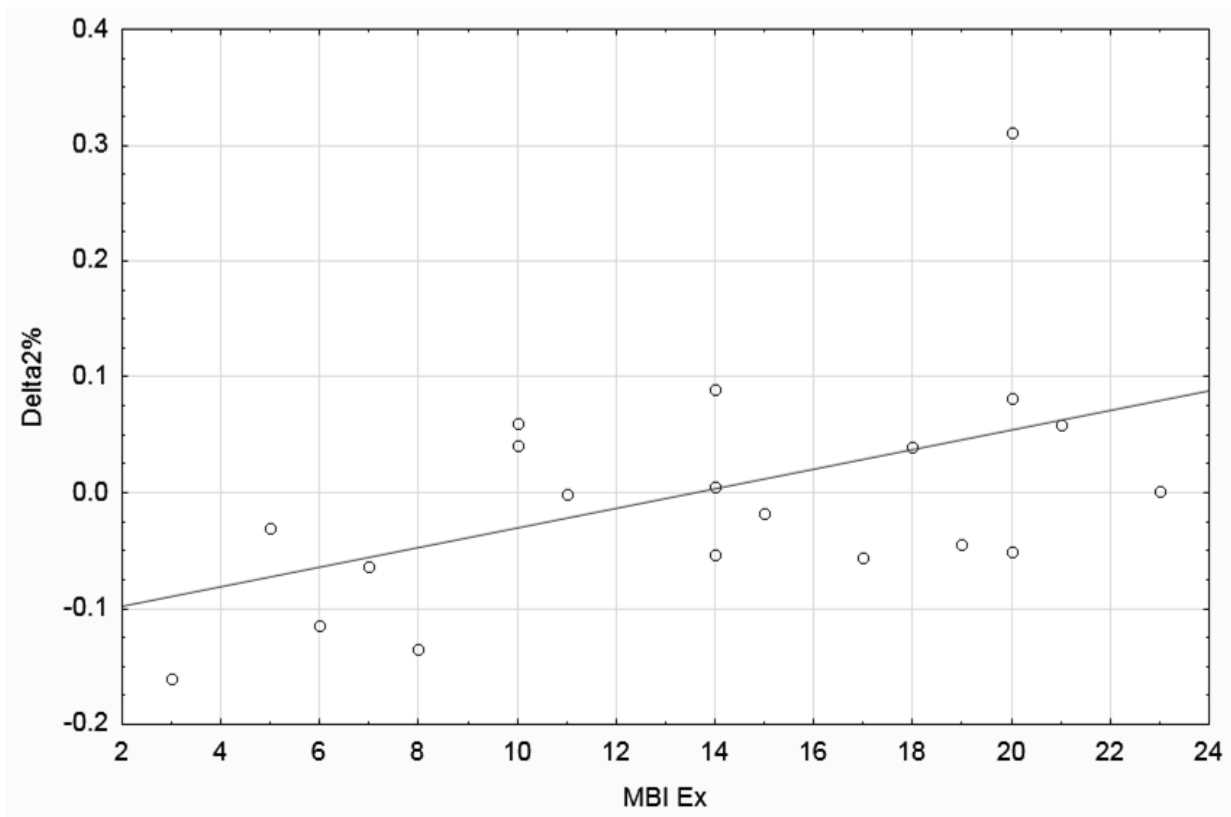
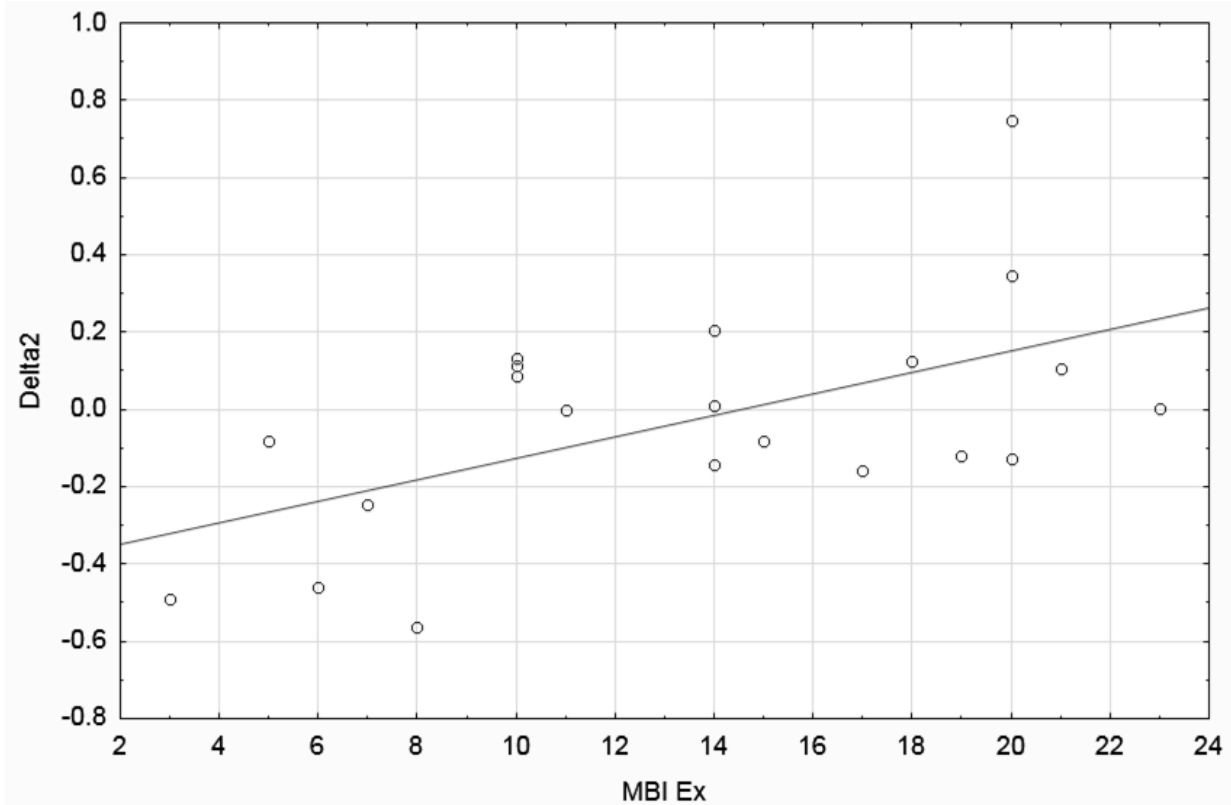


Figure 6.46 Scatterplots of the response of the Standard Deviation of Right Whole Alpha% power and MBI Exhaustion scores.

Coefficient of Variation of Right Whole Alpha% power

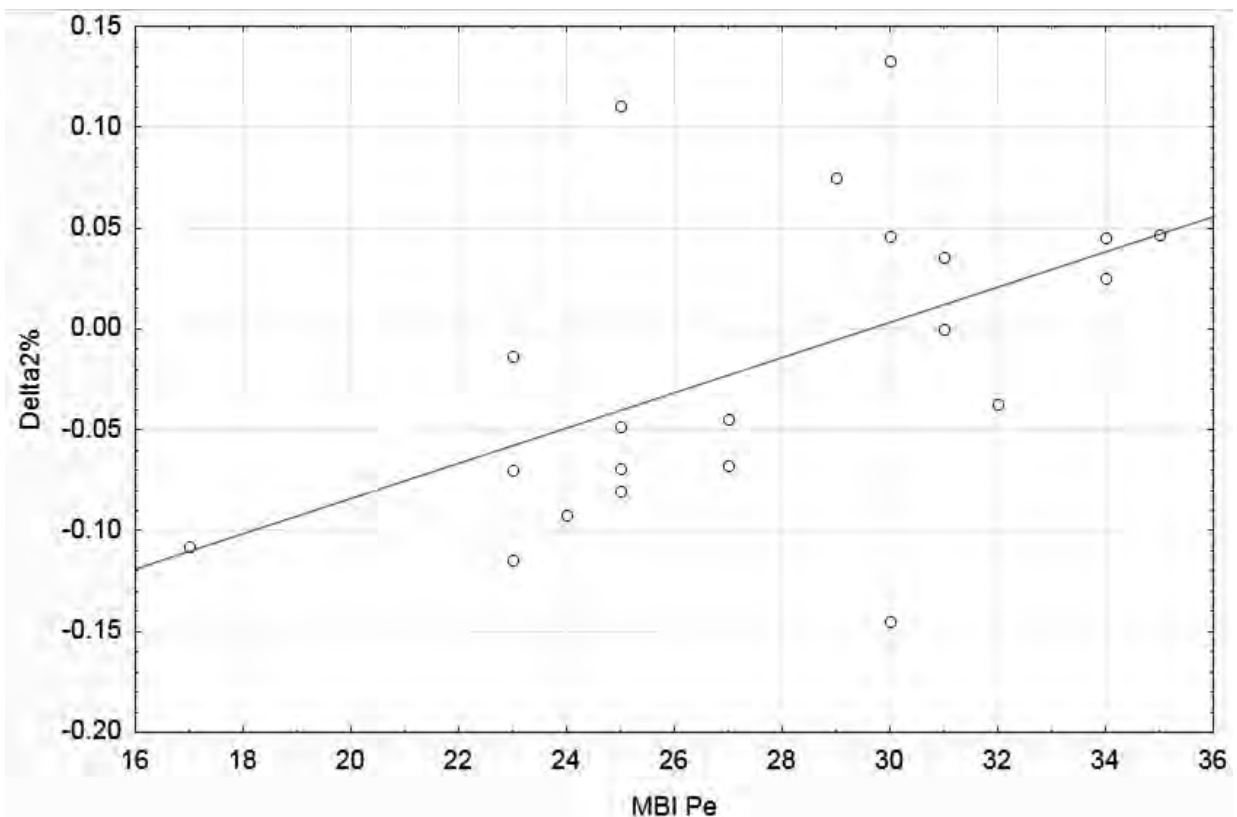
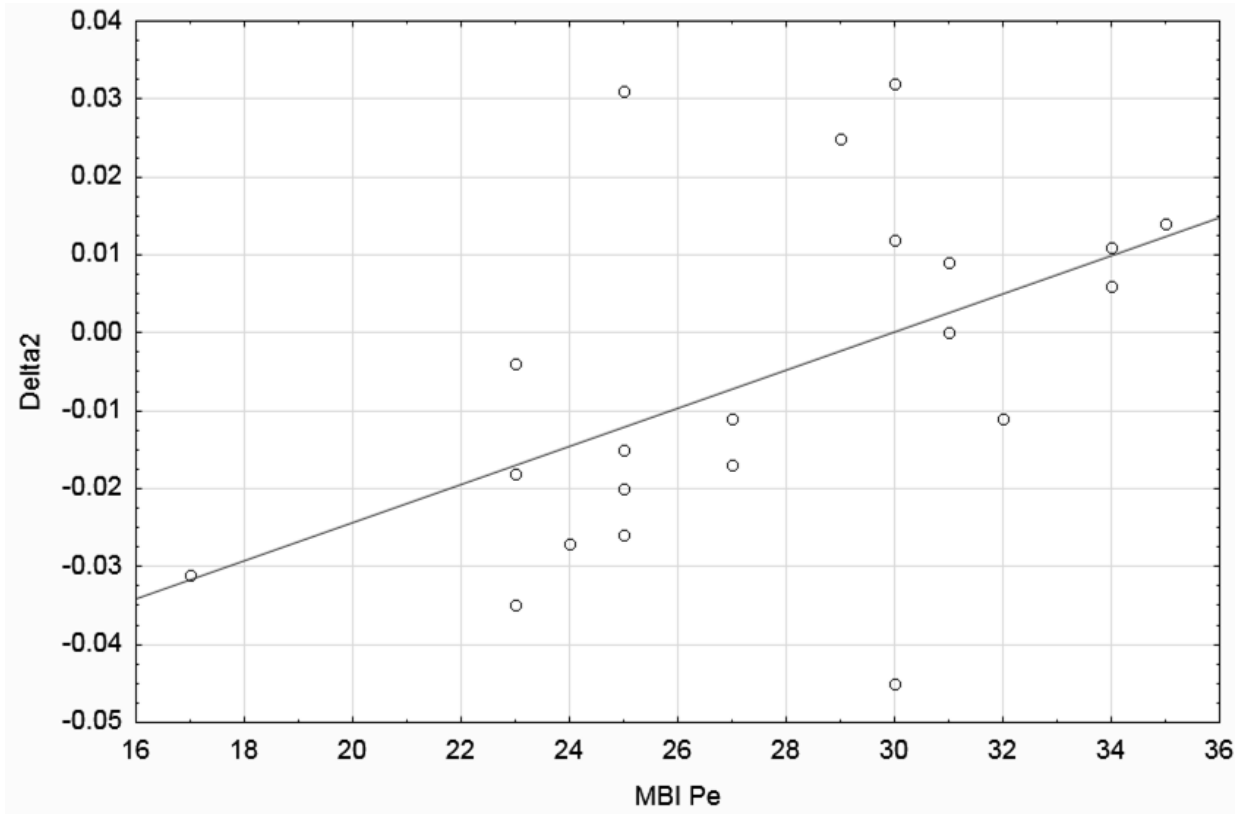


Figure 6.47 Scatterplots of the response of the Coefficient of Variation of Right Whole Alpha% power and MBI Professional Efficacy scores.

Coefficient of Variation of Left Whole Alpha% power

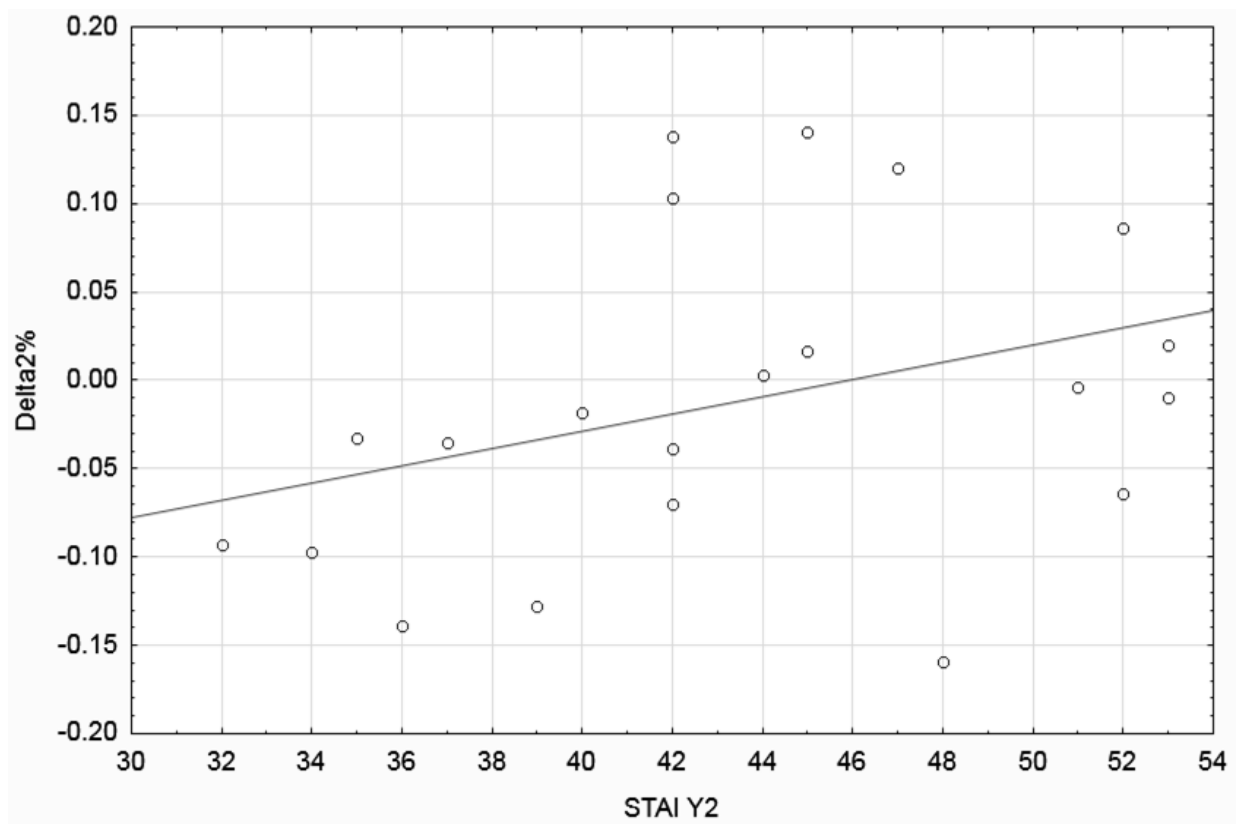
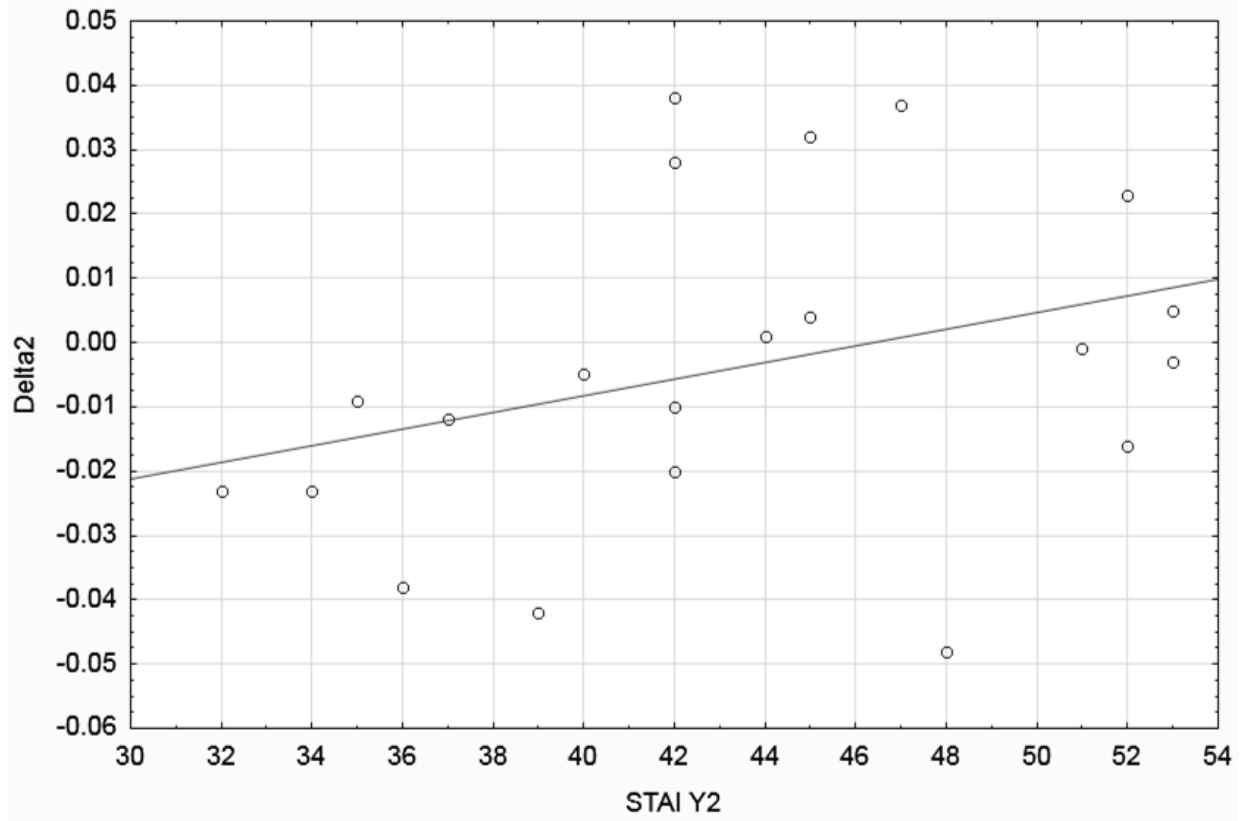


Figure 6.48 Scatterplots of the response of the Coefficient of Variation of Left Whole Alpha% power and Trait Anxiety scores.

Standard Deviation of Right Whole Alpha% power

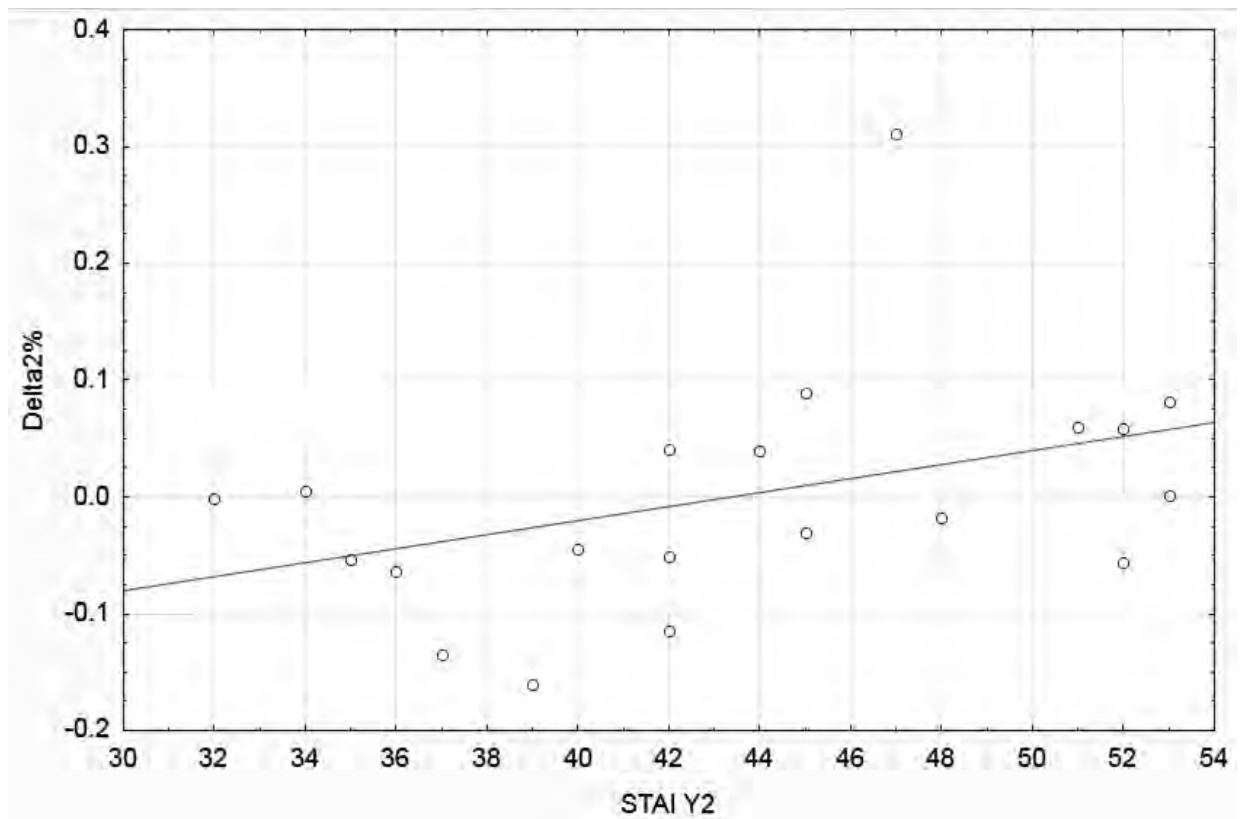
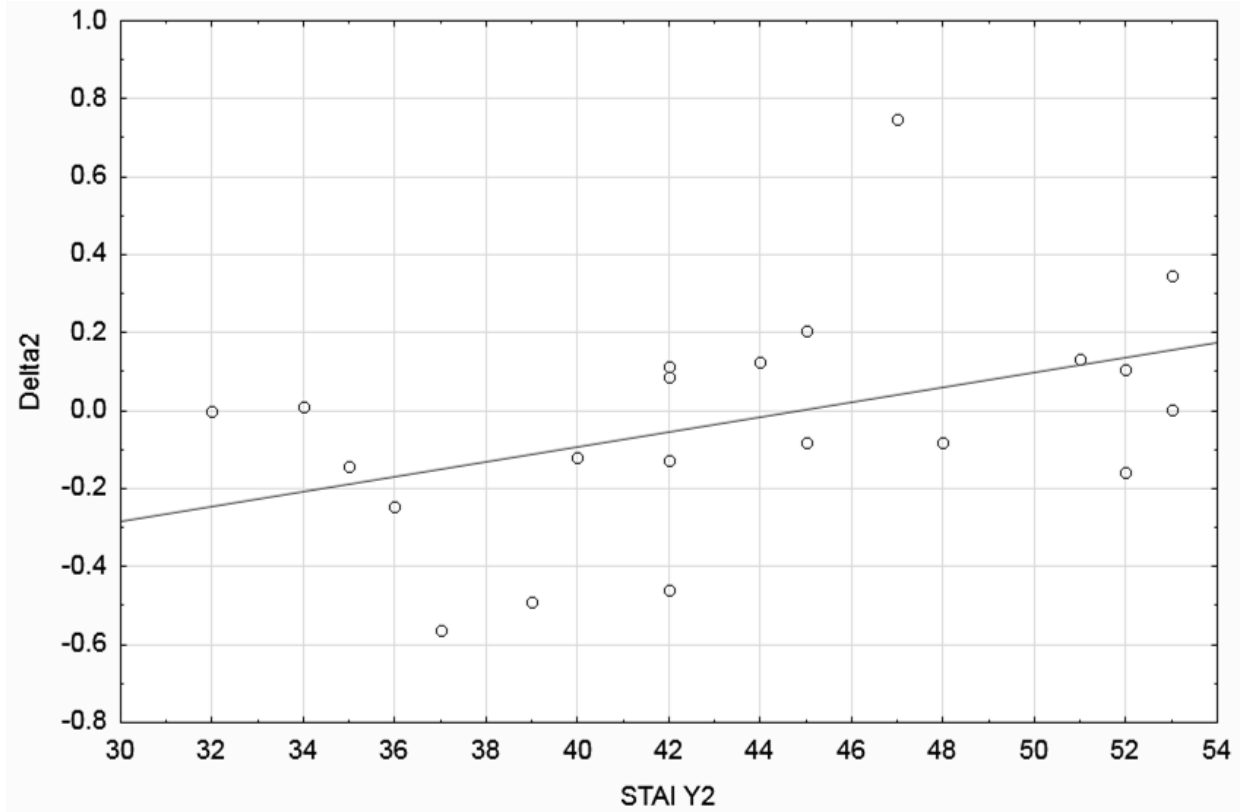


Figure 6.49 Scatterplots of the response of the Standard Deviation of Right Whole Alpha% power and Trait Anxiety scores.

Table 6.26 Spearman ranked correlations between the EEG Whole Alpha Amplitude Asymmetry variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Alpha Amplitude Asymmetry StdDev	Baseline 1	MBI Cy	0.4094	0.0653
Alpha Amplitude Asymmetry StdDev	Baseline 2	MBI Cy	0.4931	0.0231
Alpha Amplitude Asymmetry StdDev	Challenge	MBI Cy	0.3957	0.0758
Alpha Amplitude Asymmetry StdDev	Recovery	MBI Cy	0.4925	0.0233
Alpha Amplitude Asymmetry Mean	Ch-B2	MBI Pe	-0.5741	0.0065
Alpha Amplitude Asymmetry StdDev	(Ch-B2)/B2	MBI Pe	0.3858	0.0842
Alpha Amplitude Asymmetry Mean	Challenge	STAI Y1	0.4574	0.0371
Alpha Amplitude Asymmetry Mean	(Ch-B2)/B2	STAI Y1	0.5723	0.0067
Alpha Amplitude Asymmetry Mean	Challenge	STAI Y1 Pr	0.4644	0.0339
Alpha Amplitude Asymmetry Mean	(Ch-B2)/B2	STAI Y1 Pr	0.4891	0.0244
Alpha Amplitude Asymmetry StdDev	Challenge	STAI Y2	0.4376	0.0473
Alpha Amplitude Asymmetry StdDev	Ch-B2	STAI Y2	0.3991	0.0731
Alpha Amplitude Asymmetry StdDev	Challenge	STAI Y2 Pr	0.4453	0.0431
Alpha Amplitude Asymmetry StdDev	Ch-B2	STAI Y2 Pr	0.3841	0.0856

StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response,

Mean Alpha Amplitude Asymmetry

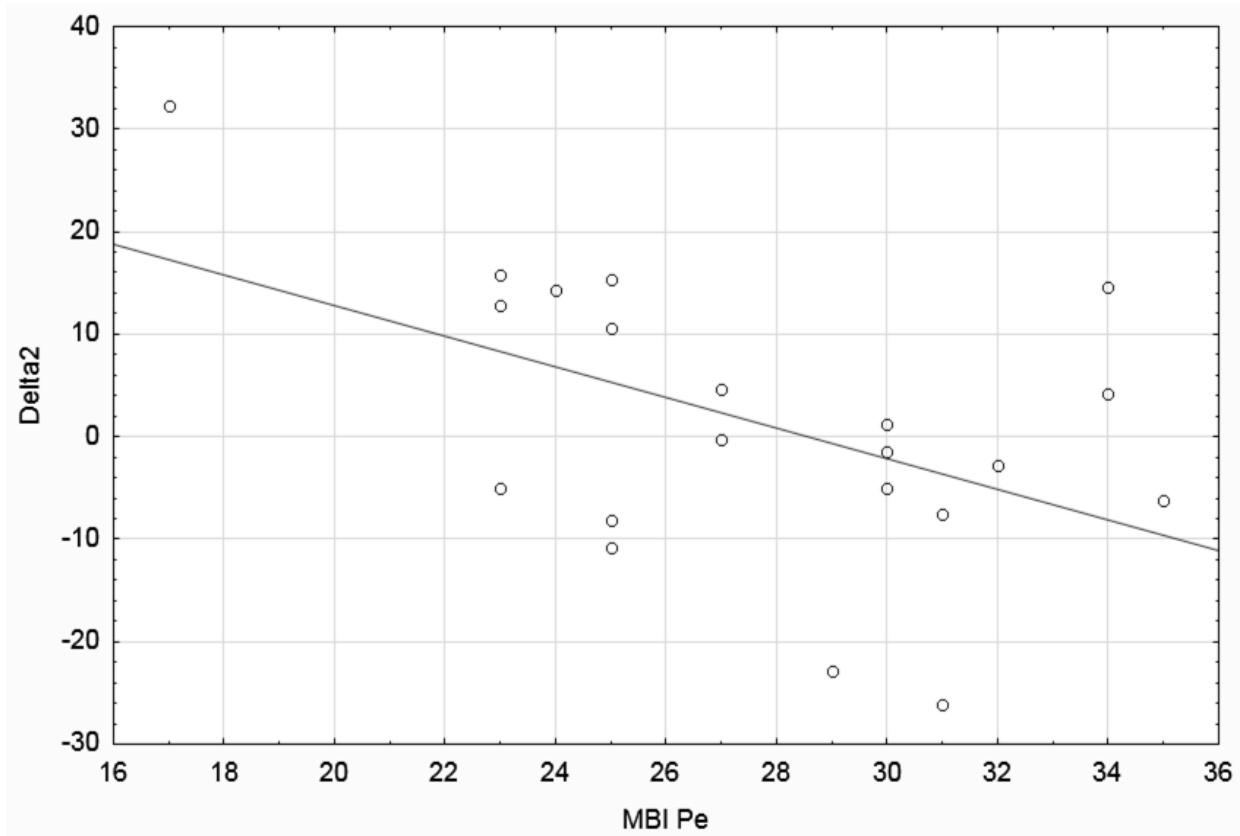


Figure 6.50 Scatterplot of the response of the Mean Alpha Amplitude Asymmetry and MBI Professional Efficacy scores.

Mean Alpha Amplitude Asymmetry

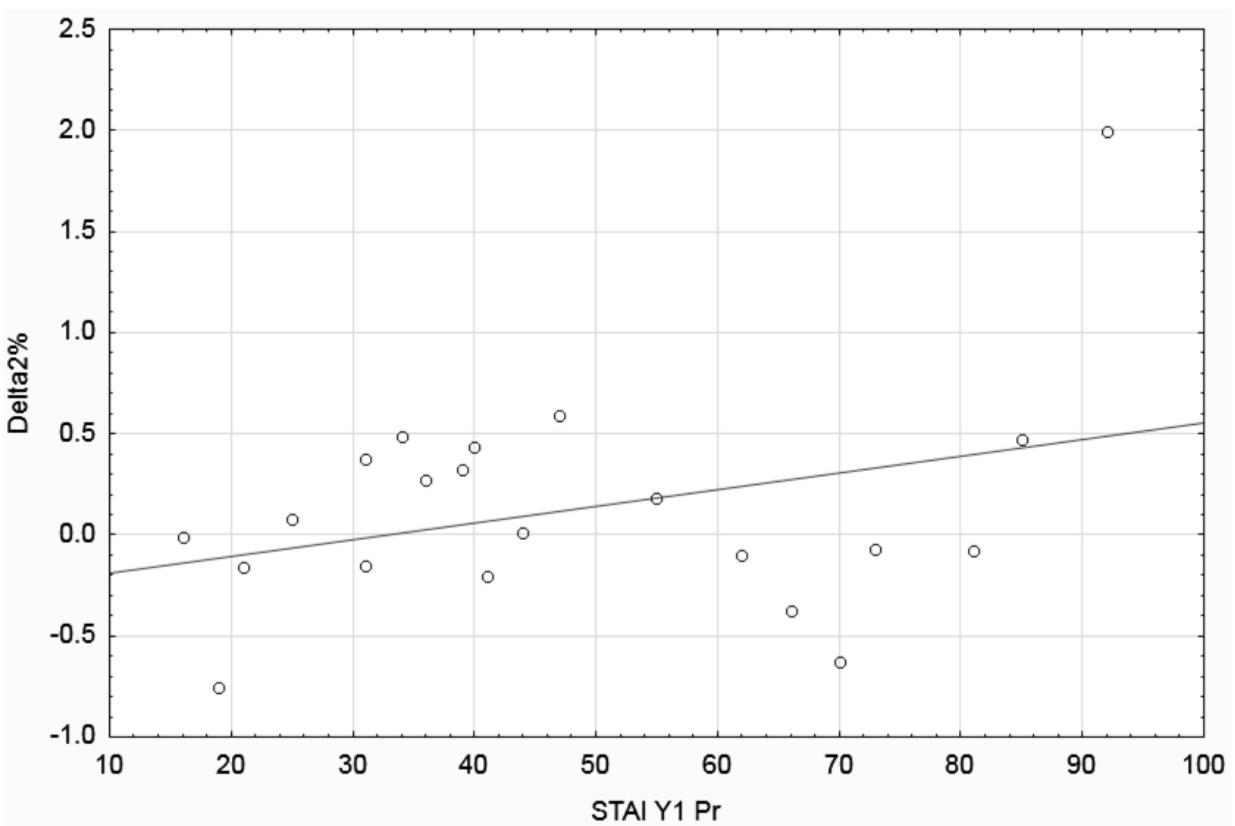
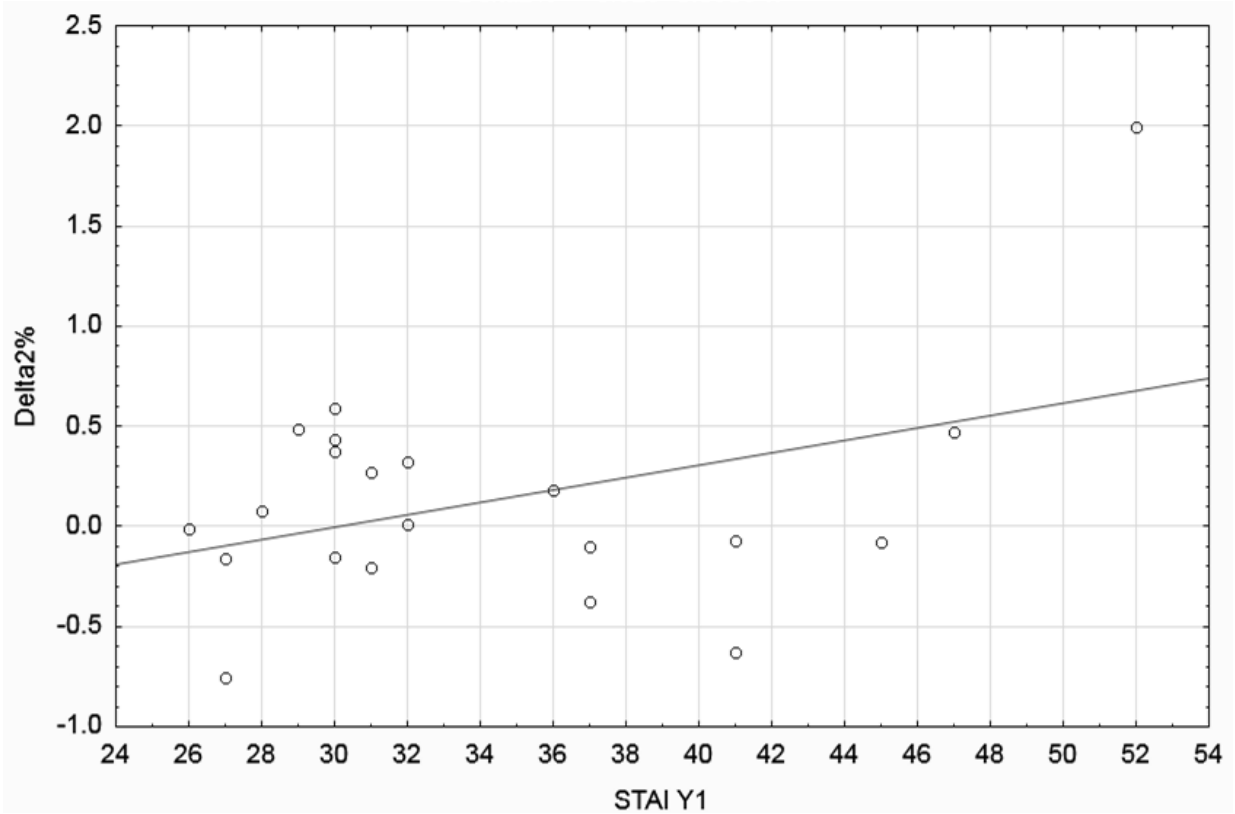


Figure 6.51 Scatterplots of the response of the Mean Alpha Amplitude Asymmetry and State Anxiety scores.

Table 6.27 Spearman ranked correlations between the EEG Whole Alpha Coherence variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Alpha Coherence Mean	Recovery	MBI Ex	-0.4211	0.0573
Alpha Coherence StdDev	Challenge	MBI Ex	0.4589	0.0364
Alpha Coherence Mean	Recovery	STAI Y2	-0.4258	0.0543
Alpha Coherence StdDev	Challenge	STAI Y2	0.4284	0.0527
Alpha Coherence StdDev	Challenge	STAI Y2 Pr	0.3867	0.0833

StdDev – Standard deviation, MBI – Maslach Burnout inventory, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y2 – Trait Anxiety, Pr – Percentile rank.

Table 6.28 Spearman ranked correlations between the EEG Whole Alpha Phase variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Alpha Phase Mean	Ch-B2	MBI Cy	-0.3695	0.0992
Alpha Phase Mean	Baseline 1	STAI Y1	-0.5403	0.0115
Alpha Phase Mean	Baseline 1	STAI Y1 Pr	-0.4359	0.0483
Alpha Phase StdDev	(Ch-B2)/B2	STAI Y2	0.5739	0.0065
Alpha Phase StdDev	Challenge	STAI Y2	0.5015	0.0206
Alpha Phase StdDev	Ch-B2	STAI Y2	0.4115	0.0638
Alpha Phase StdDev	(Ch-B2)/B2	STAI Y2 Pr	0.6172	0.0029
Alpha Phase StdDev	Challenge	STAI Y2 Pr	0.4583	0.0367
Alpha Phase StdDev	Ch-B2	STAI Y2 Pr	0.4688	0.0321

StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

Mean of Alpha Phase

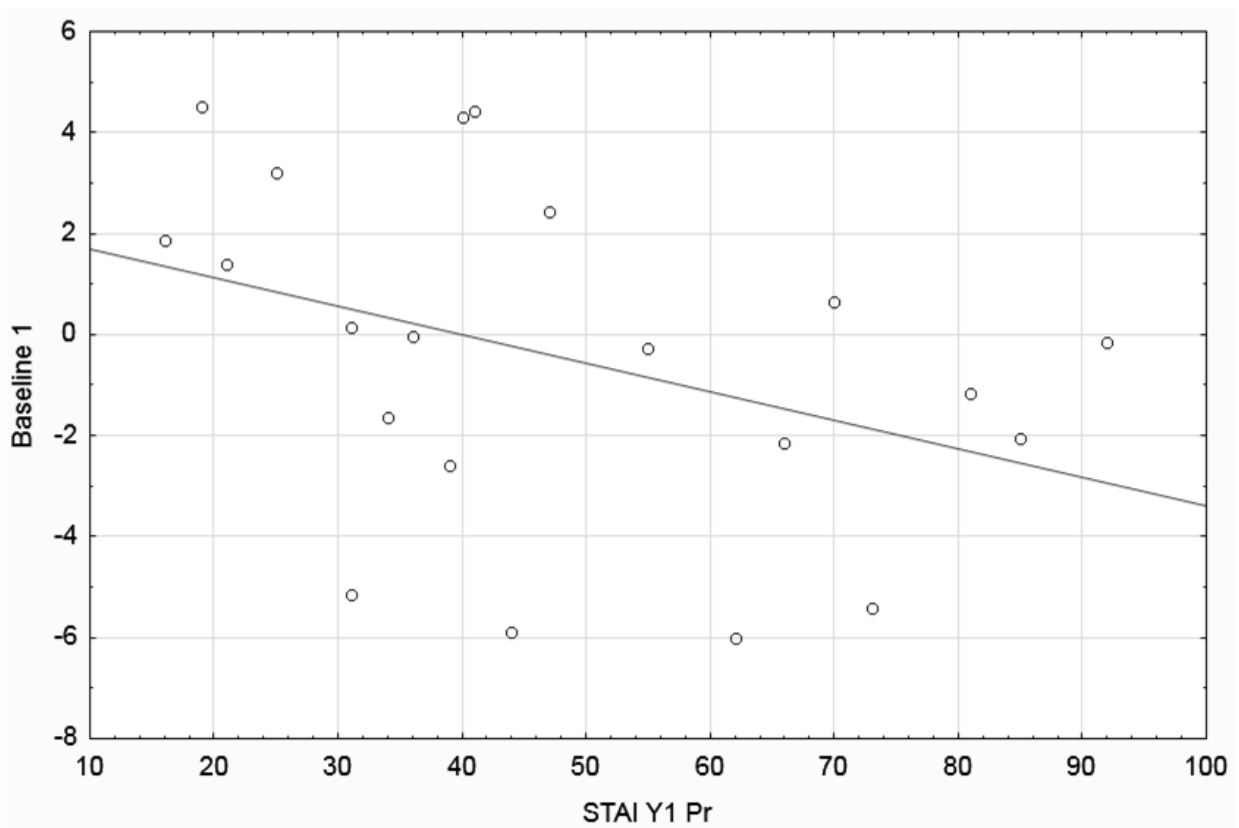
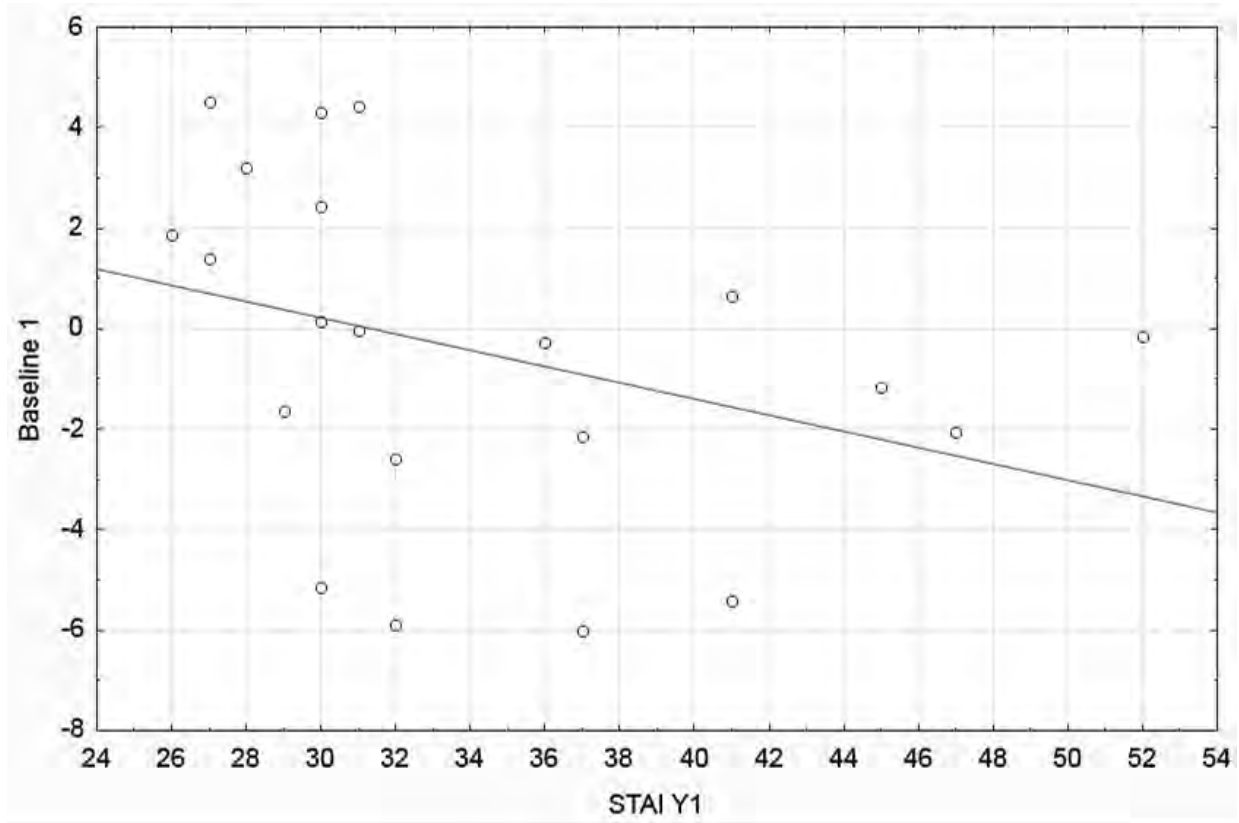


Figure 6.52 Scatterplots of the Mean of Alpha Phase at Baseline 1 and the State Anxiety scores.

Standard Deviation of Alpha Phase

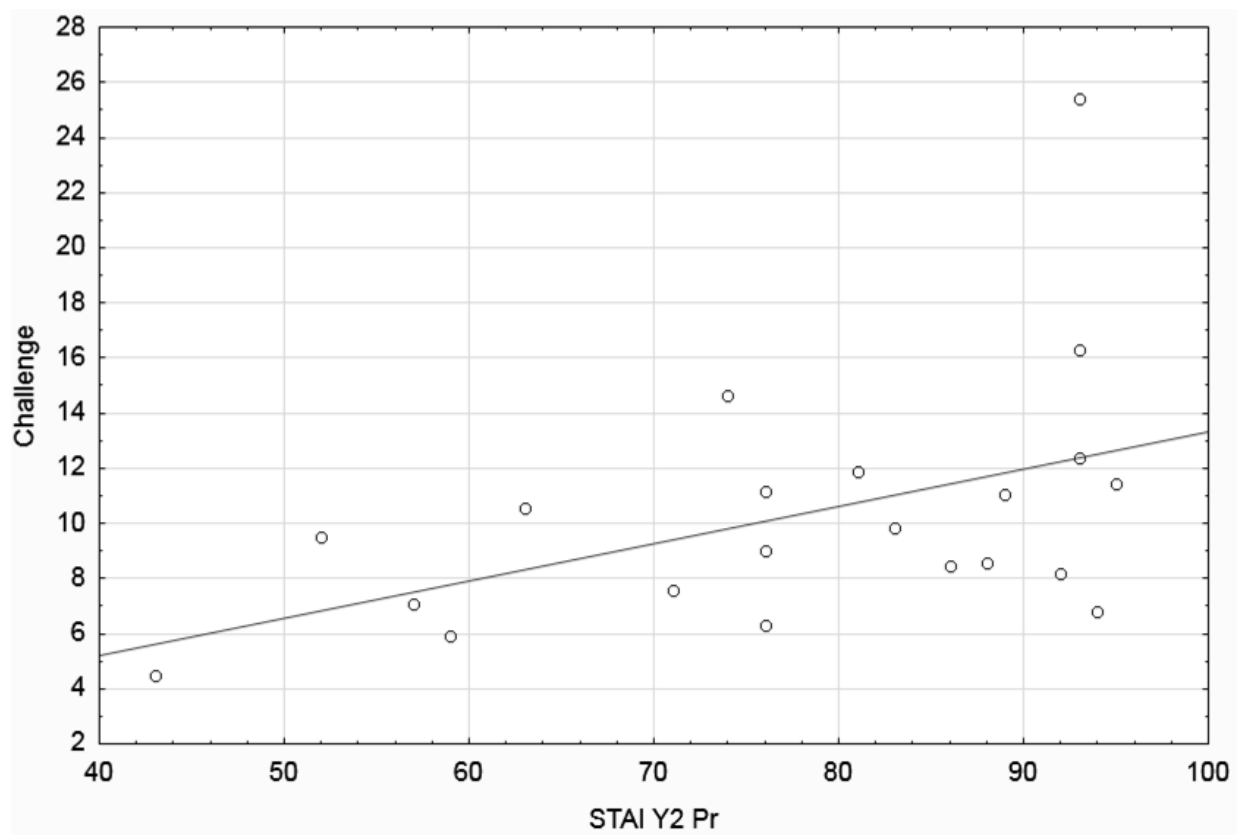
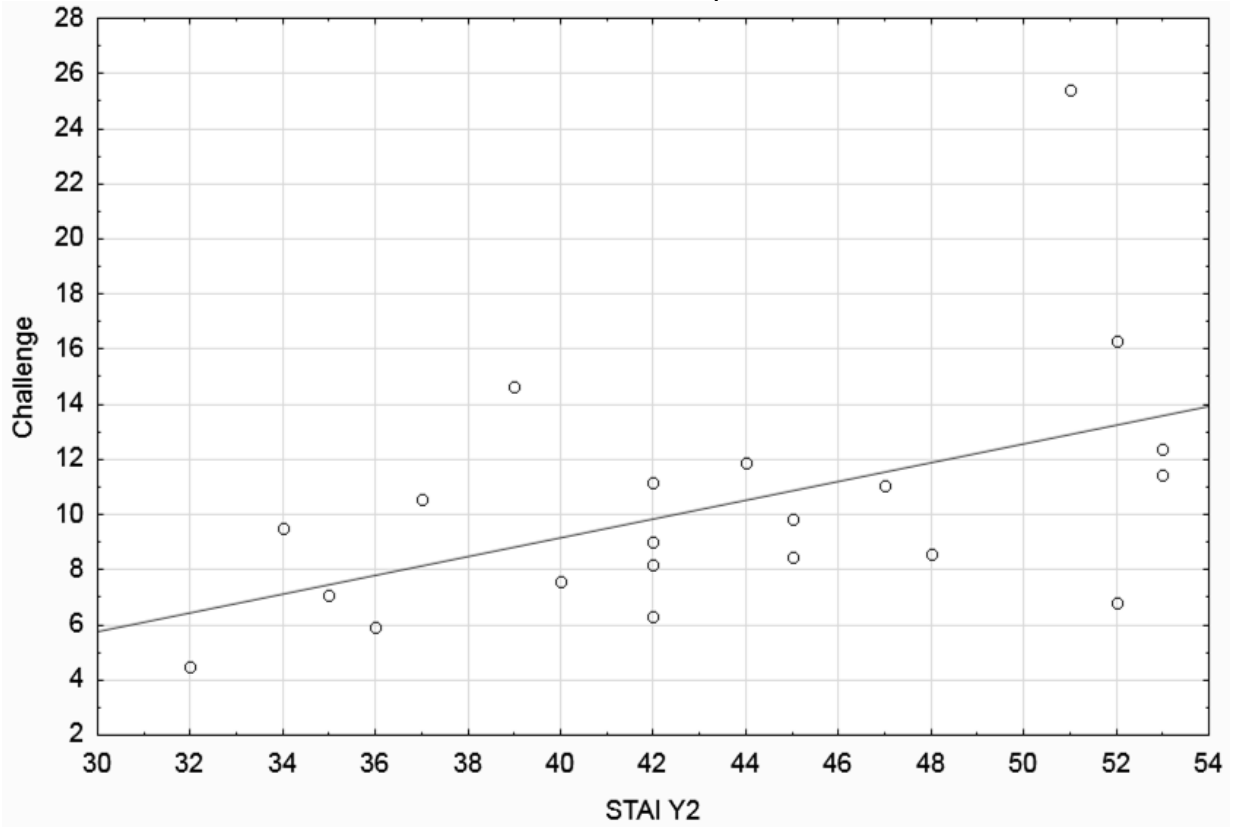
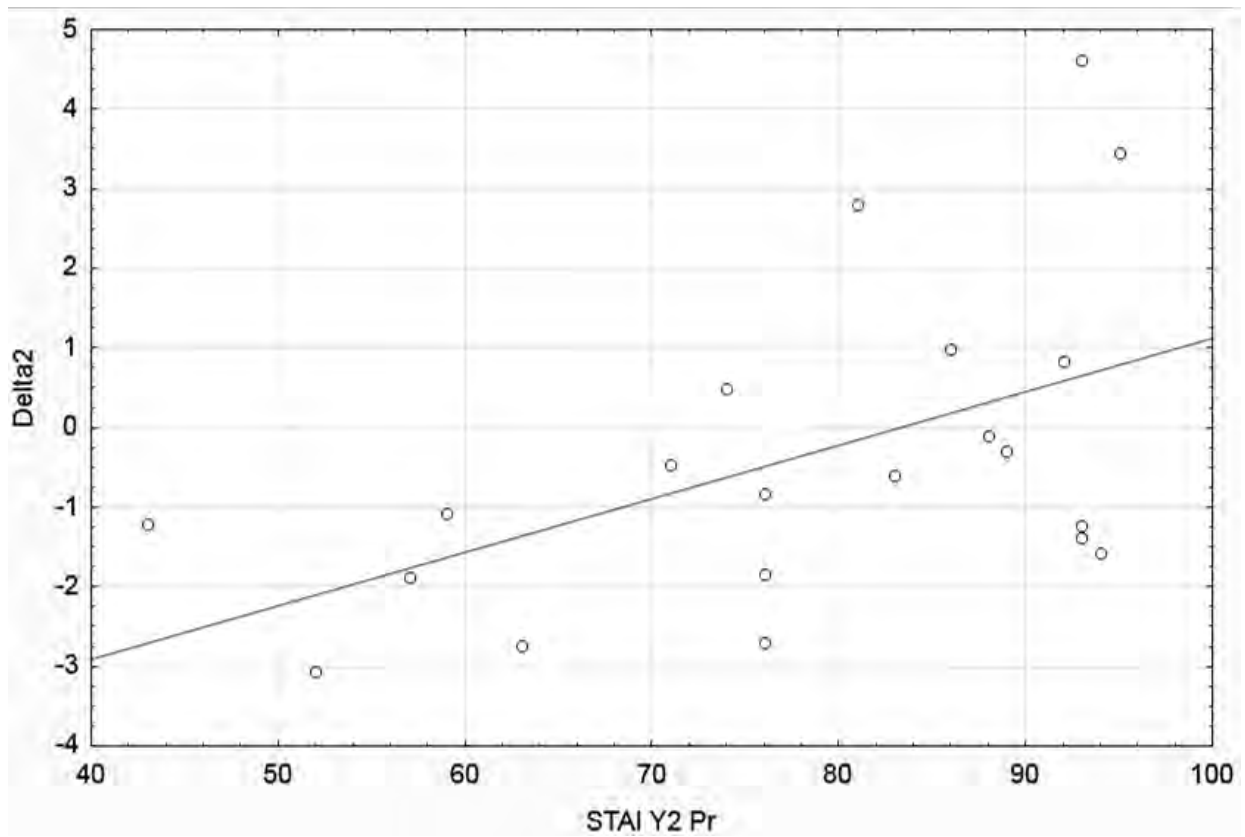
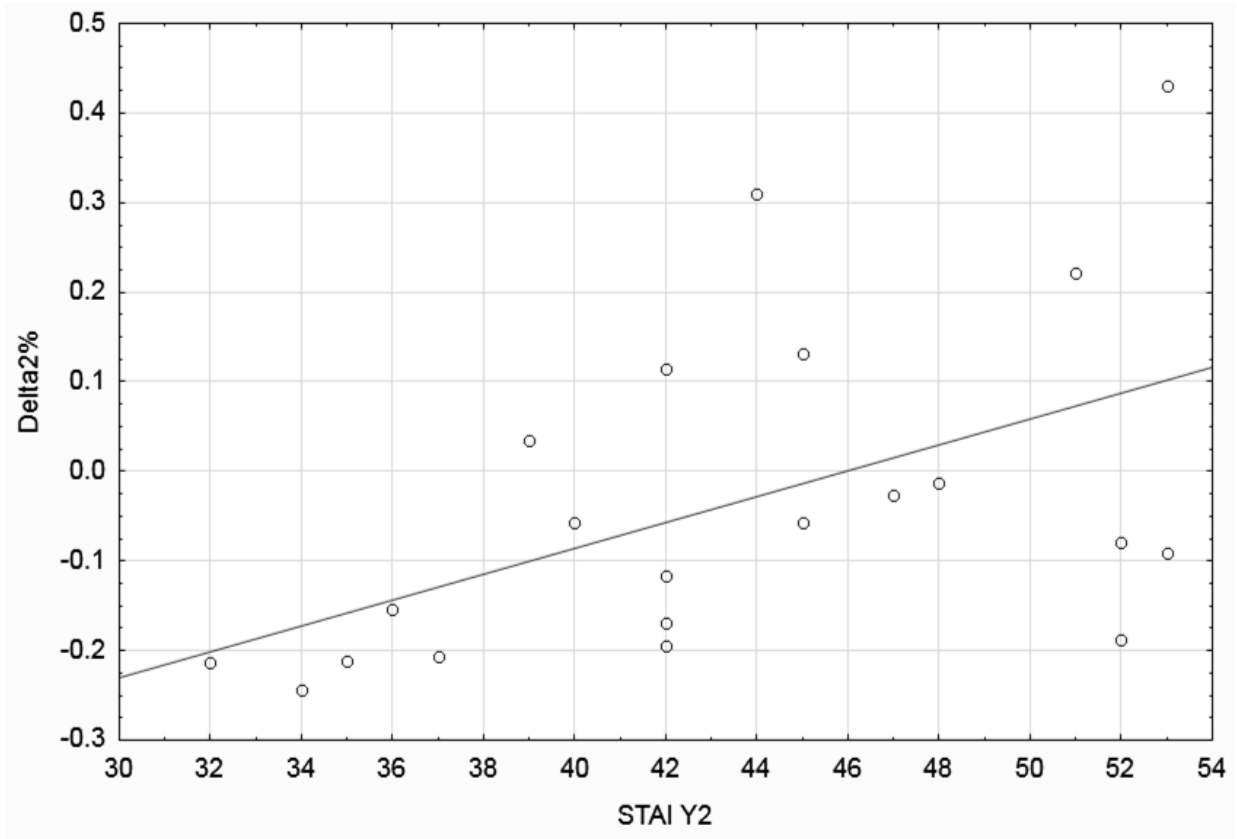


Figure 6.53 Scatterplots of the Standard Deviation of Alpha Phase at Challenge and the Trait Anxiety scores.

Standard Deviation of Alpha Phase



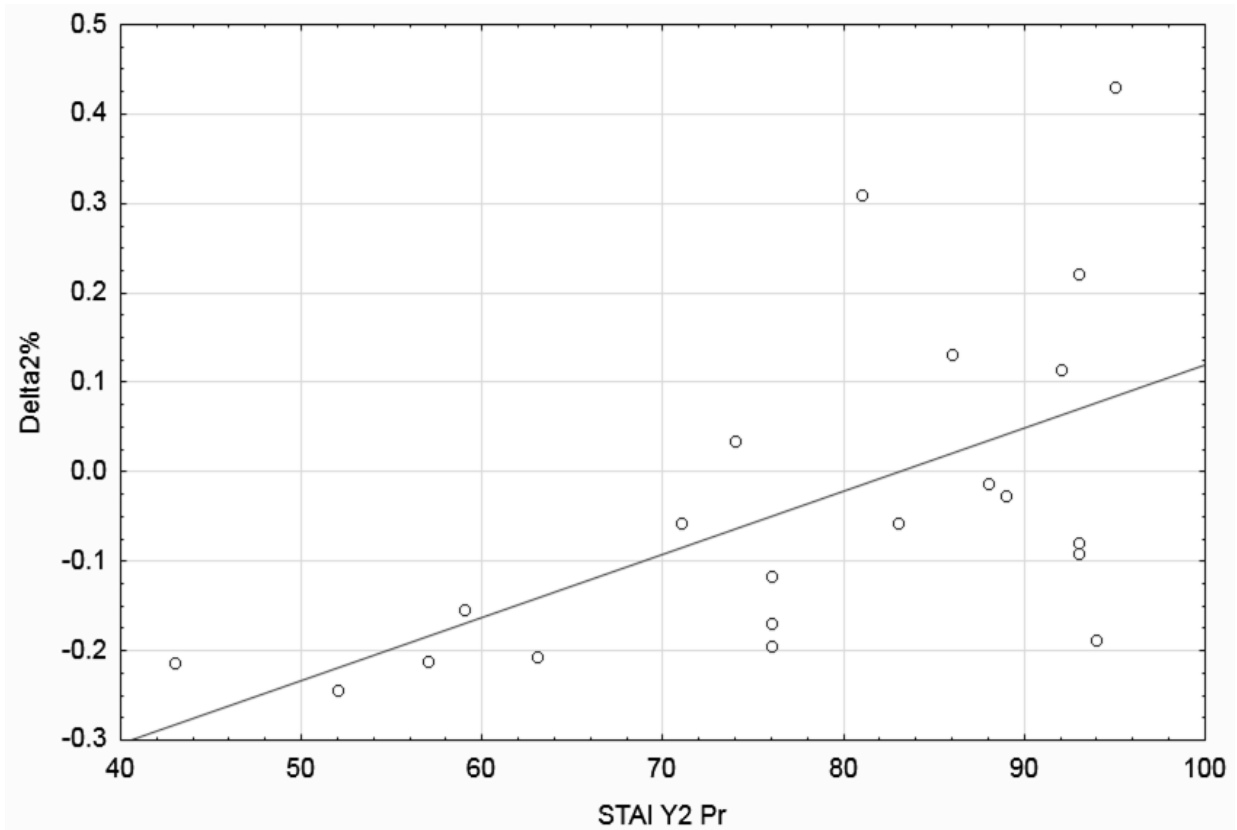


Figure 6.54 Scatterplots of the response of the Standard Deviation of Alpha Phase and Trait Anxiety scores.

6.3.14 EEG – Sensorimotor Rhythm

Table 6.29 Spearman ranked correlations between the a) Left and b) Right EEG SMR % Power variables and the psychometric items. N=21

a)

Variable Name	Step	Psychometric	Spearman r	p-value
Left SMR%Power Mean	(Ch-B2)/B2	STAI Y1	-0.4352	0.0486
Left SMR%Power Mean	Baseline 1	STAI Y1	0.3961	0.0755
Left SMR%Power Mean	Baseline 2	STAI Y1	0.4953	0.0224
Left SMR%Power Mean	Challenge	STAI Y1	0.4131	0.0627
Left SMR%Power Mean	Ch-B2	STAI Y1	-0.4326	0.0501
Left SMR%Power Mean	Recovery	STAI Y1	0.6199	0.0027
Left SMR%Power StdDev	(Ch-B2)/B2	STAI Y1	-0.5214	0.0154
Left SMR%Power StdDev	Baseline 1	STAI Y1	0.4692	0.0319
Left SMR%Power StdDev	Baseline 2	STAI Y1	0.665	0.001
Left SMR%Power StdDev	Ch-B2	STAI Y1	-0.5331	0.0128
Left SMR%Power StdDev	Recovery	STAI Y1	0.625	0.0025
Left SMR%Power Mean	(Ch-B2)/B2	STAI Y1 Pr	-0.4112	0.0641
Left SMR%Power Mean	Baseline 1	STAI Y1 Pr	0.38	0.0893
Left SMR%Power Mean	Baseline 2	STAI Y1 Pr	0.4501	0.0406
Left SMR%Power Mean	Challenge	STAI Y1 Pr	0.3774	0.0917
Left SMR%Power Mean	Ch-B2	STAI Y1 Pr	-0.4112	0.0641
Left SMR%Power Mean	Recovery	STAI Y1 Pr	0.582	0.0056
Left SMR%Power StdDev	(Ch-B2)/B2	STAI Y1 Pr	-0.4898	0.0242
Left SMR%Power StdDev	Baseline 1	STAI Y1 Pr	0.4488	0.0413
Left SMR%Power StdDev	Baseline 2	STAI Y1 Pr	0.6833	0.0006
Left SMR%Power StdDev	Ch-B2	STAI Y1 Pr	-0.5002	0.0209
Left SMR%Power StdDev	Recovery	STAI Y1 Pr	0.5757	0.0063



b)

Variable Name	Step	Psychometric	Spearman r	p-value
Right SMR%Power Mean	Baseline 1	STAI Y1	0.616	0.0029
Right SMR%Power Mean	Baseline 2	STAI Y1	0.5503	0.0097
Right SMR%Power Mean	Challenge	STAI Y1	0.4242	0.0553
Right SMR%Power Mean	Ch-B2	STAI Y1	-0.3765	0.0925
Right SMR%Power Mean	Recovery	STAI Y1	0.5932	0.0046
Right SMR%Power Mean	(Ch-B2)/B2	STAI Y1 Pr	-0.43	0.0517
Right SMR%Power Mean	Baseline 1	STAI Y1 Pr	0.5632	0.0079
Right SMR%Power Mean	Baseline 2	STAI Y1 Pr	0.525	0.0145
Right SMR%Power Mean	Ch-B2	STAI Y1 Pr	-0.443	0.0443
Right SMR%Power Mean	Recovery	STAI Y1 Pr	0.5729	0.0066
Right SMR%Power StdDev	Baseline 1	MBI Ex	-0.3834	0.0862
Right SMR%Power StdDev	(Ch-B2)/B2	STAI Y1	-0.4581	0.0368
Right SMR%Power StdDev	Baseline 1	STAI Y1	0.5575	0.0087
Right SMR%Power StdDev	Baseline 2	STAI Y1	0.5599	0.0083
Right SMR%Power StdDev	Challenge	STAI Y1	0.5038	0.0199
Right SMR%Power StdDev	Ch-B2	STAI Y1	-0.4396	0.0461
Right SMR%Power StdDev	Recovery	STAI Y1	0.6623	0.0011
Right SMR%Power StdDev	(Ch-B2)/B2	STAI Y1 Pr	-0.5281	0.0139
Right SMR%Power StdDev	Baseline 1	STAI Y1 Pr	0.5042	0.0198
Right SMR%Power StdDev	Baseline 2	STAI Y1 Pr	0.5638	0.0078
Right SMR%Power StdDev	Challenge	STAI Y1 Pr	0.4716	0.0309
Right SMR%Power StdDev	Ch-B2	STAI Y1 Pr	-0.5101	0.0182
Right SMR%Power StdDev	Recovery	STAI Y1 Pr	0.6281	0.0023
Right SMR%PowerCoefVar	(Ch-B2)/B2	MBI Pe	0.5675	0.0073
Right SMR%PowerCoefVar	Ch-B2	MBI Pe	0.5608	0.0082

SMR – Sensorimotor rhythm, Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

Coefficient of Variation of Right SMR% power

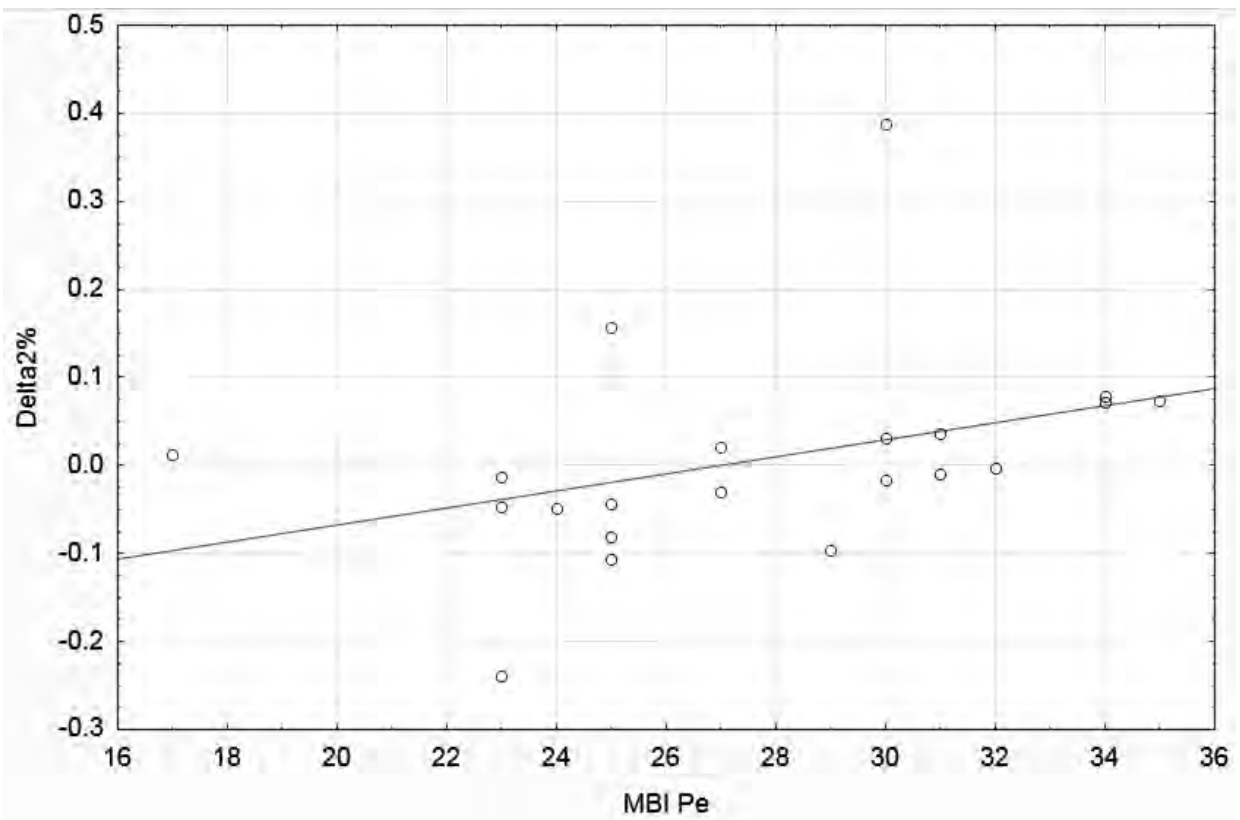
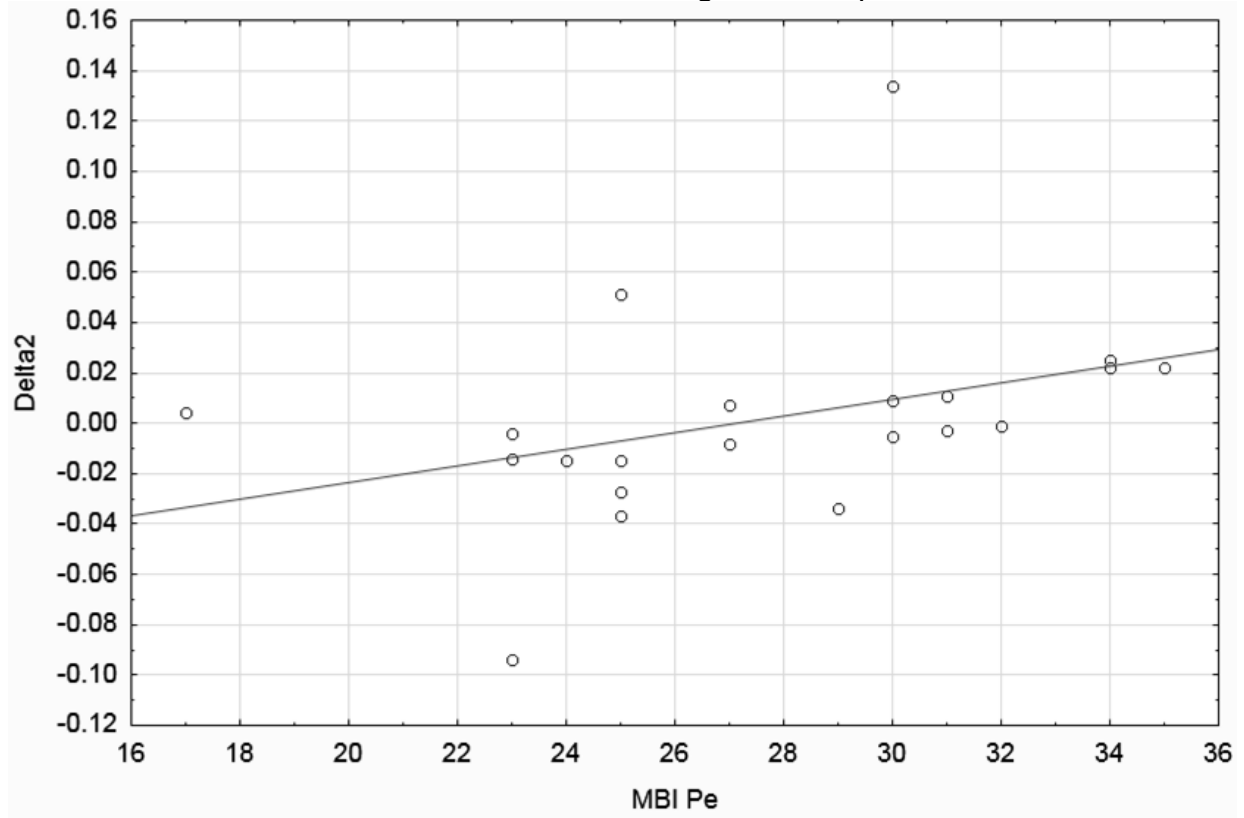


Figure 6.55 Scatterplots of the response of the Coefficient of Variation of Right SMR% power and MBI Professional Efficacy scores.

Mean of Left SMR% power

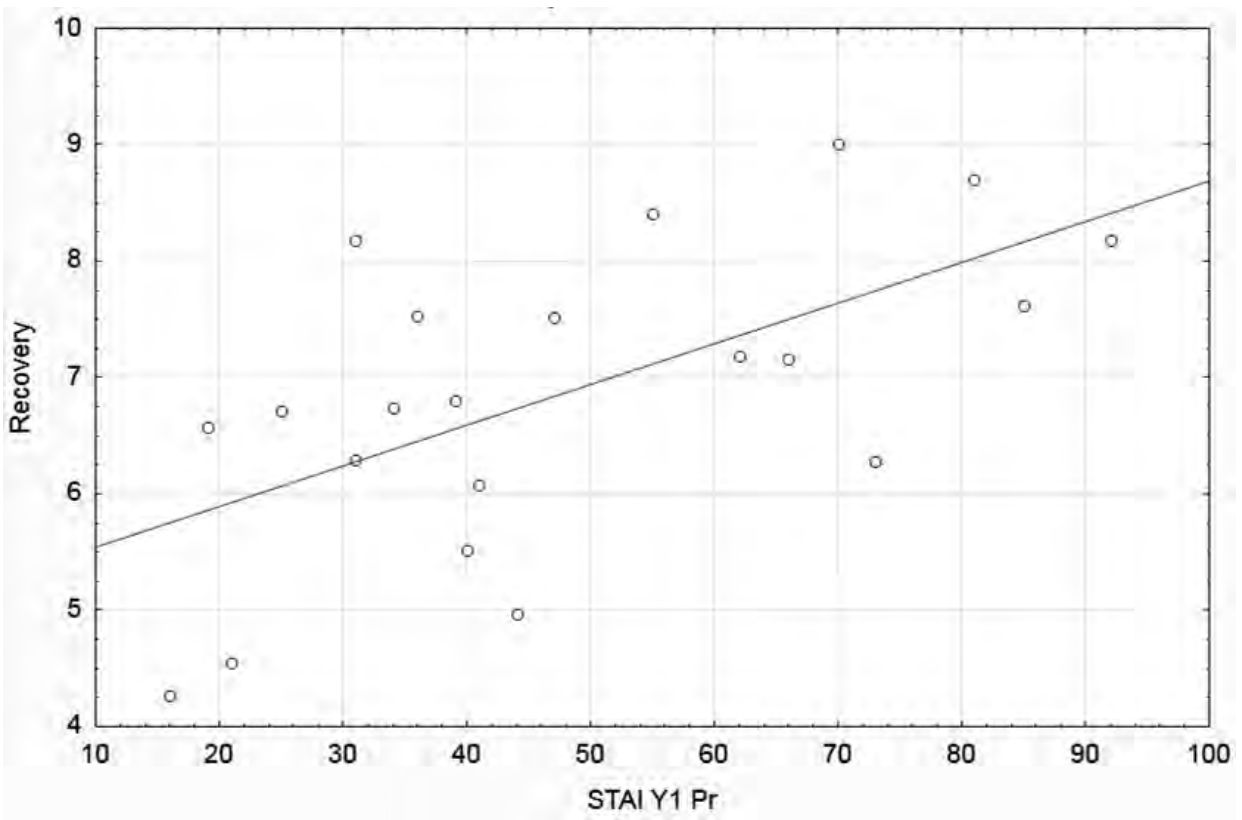
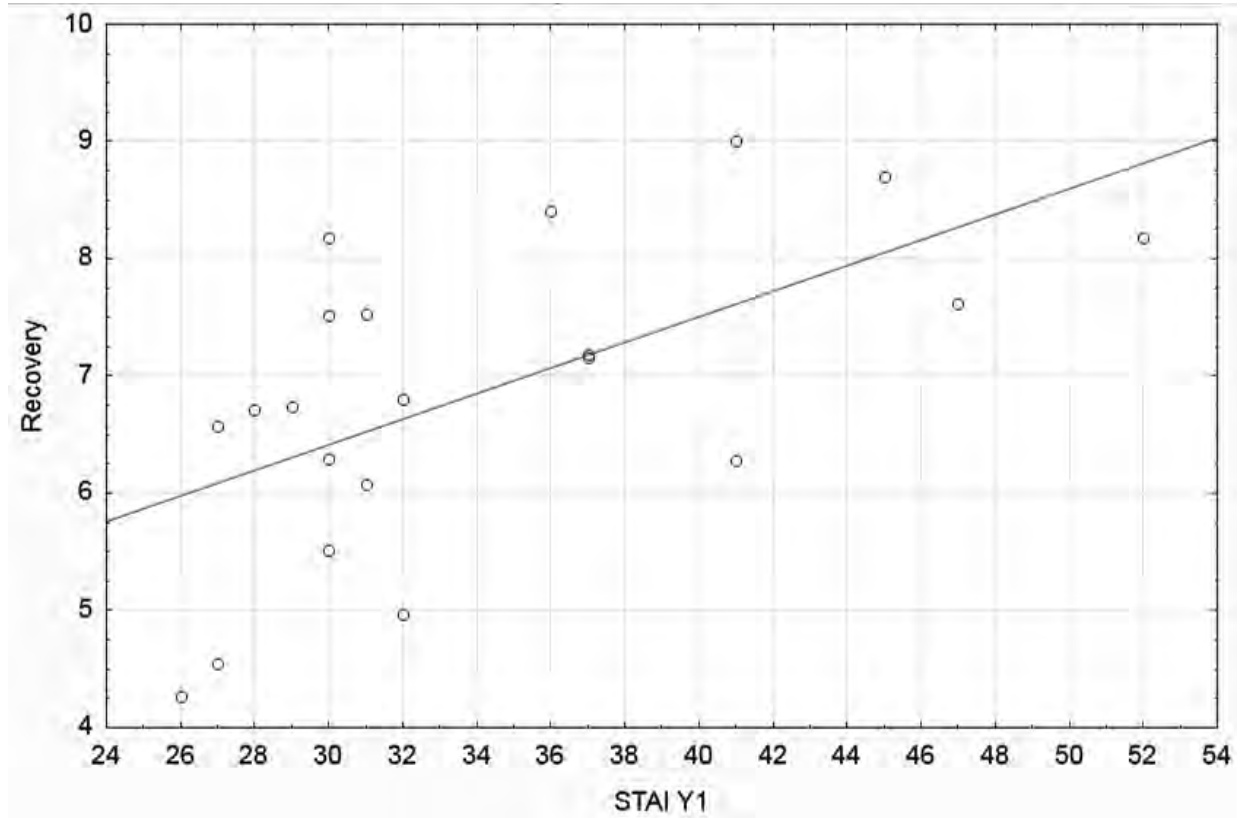


Figure 6.56 Scatterplots of the Mean of Left SMR% power at Recovery and State Anxiety scores.

Mean of Right SMR% of power

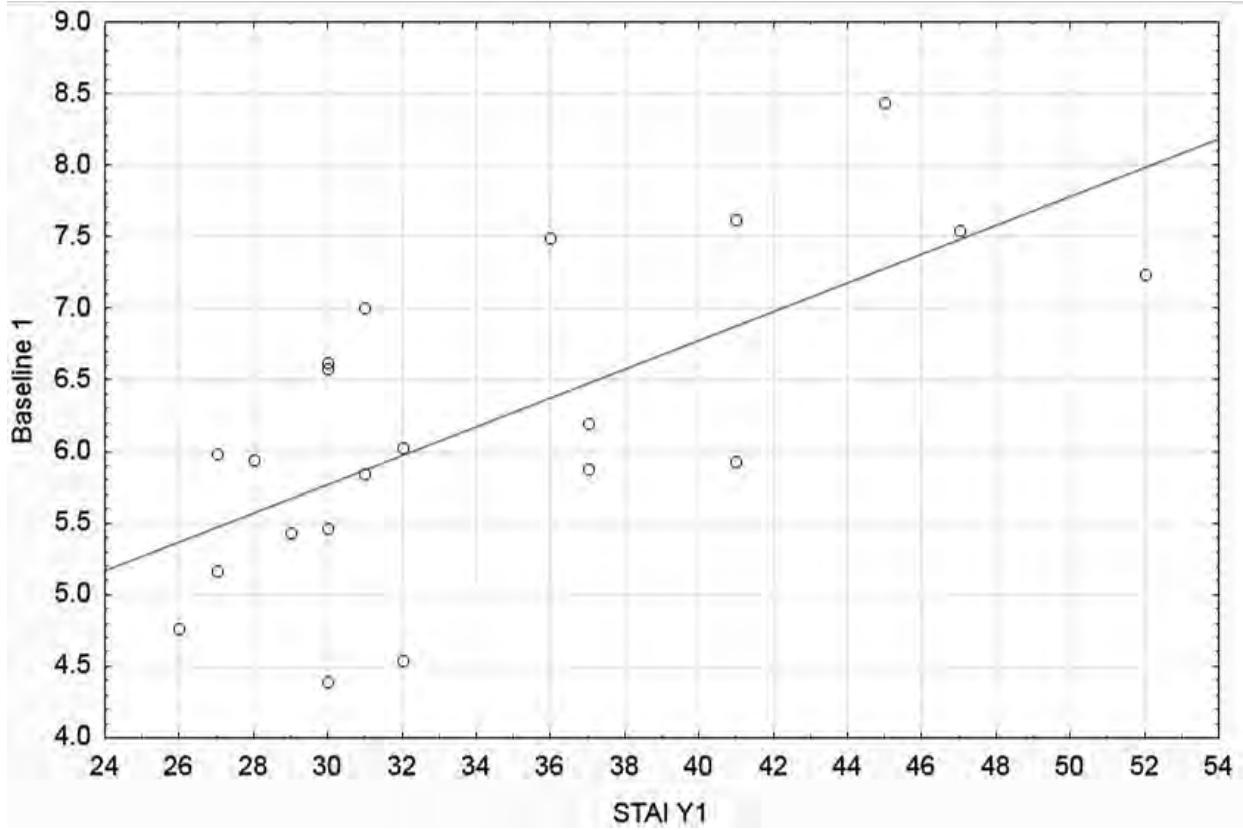


Figure 6.57 Scatterplot of the Mean Right SMR% power at Baseline 1 and State Anxiety Scores.

Mean of Left SMR% power

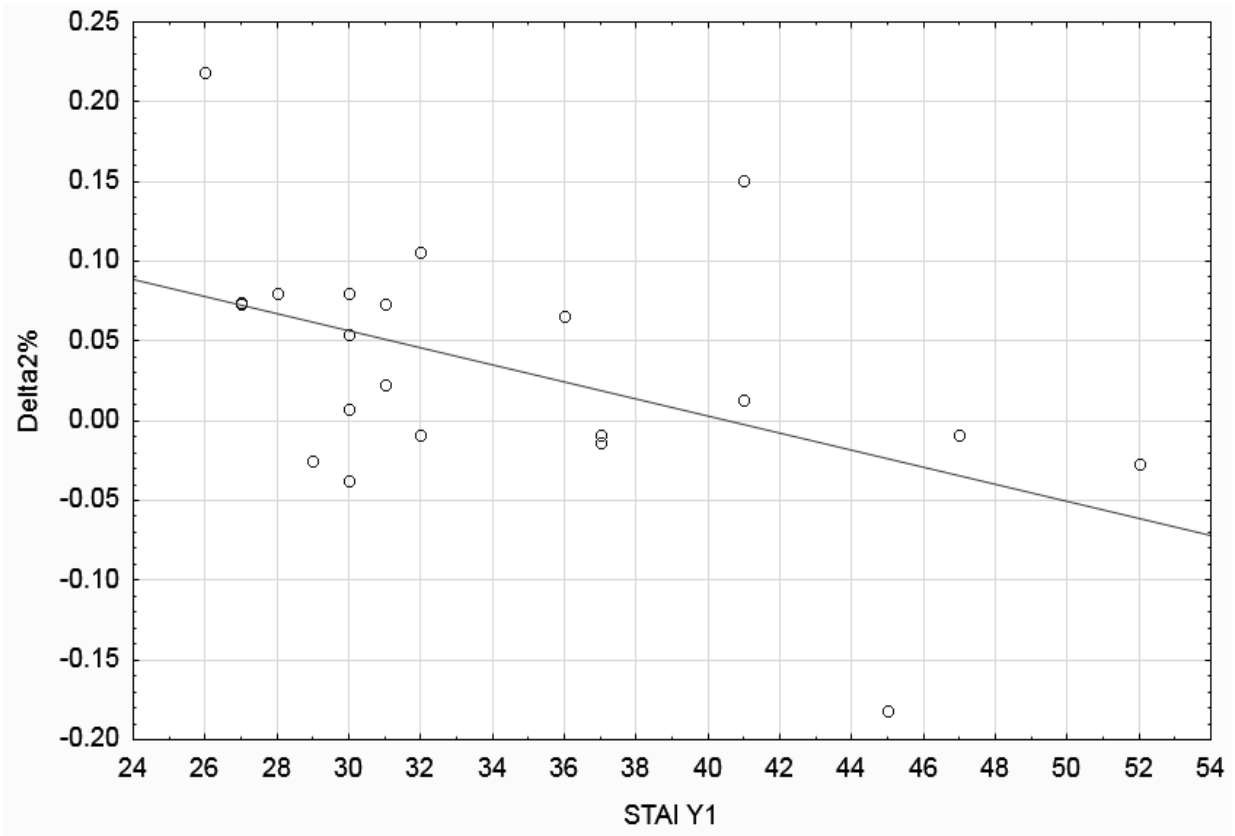


Figure 6.58 Scatterplot of the response of the Mean Left SMR% power and State Anxiety scores.

Mean of Right SMR% of power

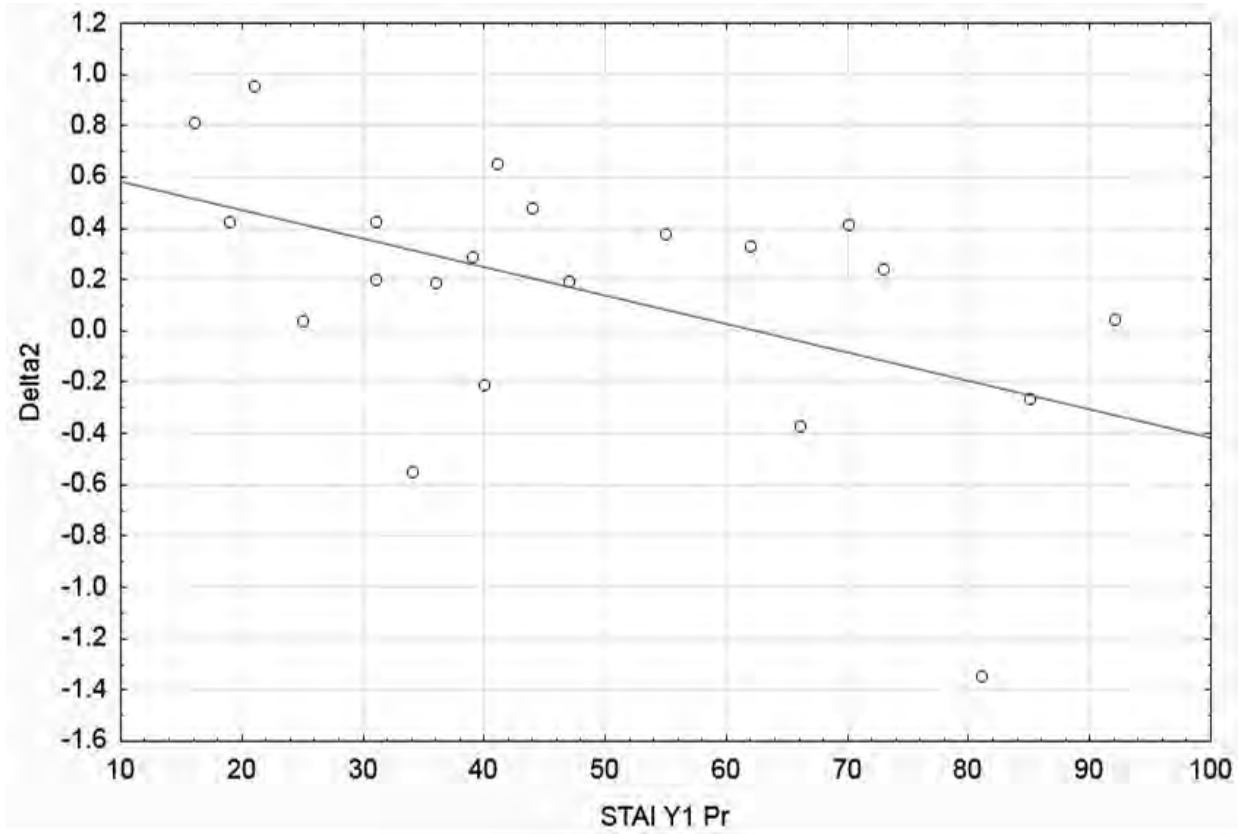


Figure 6.59 Scatterplot of the response of Mean Right SMR% power and State Anxiety scores.

Standard Deviation of Left SMR% of power

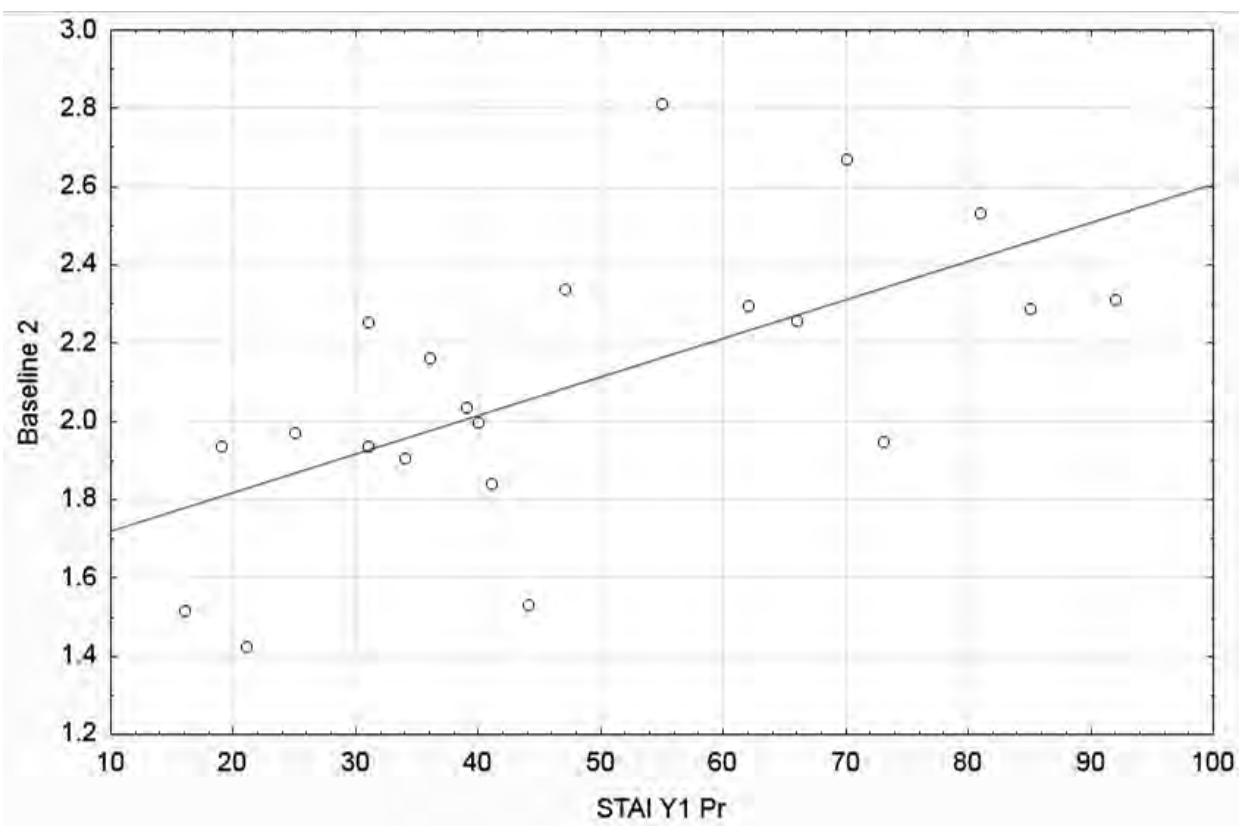
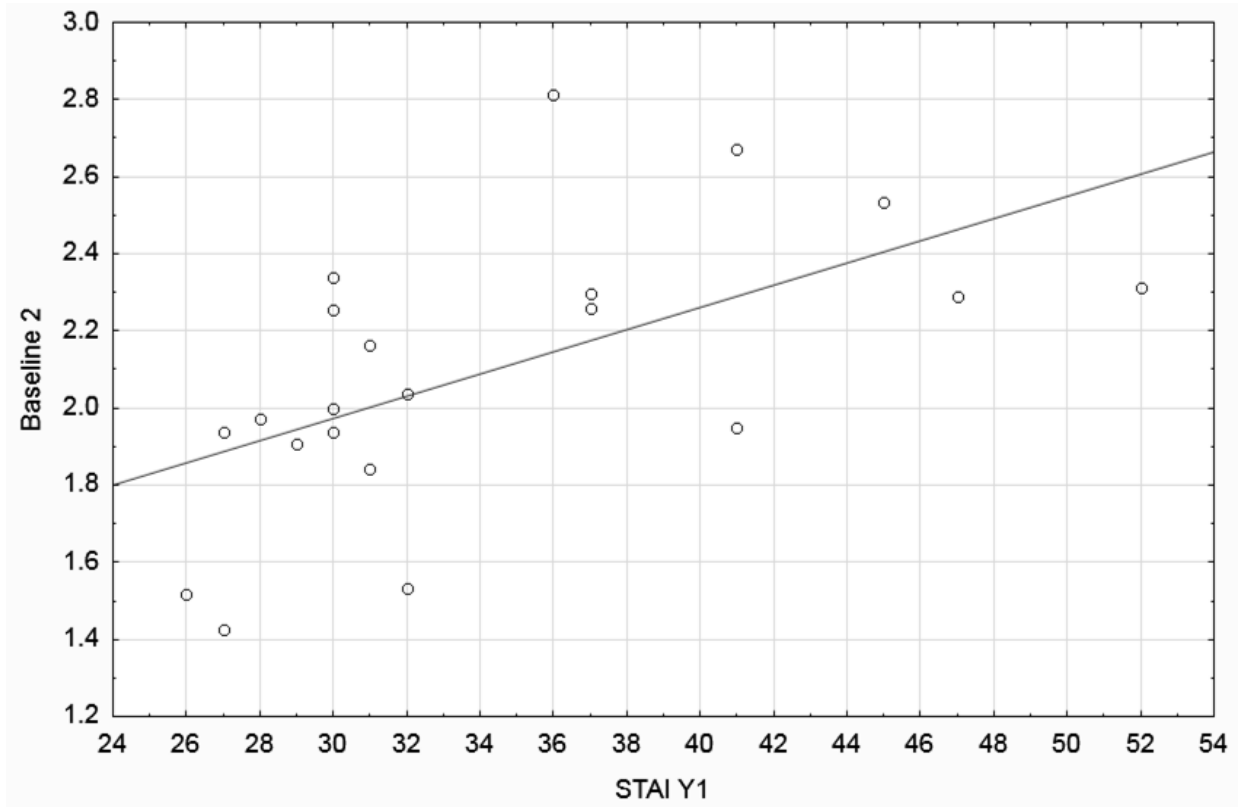


Figure 6.60 Scatterplots of the Standard Deviation of Left SMR% power at Baseline 2 and State Anxiety scores.

Standard Deviation of Left SMR% of power

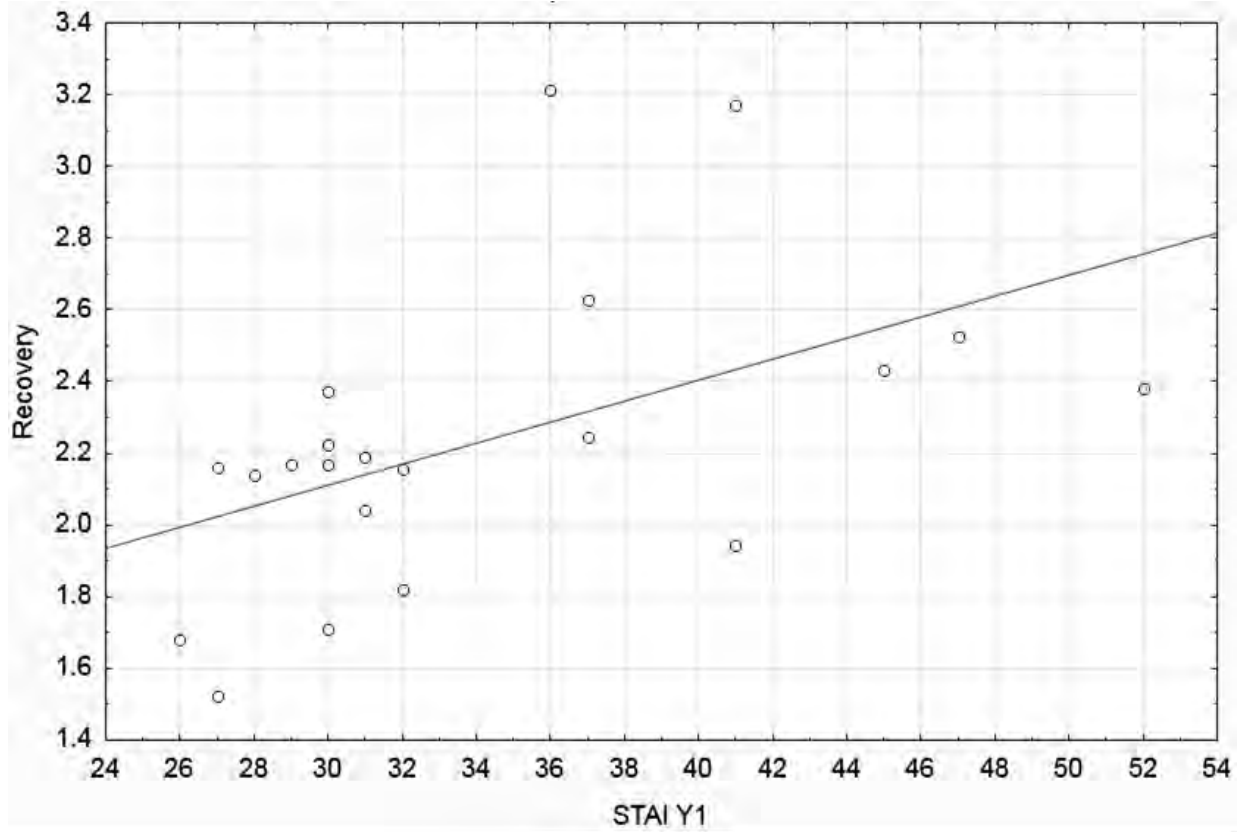


Figure 6.61 Scatterplots of the Standard Deviation of Left SMR% power at Recovery and State Anxiety scores

Standard Deviation of Right SMR% of power

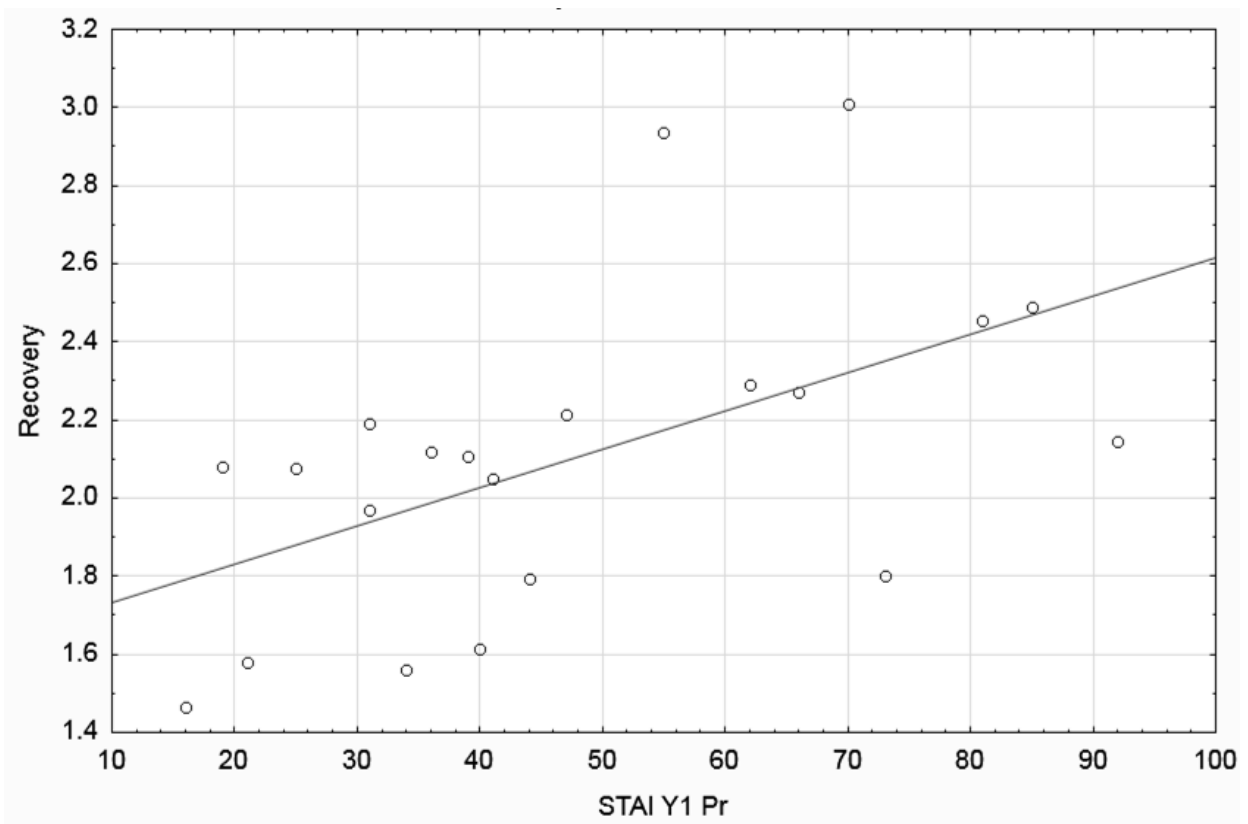
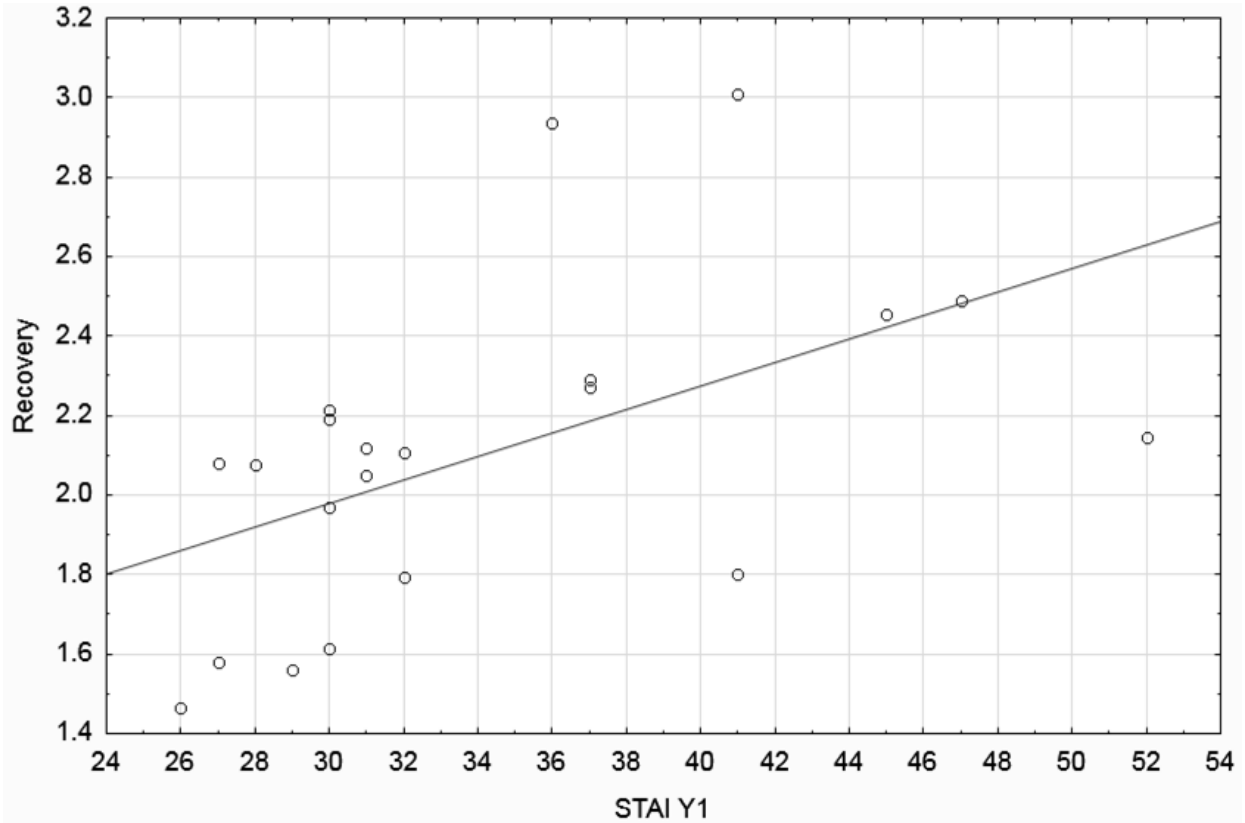
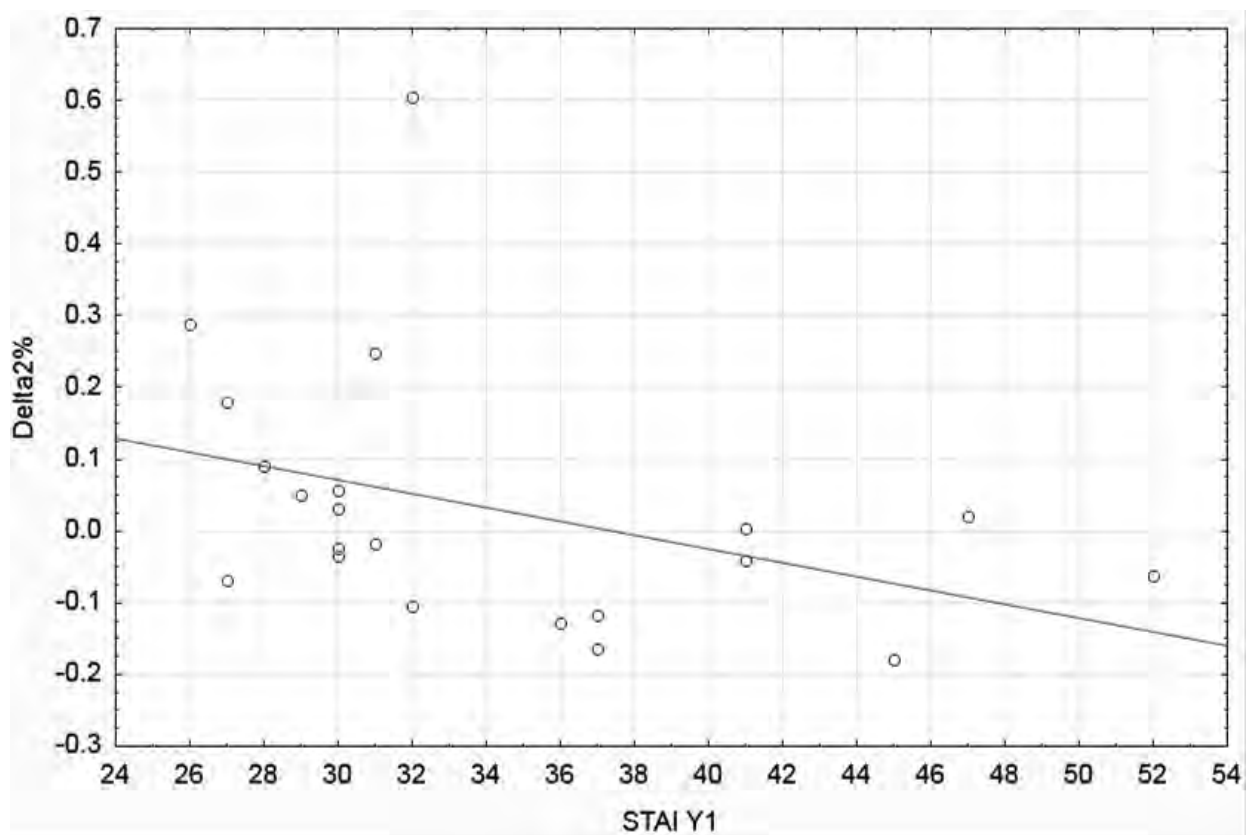
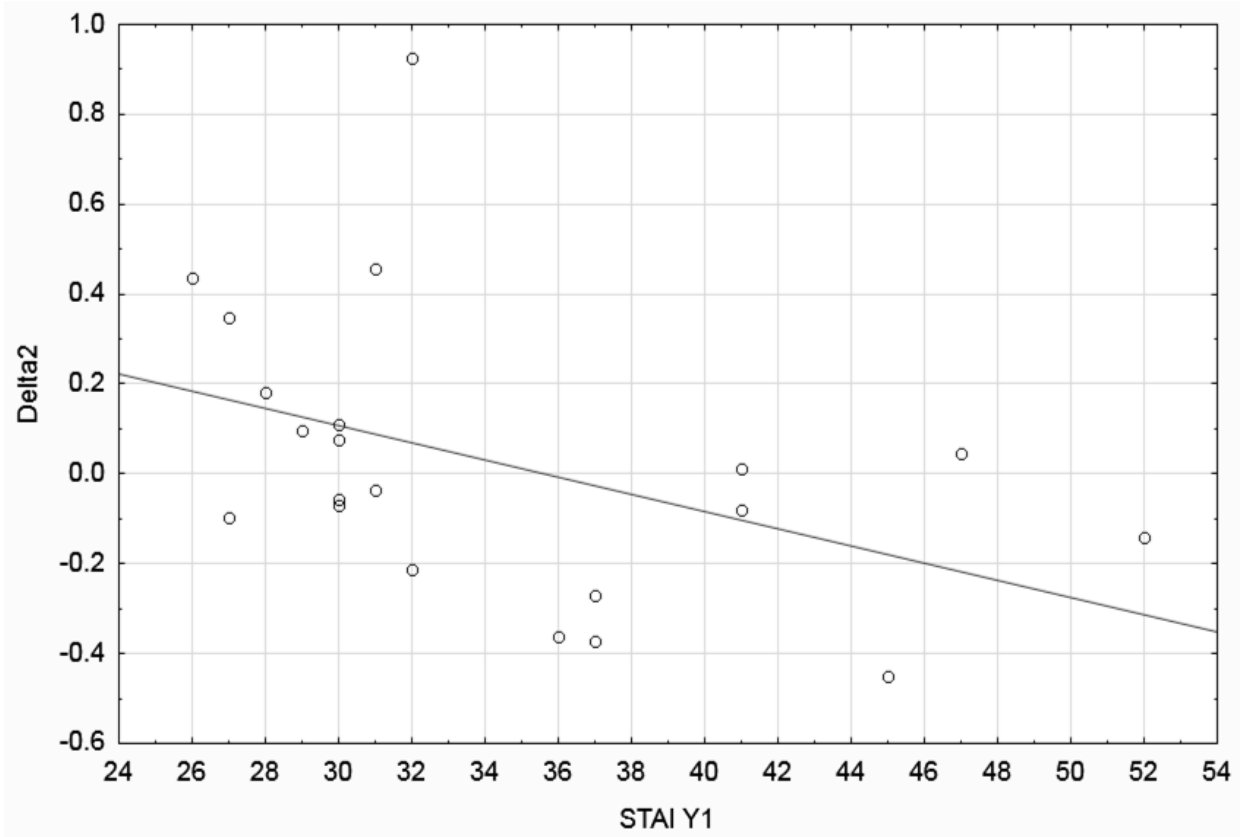


Figure 6.62 Scatterplots of the Standard Deviation of Right SMR% power at Recovery and State Anxiety scores.

Standard Deviation of Left SMR% of power



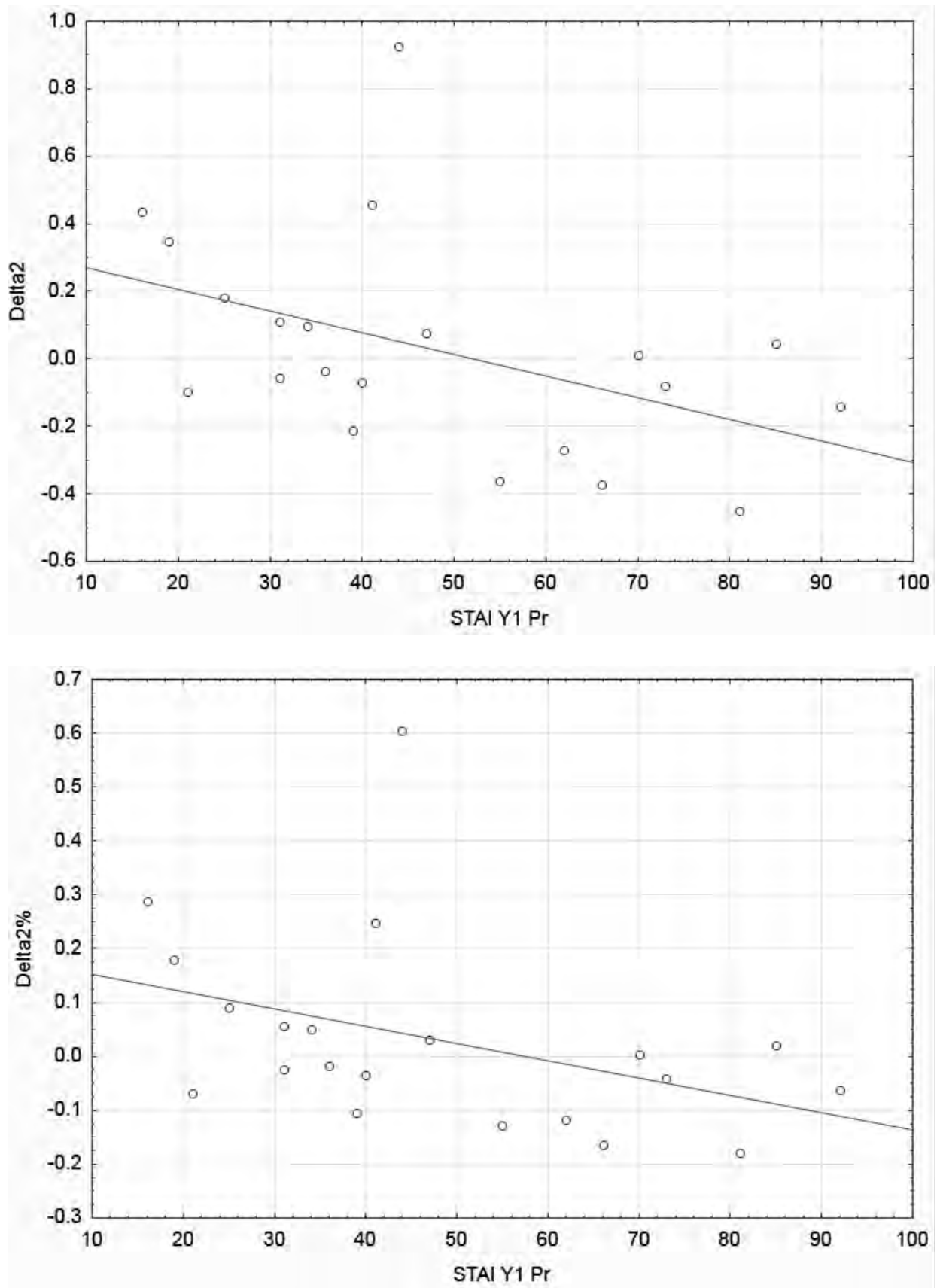
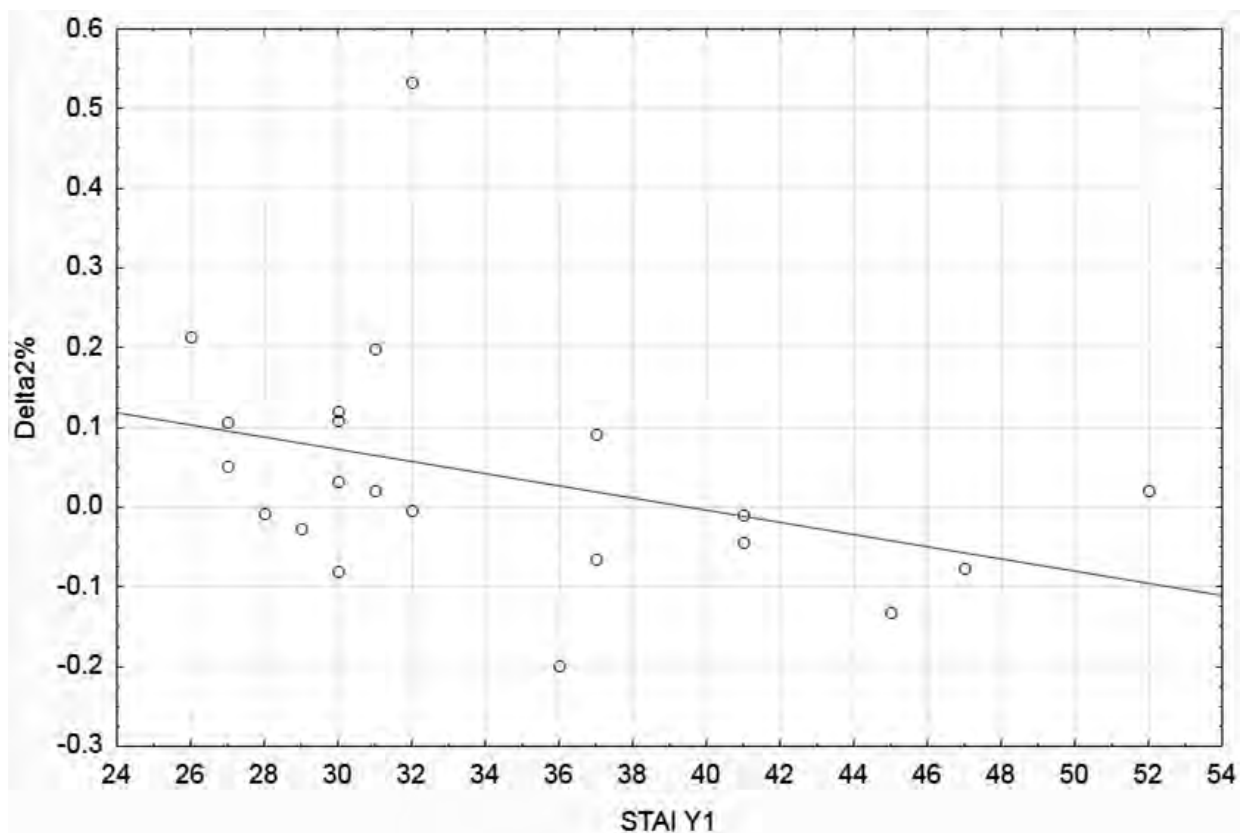
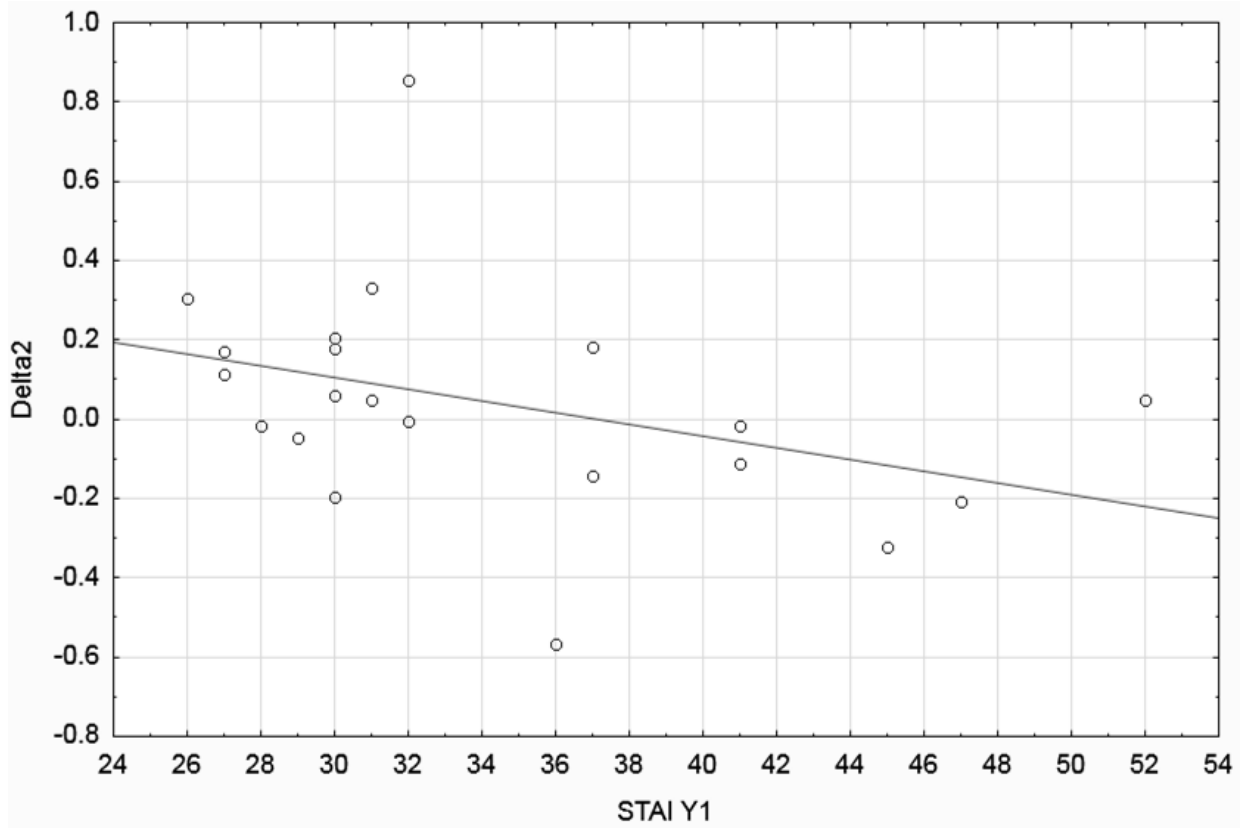


Figure 6.63 Scatterplots of the response of the Standard Deviation of Left SMR% power and State Anxiety scores.

Standard Deviation of Right SMR% of power



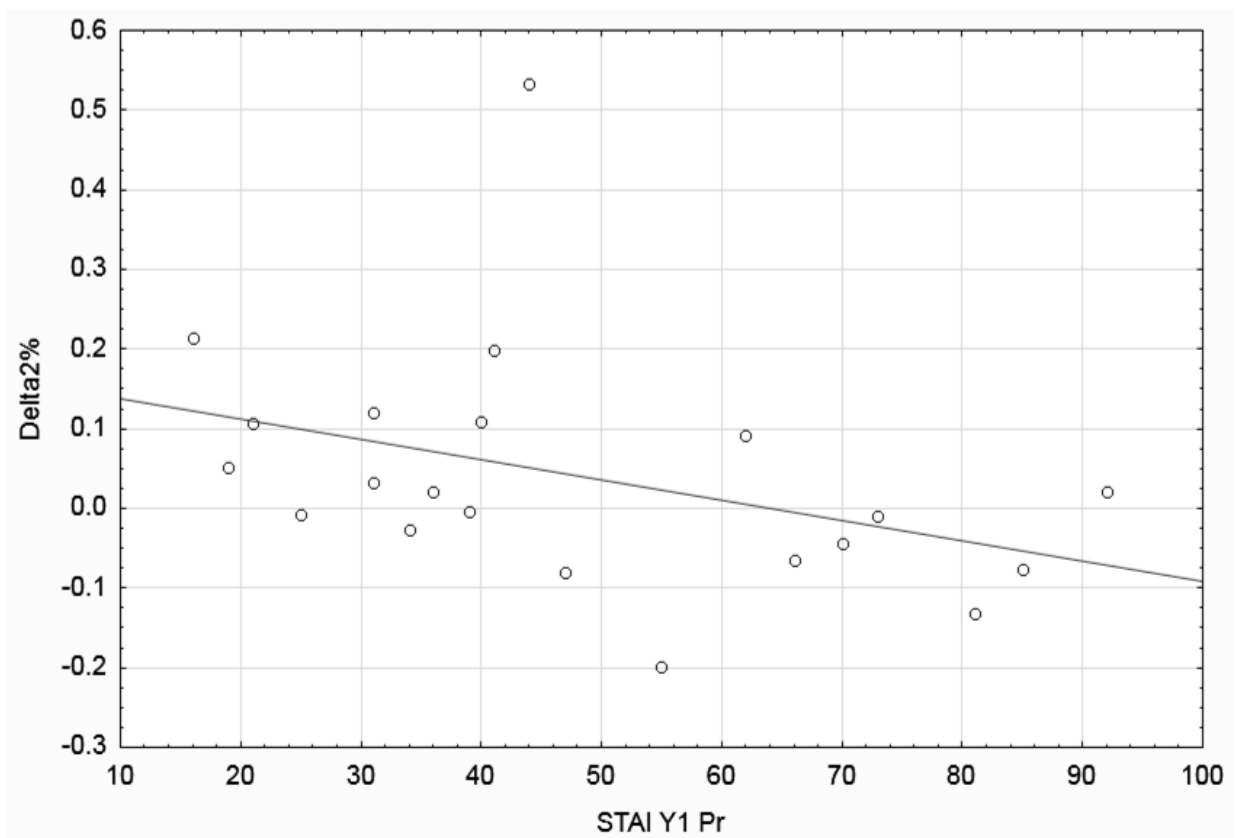
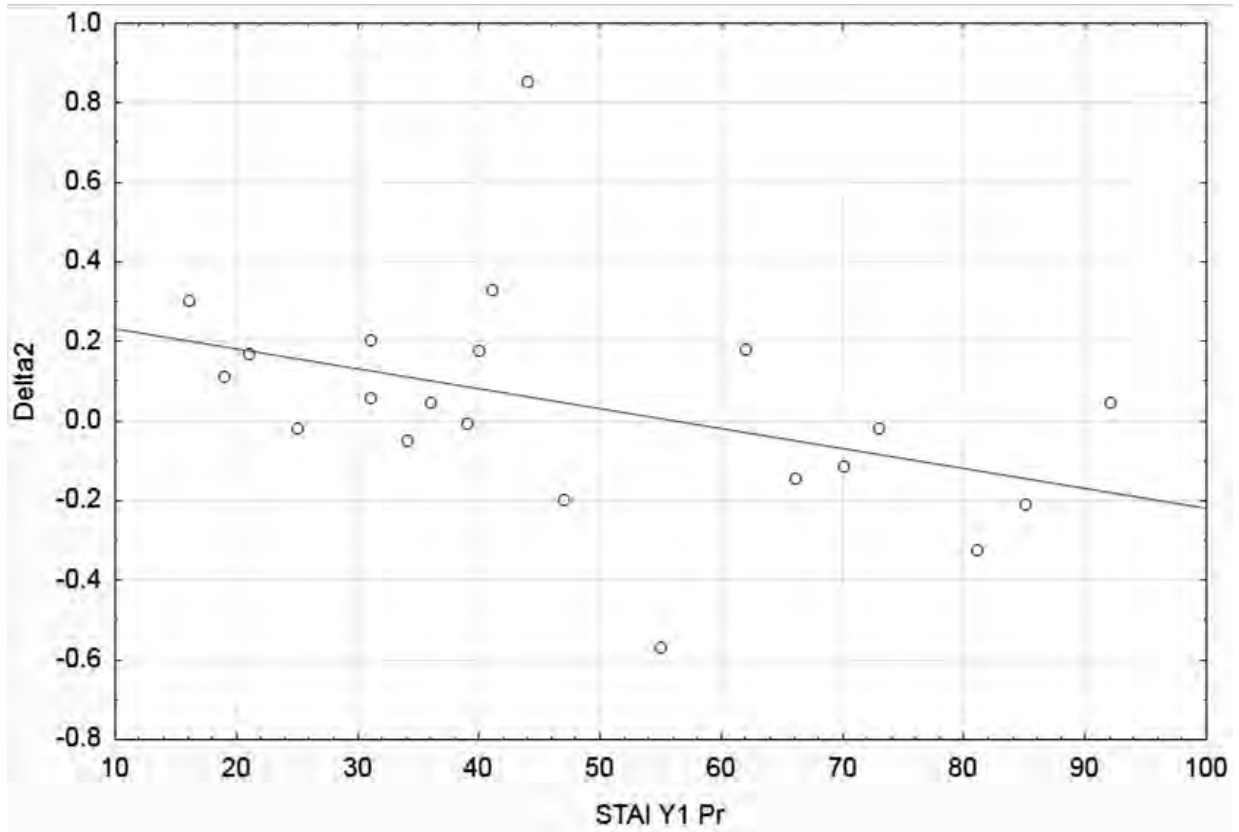


Figure 6.64 Scatterplots of the response of the Standard Deviation of Right SMR% power and State Anxiety scores.

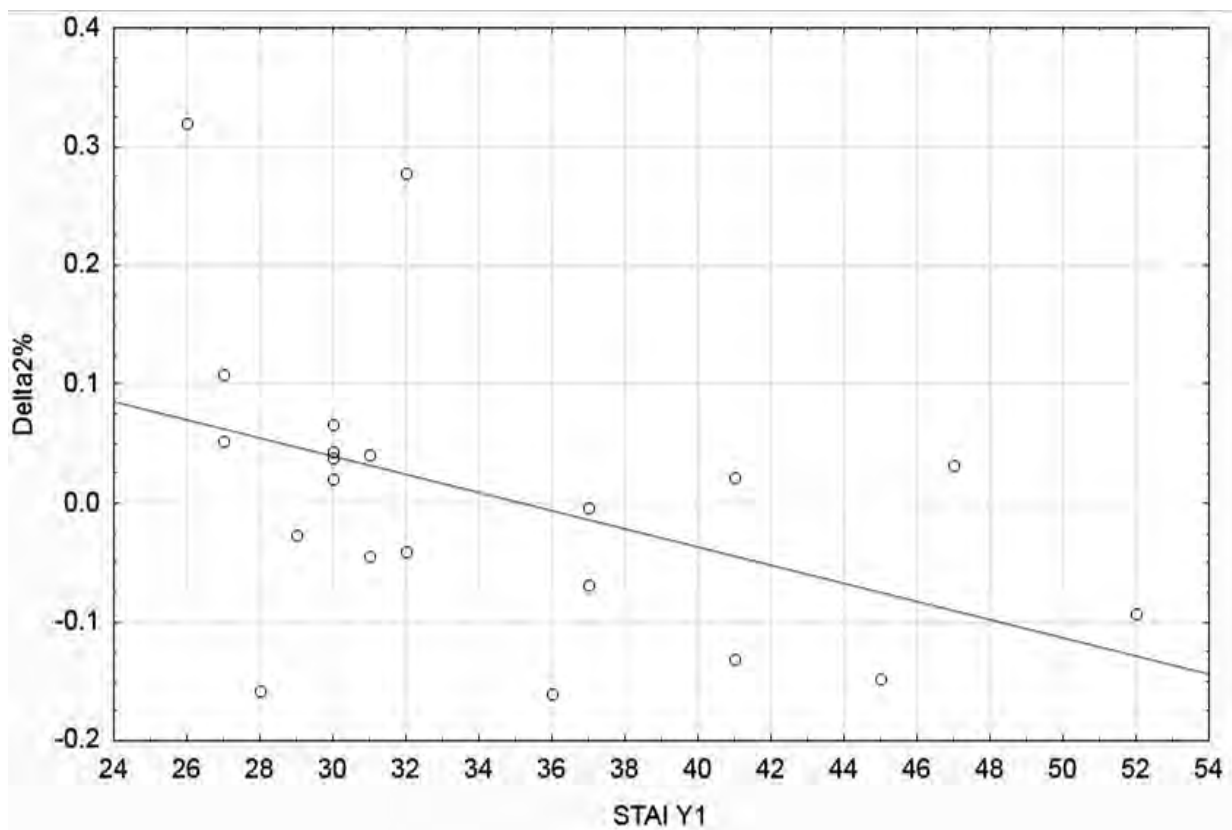
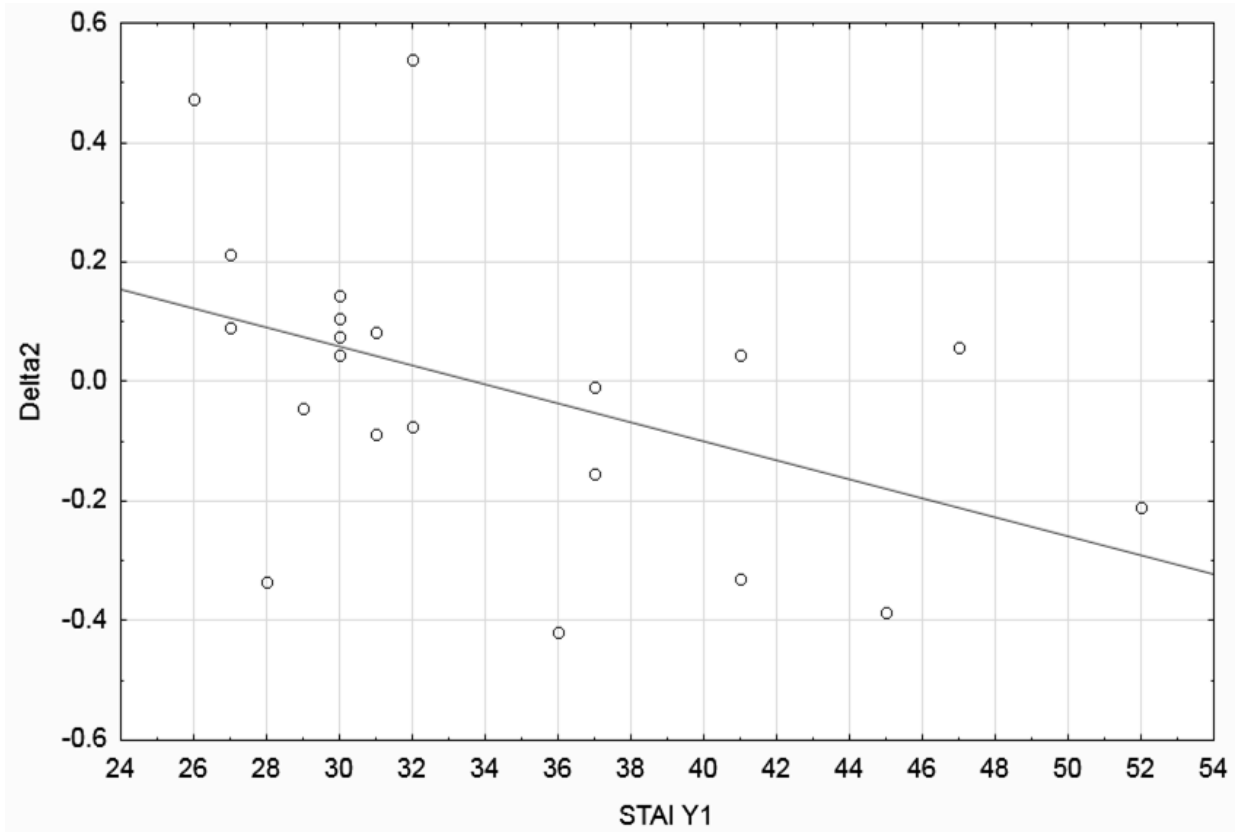
6.3.15 EEG – Beta Rhythm

Table 6.30 Spearman ranked correlations between the EEG Beta1 % Power variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Right Beta1%Power CoefVar	Baseline 1	MBI Cy	-0.4313	0.0509
Right Beta1%Power CoefVar	Recovery	MBI Cy	-0.4004	0.0721
Right Beta1%Power StdDev	Baseline 1	MBI Ex	-0.4394	0.0463
Left Beta1%Power CoefVar	Challenge	STAI Y1	-0.4928	0.0232
Left Beta1%Power Mean	Baseline 1	STAI Y1	0.4450	0.0432
Left Beta1%Power Mean	Baseline 2	STAI Y1	0.4966	0.022
Left Beta1%Power Mean	Challenge	STAI Y1	0.4894	0.0243
Left Beta1%Power Mean	Recovery	STAI Y1	0.4313	0.0509
Left Beta1%Power StdDev	(Ch-B2)/B2	STAI Y1	-0.5083	0.0186
Left Beta1%Power StdDev	Baseline 1	STAI Y1	0.5025	0.0204
Left Beta1%Power StdDev	Baseline 2	STAI Y1	0.5207	0.0155
Left Beta1%Power StdDev	Ch-B2	STAI Y1	-0.5194	0.0158
Left Beta1%Power StdDev	Recovery	STAI Y1	0.427	0.0535
Right Beta1%Power CoefVar	Challenge	STAI Y1	-0.4281	0.0529
Right Beta1%Power CoefVar	Ch-B2	STAI Y1	-0.3733	0.0956
Right Beta1%Power Mean	Baseline 2	STAI Y1	0.462	0.035
Right Beta1%Power Mean	Challenge	STAI Y1	0.4679	0.0324
Right Beta1%Power Mean	Recovery	STAI Y1	0.4424	0.0446
Right Beta1%Power StdDev	Baseline 2	STAI Y1	0.4626	0.0347
Right Beta1%Power StdDev	Ch-B2	STAI Y1	-0.3837	0.086
Left Beta1%Power CoefVar	Challenge	STAI Y1 Pr	-0.3775	0.0916
Left Beta1%Power Mean	Baseline 1	STAI Y1 Pr	0.4644	0.0339
Left Beta1%Power Mean	Baseline 2	STAI Y1 Pr	0.4969	0.0219
Left Beta1%Power Mean	Challenge	STAI Y1 Pr	0.4787	0.0281
Left Beta1%Power Mean	Recovery	STAI Y1 Pr	0.4079	0.0664
Left Beta1%Power StdDev	(Ch-B2)/B2	STAI Y1 Pr	-0.5008	0.0208
Left Beta1%Power StdDev	Baseline 1	STAI Y1 Pr	0.5151	0.0169
Left Beta1%Power StdDev	Baseline 2	STAI Y1 Pr	0.558	0.0086
Left Beta1%Power StdDev	Ch-B2	STAI Y1 Pr	-0.508	0.0187
Left Beta1%Power StdDev	Recovery	STAI Y1 Pr	0.4374	0.0474
Right Beta1%Power Mean	Baseline 1	STAI Y1 Pr	0.3696	0.0991
Right Beta1%Power Mean	Baseline 2	STAI Y1 Pr	0.4885	0.0247
Right Beta1%Power Mean	Challenge	STAI Y1 Pr	0.4729	0.0304
Right Beta1%Power Mean	Recovery	STAI Y1 Pr	0.4385	0.0468
Right Beta1%Power StdDev	Baseline 2	STAI Y1 Pr	0.4989	0.0213
Right Beta1%Power StdDev	Ch-B2	STAI Y1 Pr	-0.3832	0.0864
Right Beta1%Power StdDev	Recovery	STAI Y1 Pr	0.3884	0.0818

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

Standard Deviation of Left Beta1% of power



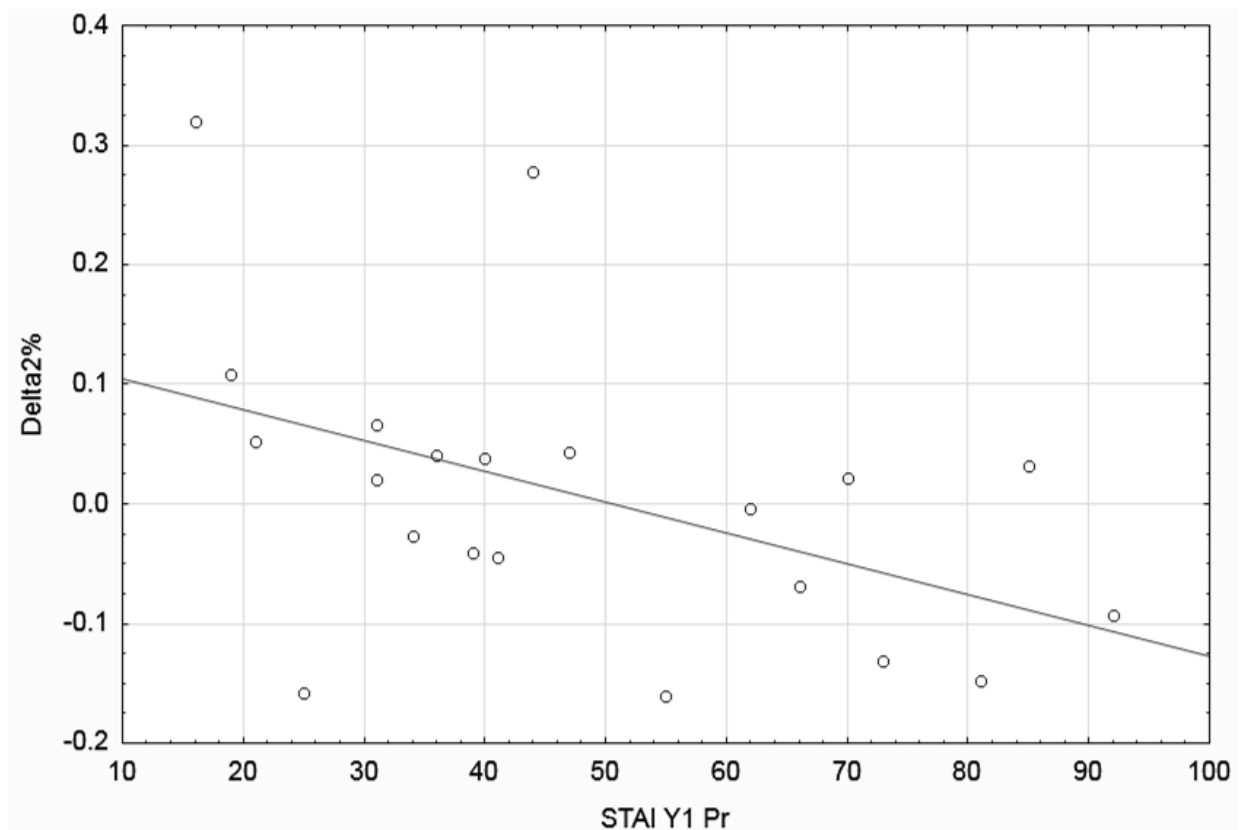
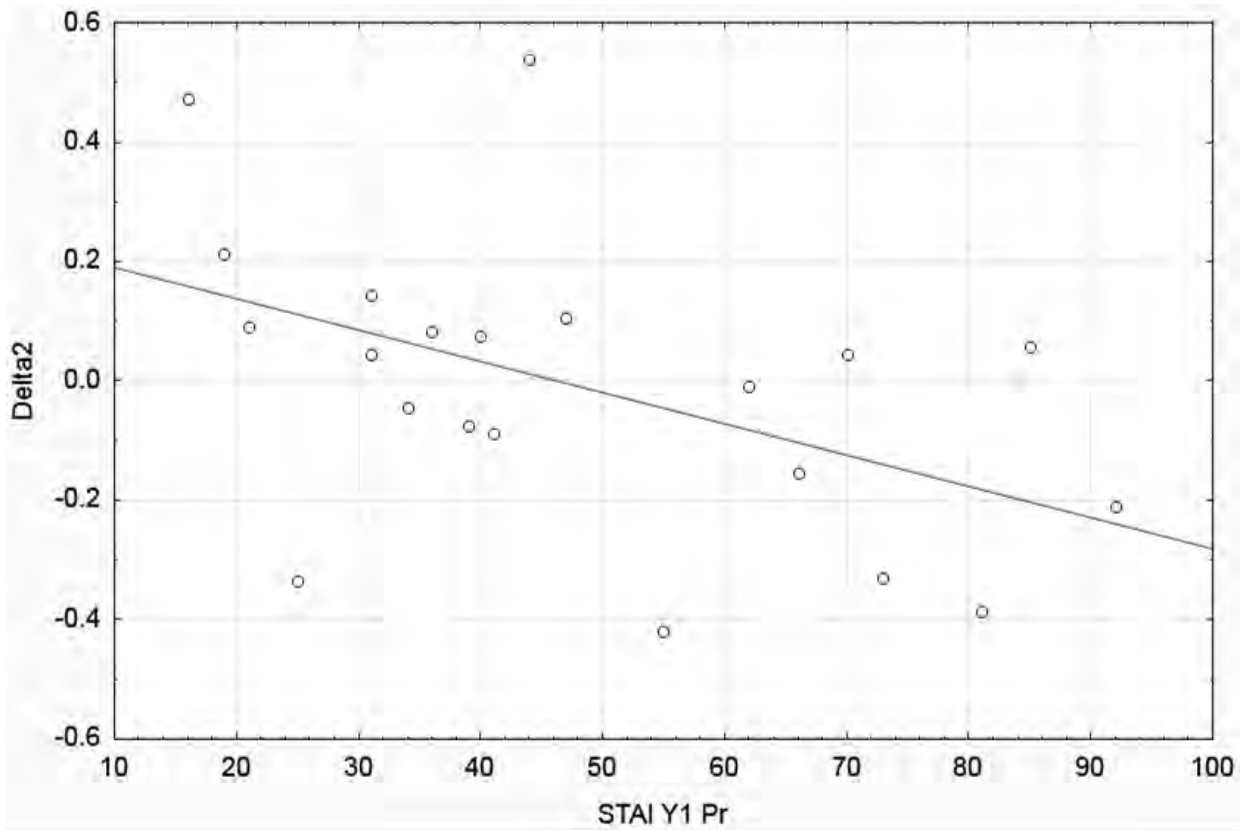


Figure 6.65 Scatterplots of the response of Standard Deviation of Left Beta1% power and State Anxiety.



Table 6.31 Spearman ranked correlations between the EEG Beta2 % Power variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Right Beta2%Power CoefVar	(Ch-B2)/B2	MBI Pe	0.3916	0.0791
Right Beta2%Power CoefVar	Ch-B2	MBI Pe	0.3792	0.09
Right Beta2%Power CoefVar	Challenge	STAI Y1	-0.4594	0.0362
Right Beta2%Power Mean	Challenge	STAI Y1	0.3902	0.0803
Right Beta2%Power CoefVar	Challenge	STAI Y1 Pr	-0.3703	0.0985

Coefvar – coefficient of variation, MBI – Maslach Burnout inventory, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

Table 6.32 Spearman ranked correlations between the EEG High Beta % Power variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Right High Beta%Power Mean	Baseline 1	MBI Cy	0.4055	0.0682
Left High Beta%Power Mean	(Ch-B2)/B2	MBI Ex	-0.4146	0.0617
Left High Beta%Power Mean	Ch-B2	MBI Ex	-0.4511	0.0401
Right High Beta%Power Mean	(Ch-B2)/B2	MBI Ex	-0.5359	0.0123
Right High Beta%Power Mean	Ch-B2	MBI Ex	-0.575	0.0064
Right High Beta%Power Mean	Recovery	MBI Ex	0.369	0.0998
Left High Beta%PowerCoefVar	Ch-B2	MBI Pe	0.3799	0.0894
Left High Beta%Power StdDev	Baseline 1	MBI Pe	0.3949	0.0764
Right High Beta%Power StdDev	(Ch-B2)/B2	MBI Pe	0.4224	0.0565
Right High Beta%Power StdDev	Baseline 1	MBI Pe	0.4289	0.0524
Right High Beta%Power StdDev	Ch-B2	MBI Pe	0.3871	0.083
Right High Beta%Power StdDev	Recovery	STAI Y1	-0.4392	0.0464
Right High Beta%Power StdDev	Recovery	STAI Y1 Pr	-0.4229	0.0562

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

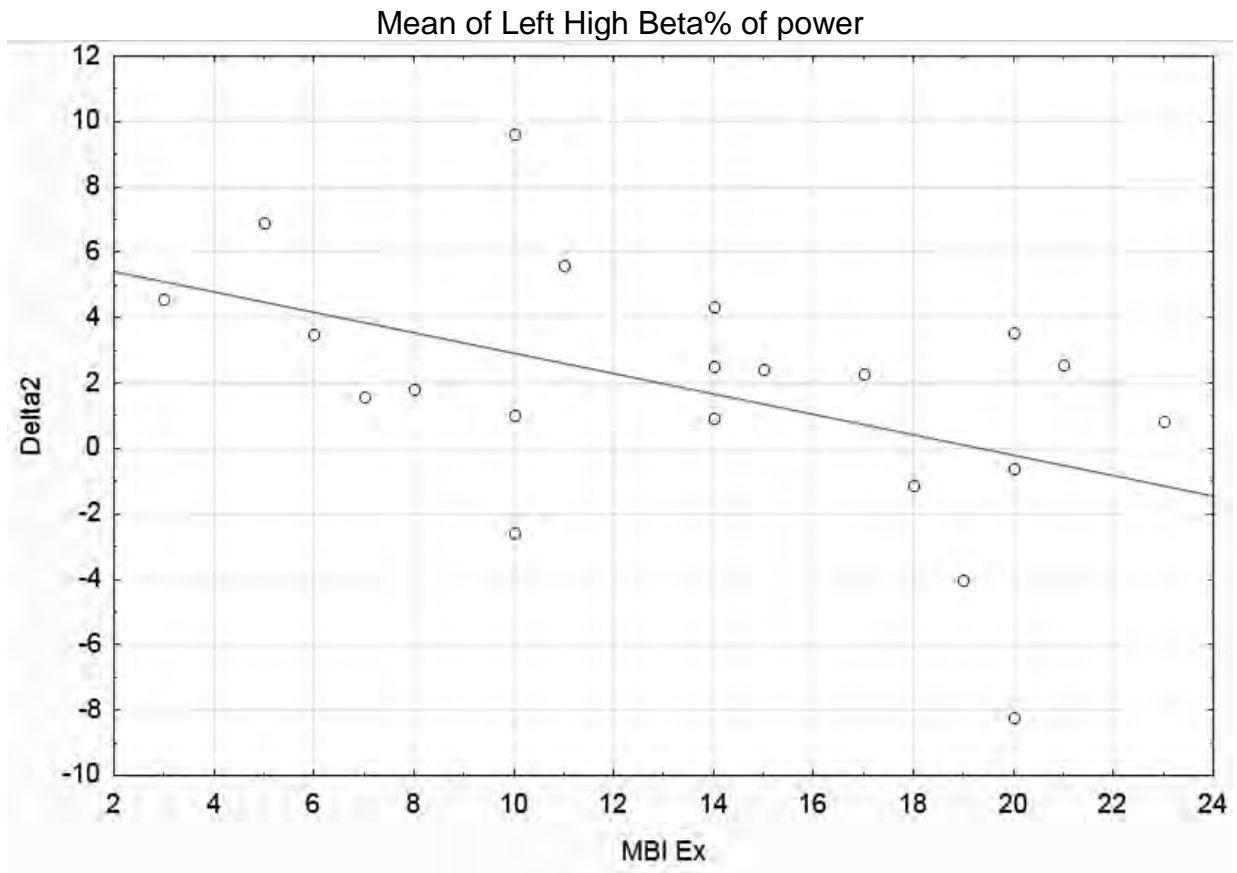


Figure 6.66 Scatterplot of the response of the Mean of Left High Beta% power and MBI Exhaustion scores.

Mean of Right High Beta% of power

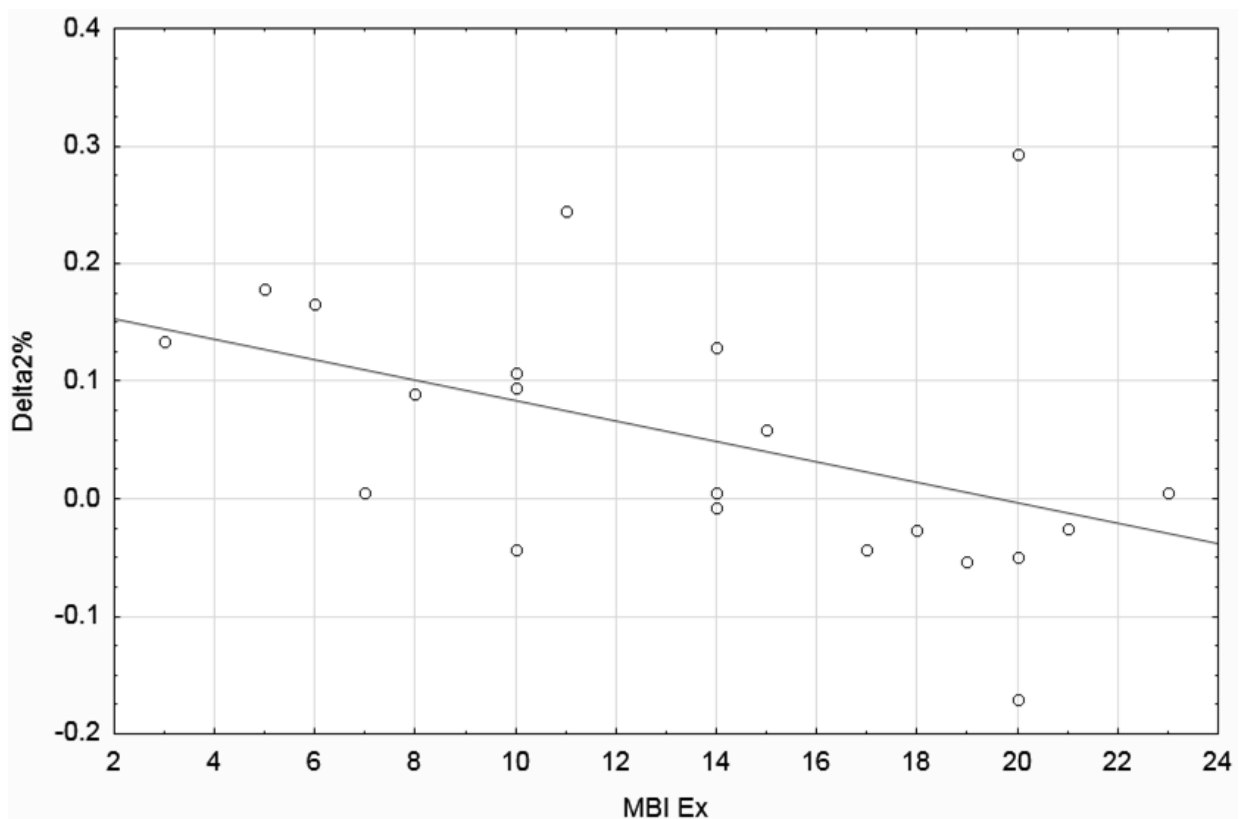
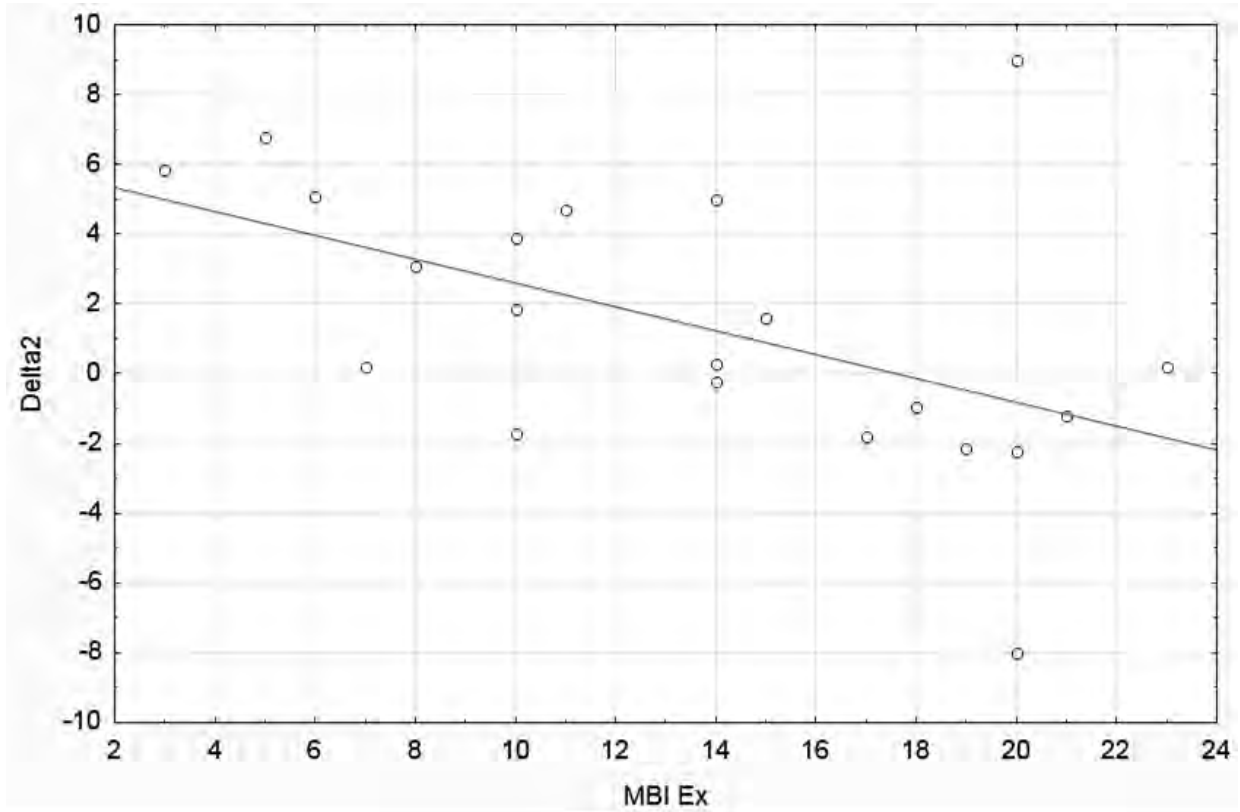


Figure 6.67 Scatterplots of the response of Mean Right High Beta% power and MBI Exhaustion scores.

Table 6.33 Spearman ranked correlations between the EEG Whole Beta Amplitude Asymmetry variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Beta Amplitude Asymmetry StdDev	Baseline 2	MBI Cy	0.4532	0.0391
Beta Amplitude Asymmetry StdDev	Baseline 1	MBI Ex	0.3729	0.096
Beta Amplitude Asymmetry Mean	Ch-B2	MBI Pe	-0.3929	0.078
Beta Amplitude Asymmetry Mean	Baseline 1	STAI Y1	0.3883	0.082
Beta Amplitude Asymmetry Mean	Baseline 2	STAI Y1	0.4078	0.0665
Beta Amplitude Asymmetry Mean	Challenge	STAI Y1	0.4111	0.0641
Beta Amplitude Asymmetry Mean	Recovery	STAI Y1	0.4118	0.0637
Beta Amplitude Asymmetry StdDev	Recovery	STAI Y1	-0.3706	0.0981
Beta Amplitude Asymmetry Mean	Baseline 1	STAI Y1 Pr	0.406	0.0678
Beta Amplitude Asymmetry Mean	Baseline 2	STAI Y1 Pr	0.4034	0.0698
Beta Amplitude Asymmetry Mean	Challenge	STAI Y1 Pr	0.3911	0.0796
Beta Amplitude Asymmetry Mean	Recovery	STAI Y1 Pr	0.4131	0.0627
Beta Amplitude Asymmetry StdDev	Challenge	STAI Y2 Pr	0.4167	0.0602

StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response

Table 6.34 Spearman ranked correlations between the EEG Whole Beta Coherence variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Beta Coherence StdDev	Baseline 2	MBI Cy	0.4212	0.0572
Beta Coherence CoefVar	Challenge	STAI Y2	0.4532	0.0391
Beta Coherence Mean	Baseline 2	STAI Y2	-0.3828	0.0868
Beta Coherence Mean	Challenge	STAI Y2	-0.4317	0.0507
Beta Coherence Mean	Recovery	STAI Y2	-0.4258	0.0543
Beta Coherence StdDev	(Ch-B2)/B2	STAI Y2	0.3965	0.0752
Beta Coherence CoefVar	Challenge	STAI Y2 Pr	0.5117	0.0177
Beta Coherence Mean	Baseline 2	STAI Y2 Pr	-0.3945	0.0767
Beta Coherence Mean	Challenge	STAI Y2 Pr	-0.4831	0.0265
Beta Coherence Mean	Recovery	STAI Y2 Pr	-0.4544	0.0385
Beta Coherence StdDev	(Ch-B2)/B2	STAI Y2 Pr	0.3776	0.0915

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, STAI – State-Trait Anxiety Inventory, Y2 – Trait Anxiety, Pr – Percentile rank, (Ch-B2)/B2 – Relative response

Table 6.35 Spearman ranked correlations between the EEG Whole Beta Phase variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Beta Phase Mean	(Ch-B2)/B2	MBI Cy	0.4016	0.0712
Beta Phase Mean	Recovery	MBI Cy	0.4716	0.0309
Beta Phase Mean	Baseline 1	MBI Ex	0.4863	0.0254
Beta Phase Mean	Recovery	MBI Ex	0.3755	0.0935
Beta Phase StdDev	(Ch-B2)/B2	MBI Pe	0.4028	0.0703
Beta Phase Mean	(Ch-B2)/B2	STAI Y1	0.4294	0.0521
Beta Phase Mean	Baseline 1	STAI Y1	-0.5266	0.0142
Beta Phase Mean	(Ch-B2)/B2	STAI Y1 Pr	0.3982	0.0739
Beta Phase Mean	Baseline 1	STAI Y1 Pr	-0.4222	0.0566
Beta Phase StdDev	Challenge	STAI Y2 Pr	0.3802	0.0891

StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, (Ch-B2)/B2 – Relative response

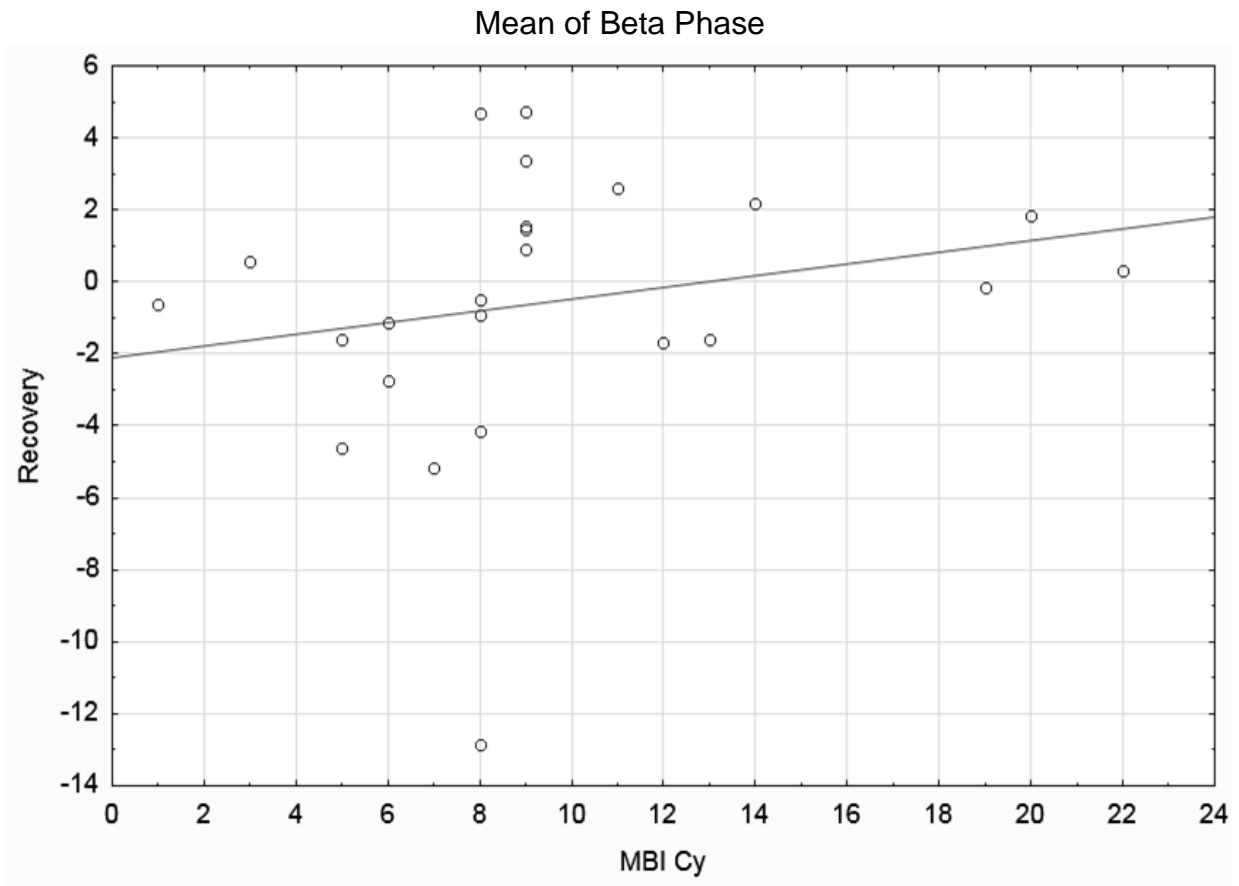


Figure 6.68 Scatterplot of the Mean Beta Phase at Recovery and MBI Cynicism scores.

Mean of Beta Phase

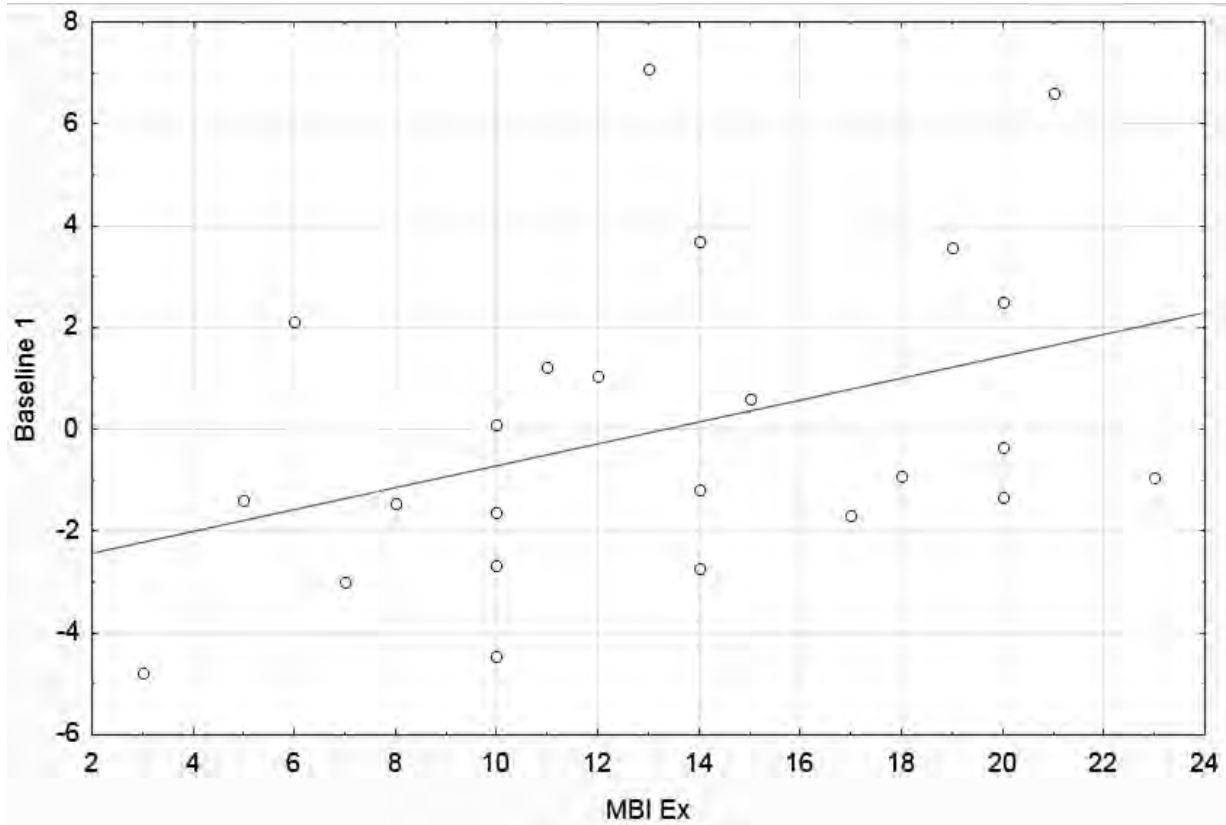


Figure 6.69 Scatterplot of the Mean Beta Phase at Baseline 1 and the MBI Exhaustion scores.

Mean of Beta Phase

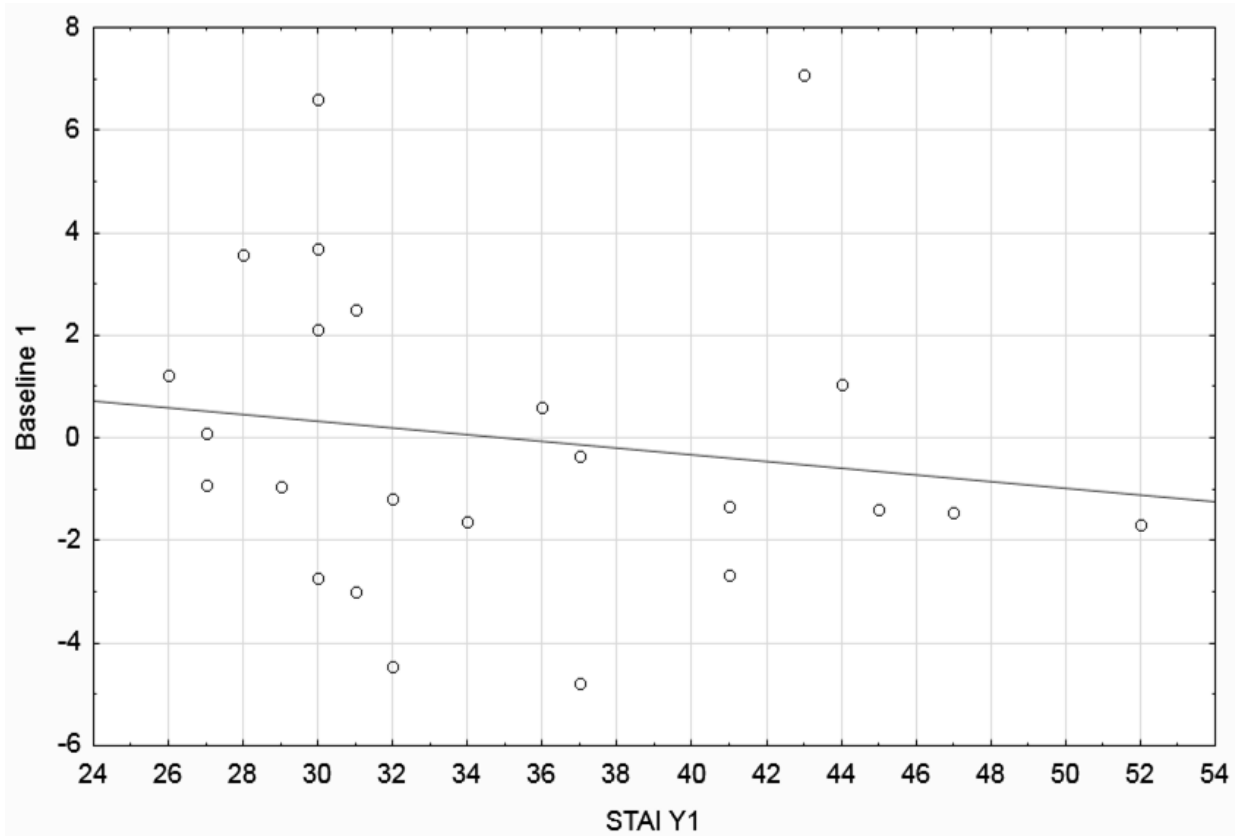


Figure 6.70 Scatterplot of the Mean Beta Phase at Baseline 1 and State Anxiety scores.

6.3.16 EEG – Gamma Rhythm

Table 6.36 Spearman ranked correlations between the EEG Gamma % Power variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Left Gamma%PowerCoefVar	(Ch-B2)/B2	MBI Cy	0.3811	0.0883
Left Gamma%PowerCoefVar	Baseline 2	MBI Cy	-0.5015	0.0206
Left Gamma%PowerCoefVar	Ch-B2	MBI Cy	0.3837	0.0859
Right Gamma%PowerCoefVar	Baseline 1	MBI Cy	-0.4246	0.055
Right Gamma%PowerCoefVar	Baseline 2	MBI Cy	-0.3702	0.0986
Right Gamma%Power Mean	Baseline 1	MBI Cy	0.3996	0.0727
Left Gamma%Power Mean	(Ch-B2)/B2	MBI Ex	-0.515	0.0169
Left Gamma%Power Mean	Ch-B2	MBI Ex	-0.5098	0.0182
Right Gamma%Power Mean	(Ch-B2)/B2	MBI Ex	-0.5111	0.0179
Right Gamma%Power Mean	Ch-B2	MBI Ex	-0.5319	0.0131

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Ex – Exhaustion subscale, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

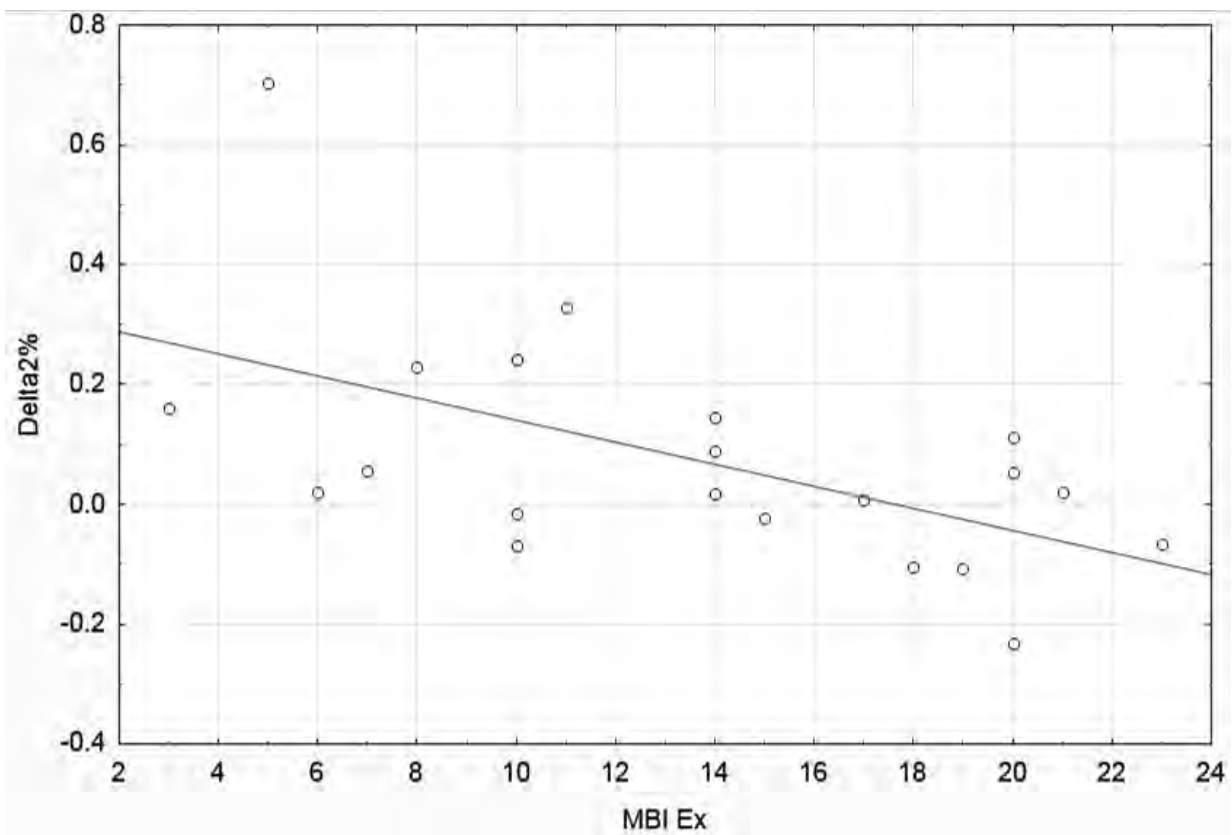
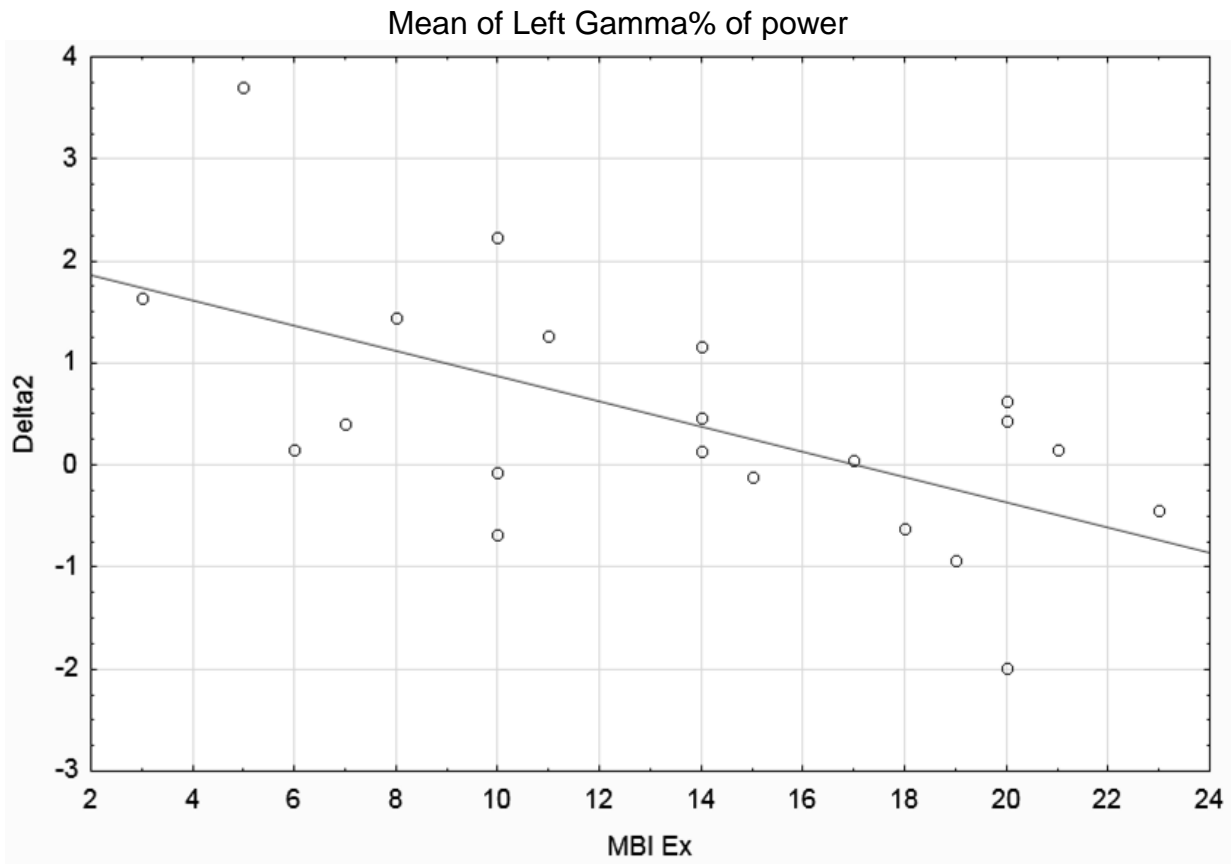


Figure 6.71 Scatterplots of the response of Mean Left Gamma% power and MBI Exhaustion scores.

Mean of Right Gamma% of power

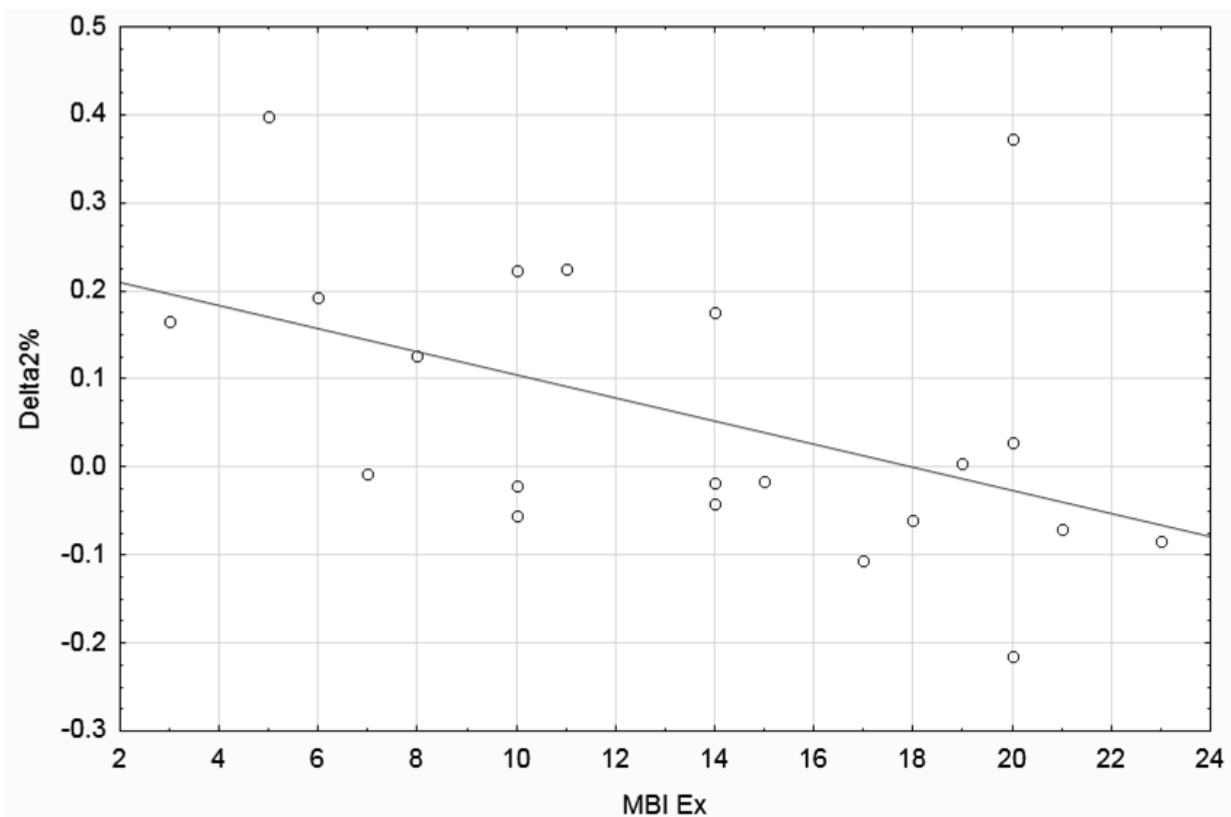
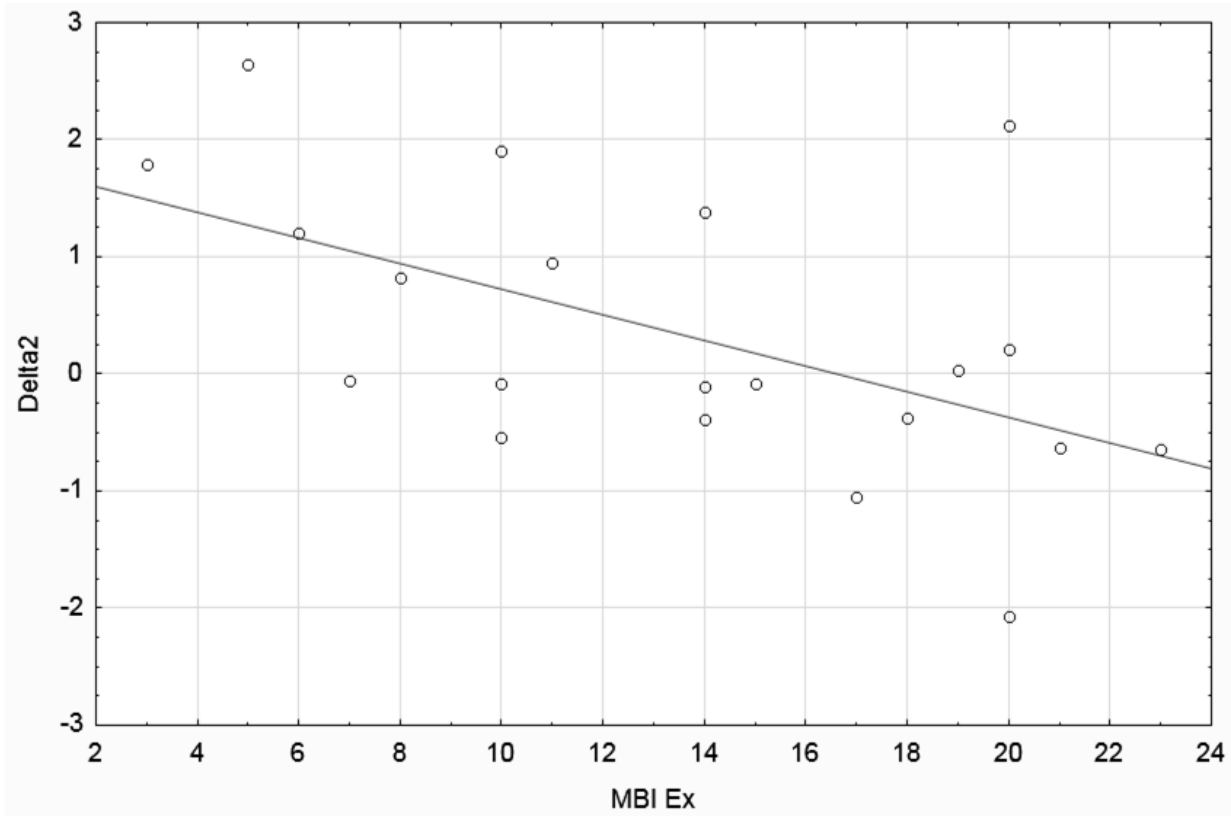


Figure 6.72 Scatterplots of the response of the Mean of Right Gamma% power and MBI Exhaustion scores.

6.3.17 EEG – Peak Frequency

Table 6.37 Spearman ranked correlations between the EEG Peak Frequency variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Right EEG Peak Frequency CoefVar	Baseline 2	MBI Cy	0.4449	0.0433
Right EEG Peak Frequency CoefVar	Challenge	MBI Cy	0.448	0.0417
Left EEG Peak Frequency Mean	Ch-B2	MBI Ex	-0.4003	0.0722
Right EEG Peak Frequency Mean	(Ch-B2)/B2	MBI Ex	-0.4694	0.0318
Right EEG Peak Frequency Mean	Ch-B2	MBI Ex	-0.5593	0.0084
Right EEG Peak Frequency StdDev	(Ch-B2)/B2	MBI Ex	-0.3807	0.0886
Right EEG Peak Frequency StdDev	Ch-B2	MBI Ex	-0.4785	0.0282
Left EEG Peak Frequency CoefVar	(Ch-B2)/B2	STAI Y1	0.5592	0.0084
Left EEG Peak Frequency CoefVar	Ch-B2	STAI Y1	0.5351	0.0124
Left EEG Peak Frequency StdDev	(Ch-B2)/B2	STAI Y1	0.3928	0.0781
Left EEG Peak Frequency StdDev	Ch-B2	STAI Y1	0.3719	0.0969
Right EEG Peak Frequency CoefVar	(Ch-B2)/B2	STAI Y1	0.37	0.0988
Right EEG Peak Frequency StdDev	(Ch-B2)/B2	STAI Y1	0.4033	0.0699
Left EEG Peak Frequency CoefVar	(Ch-B2)/B2	STAI Y1 Pr	0.5898	0.0049
Left EEG Peak Frequency CoefVar	Challenge	STAI Y1 Pr	0.4047	0.0688
Left EEG Peak Frequency CoefVar	Ch-B2	STAI Y1 Pr	0.5703	0.0069
Left EEG Peak Frequency StdDev	(Ch-B2)/B2	STAI Y1 Pr	0.3904	0.0802
Right EEG Peak Frequency CoefVar	(Ch-B2)/B2	STAI Y1 Pr	0.5067	0.0191
Right EEG Peak Frequency CoefVar	Ch-B2	STAI Y1 Pr	0.4865	0.0253
Right EEG Peak Frequency StdDev	(Ch-B2)/B2	STAI Y1 Pr	0.4151	0.0613

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response,

Mean Right EEG Peak Frequency

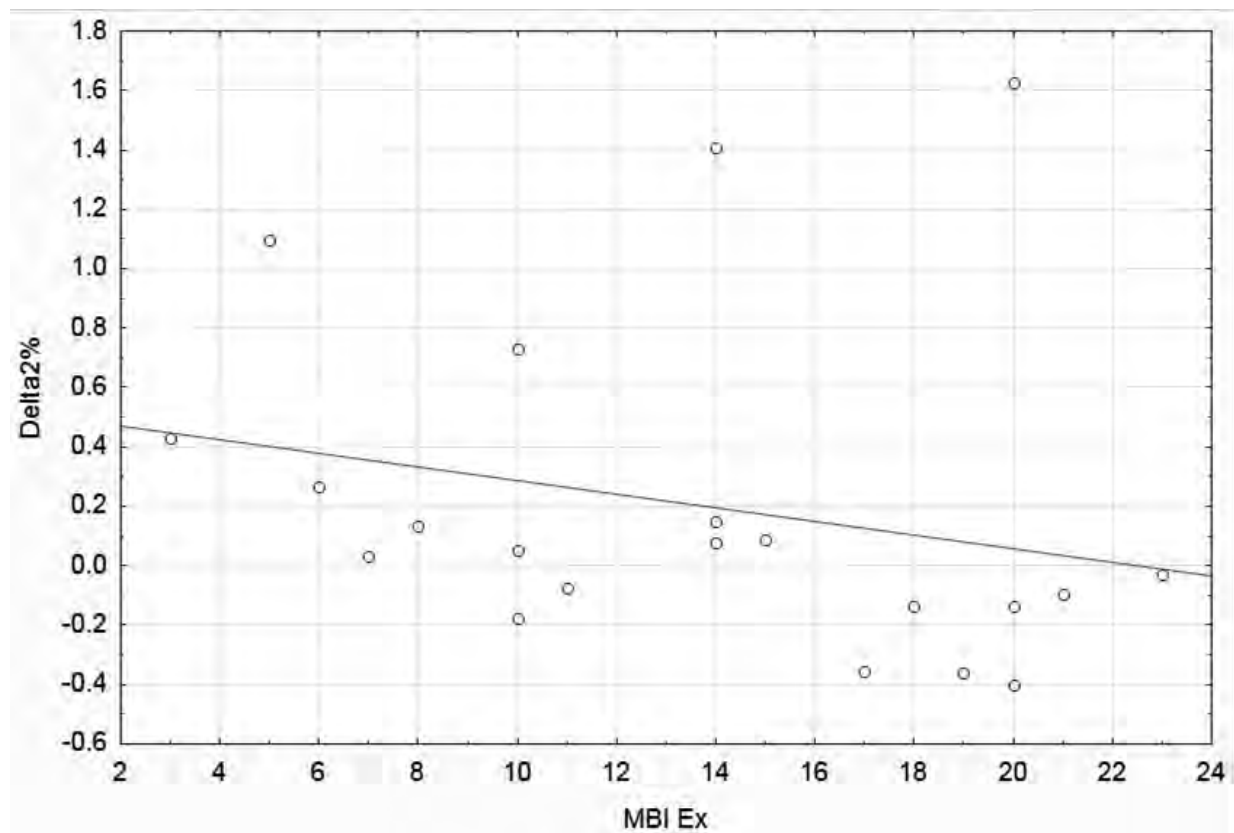
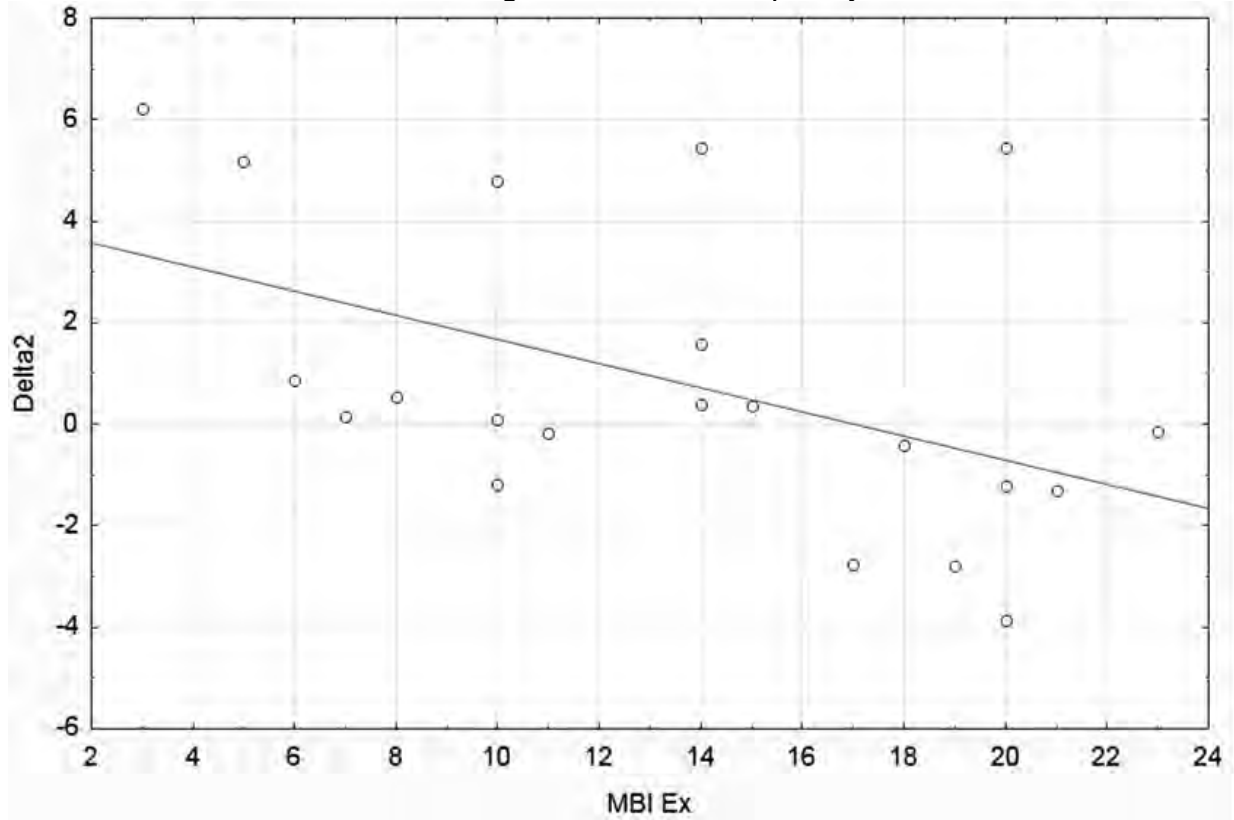


Figure 6.73 Scatterplots of the response of Mean Right EEG Peak Frequency and MBI Exhaustion scores.

Standard Deviation of Right EEG Peak Frequency

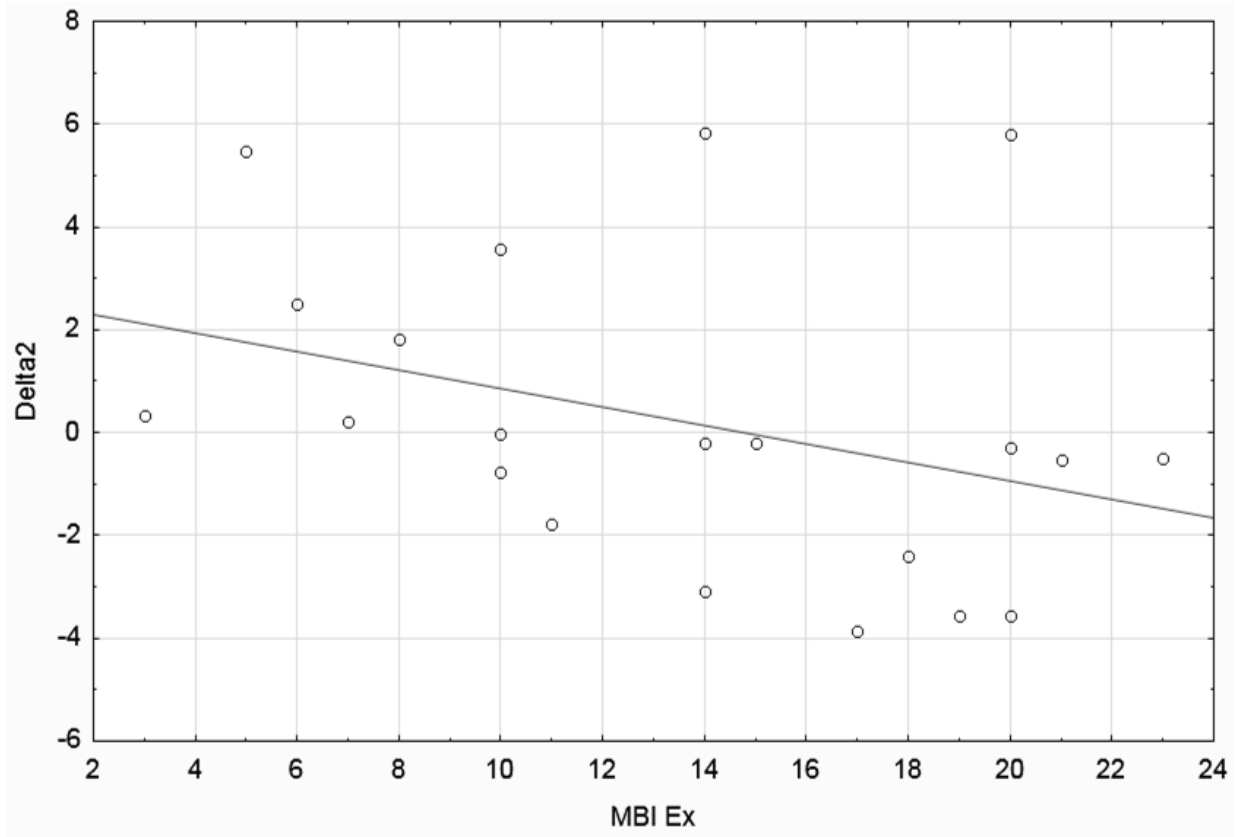
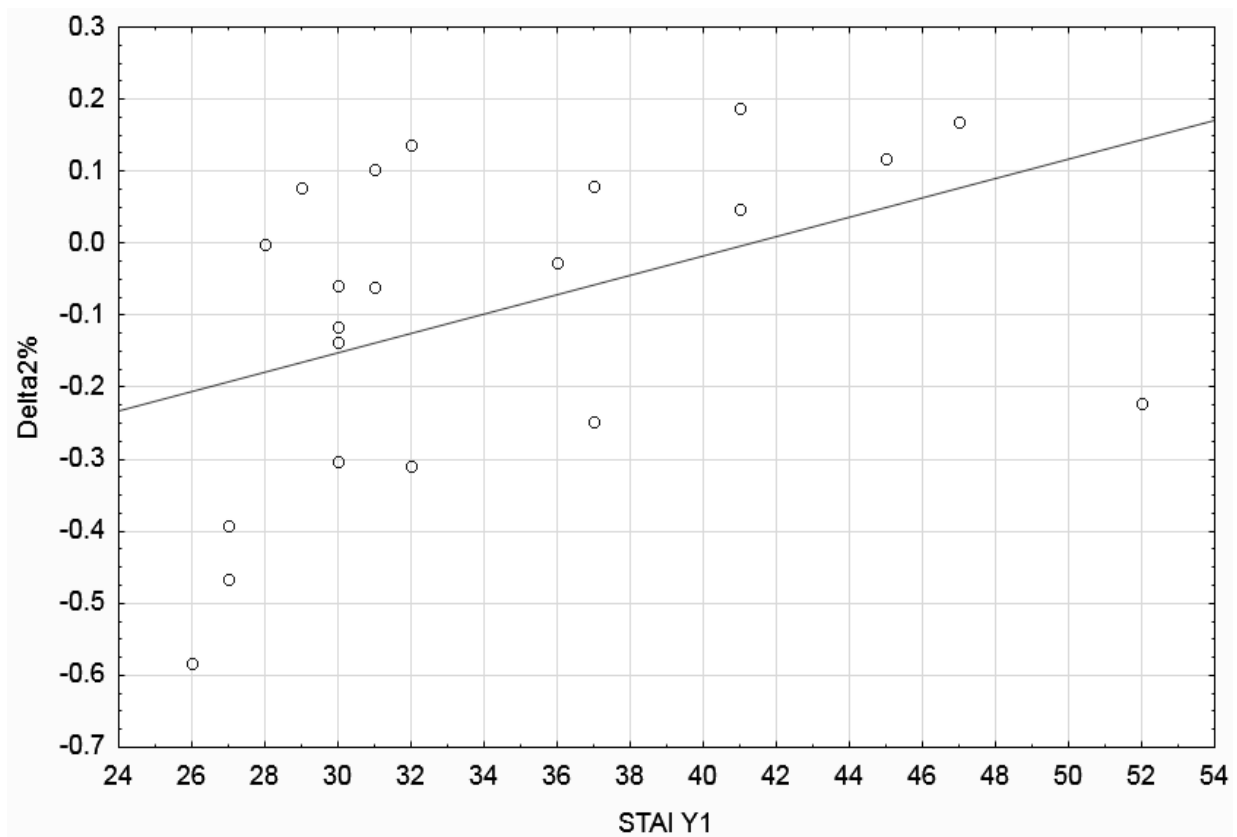
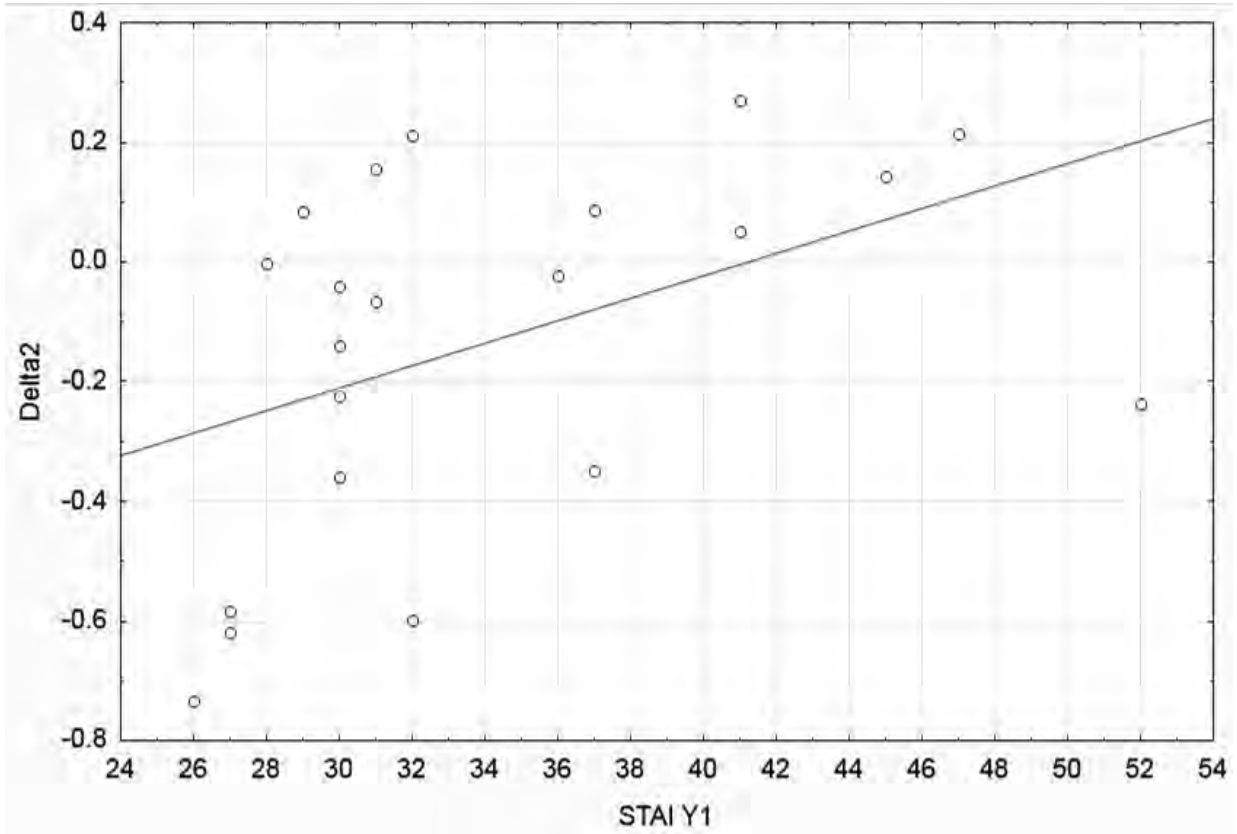


Figure 6.74 Scatterplot of the response of the Standard Deviation of Right EEG Peak Frequency and MBI Exhaustion scores.

Coefficient of Variation of Left EEG Peak Frequency



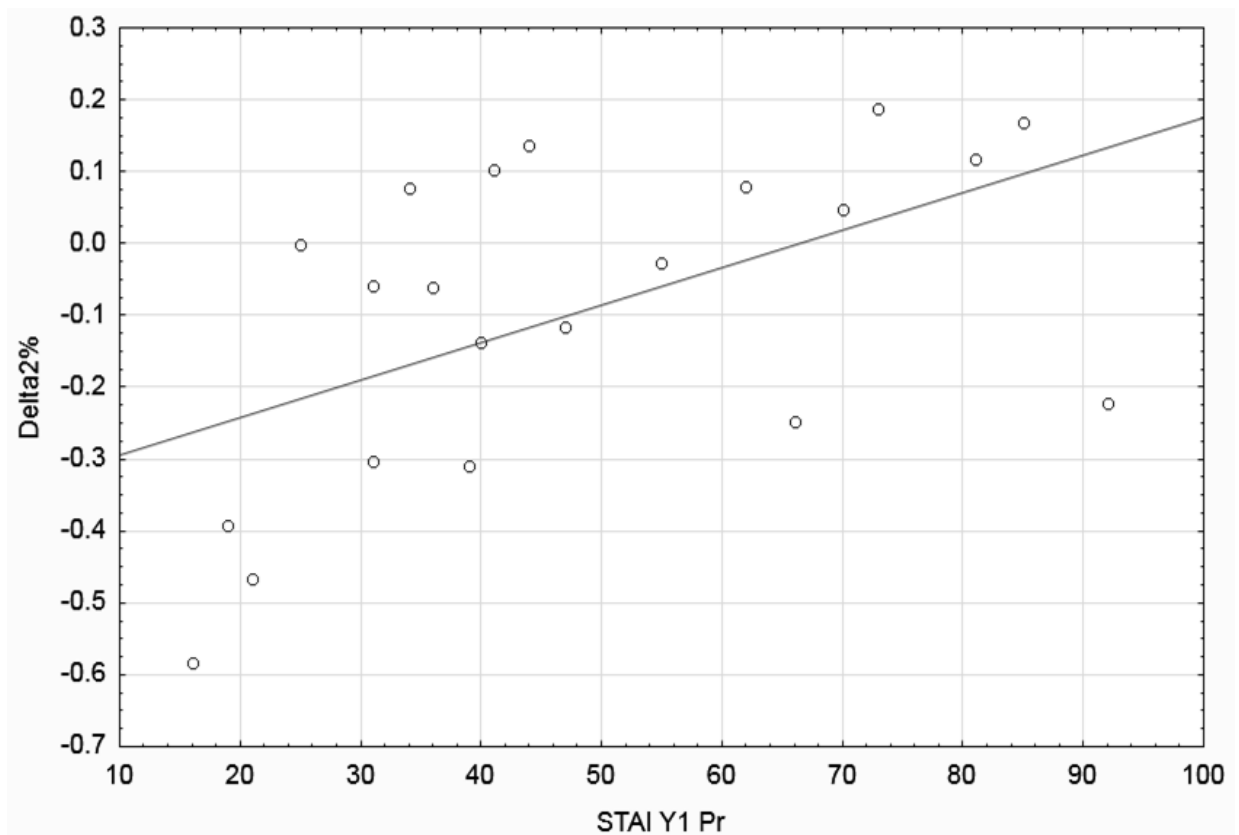
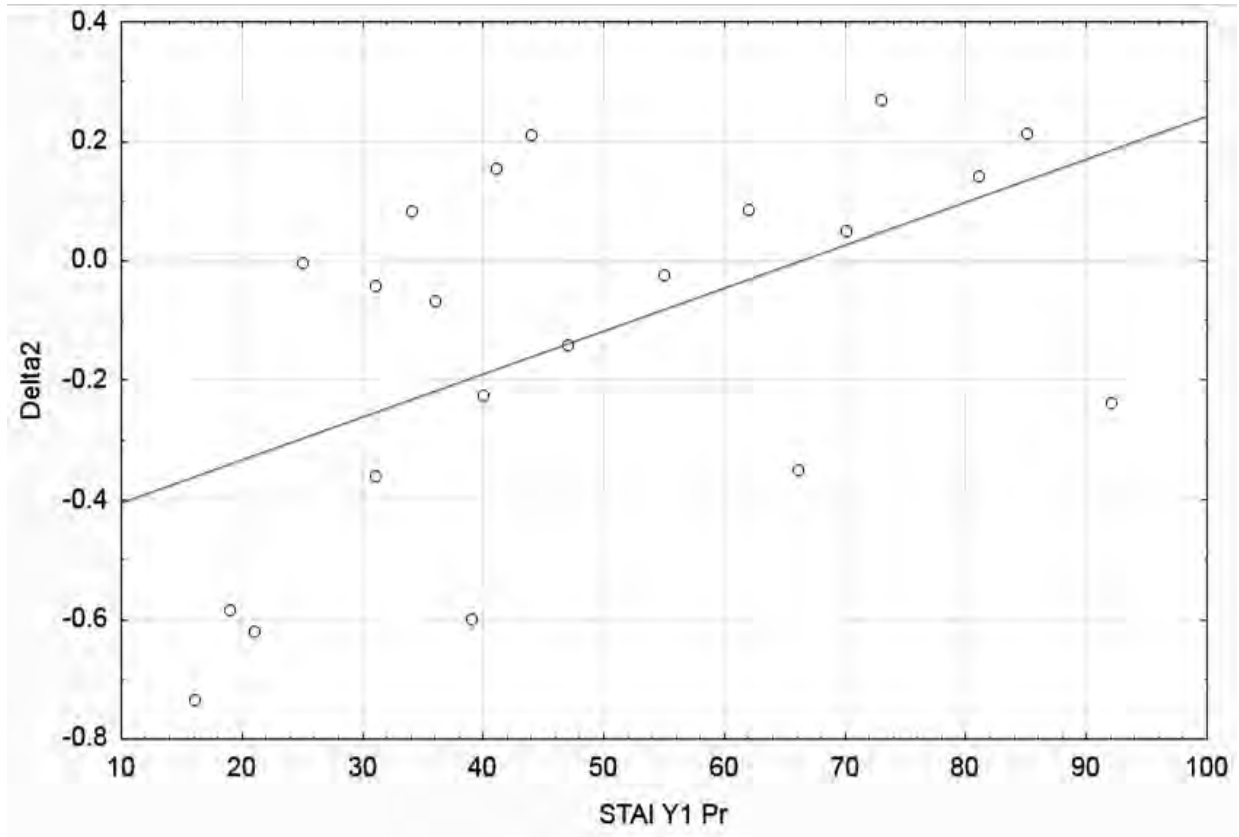


Figure 6.75 Scatterplots of the response of the Coefficient of Variation of Left EEG Peak Frequency and State Anxiety scores.

Coefficient of Variation of Right EEG Peak Frequency

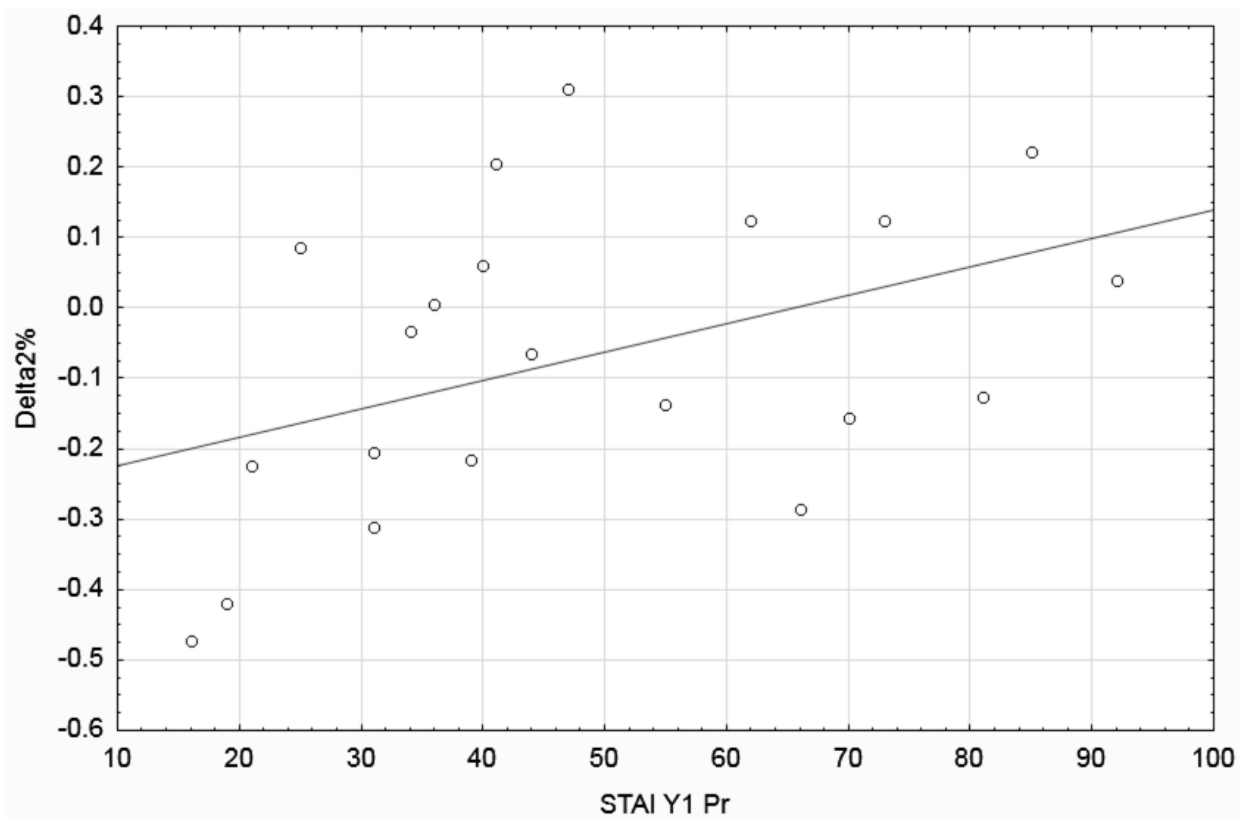
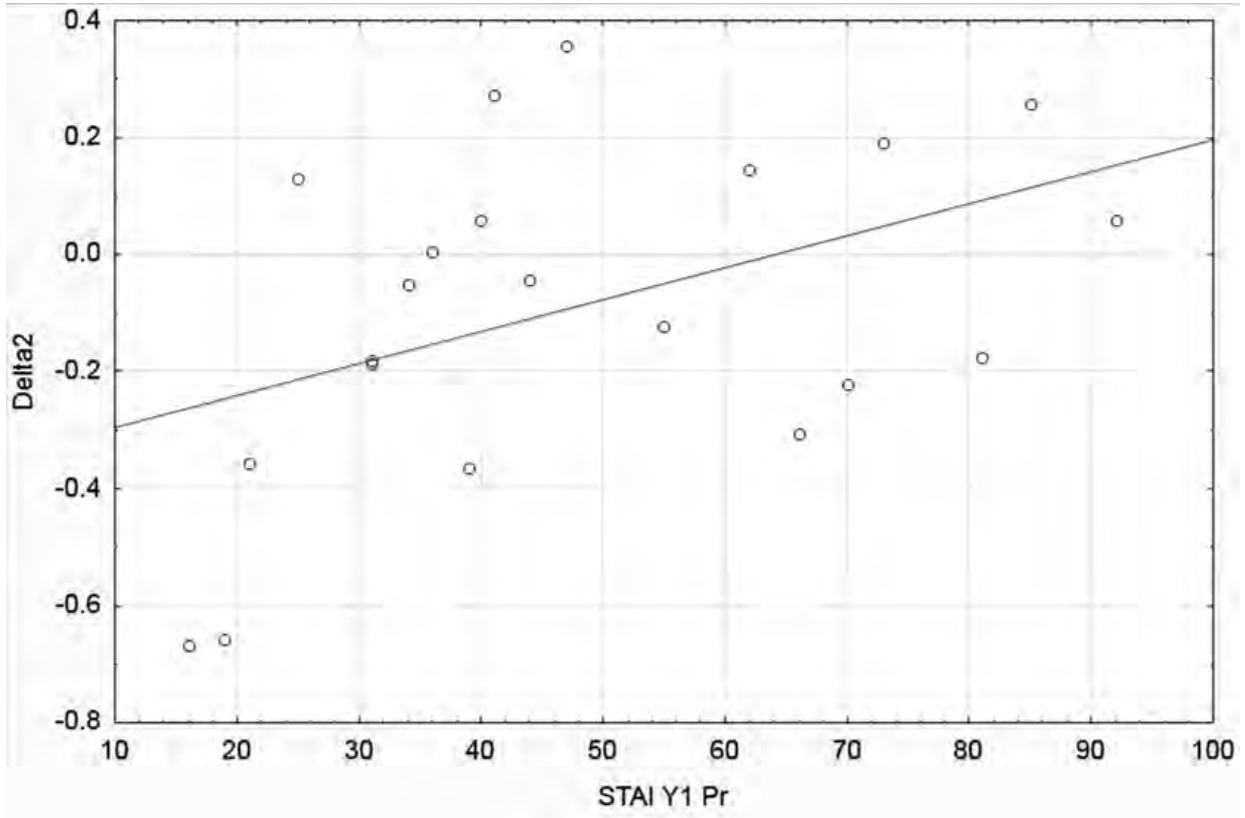


Figure 6.76 Scatterplots of the response of the Coefficient of Variation of Right EEG Peak Frequency and State Anxiety scores.

6.3.18 EEG – Alpha Peak Frequency

Table 6.38 Spearman ranked correlations between the EEG Alpha Peak Frequency variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Left Alpha Peak Frequency Mean	Baseline 1	MBI Cy	0.4663	0.0331
Left Alpha Peak Frequency Mean	Baseline 2	MBI Cy	0.3911	0.0796
Left Alpha Peak Frequency Mean	Challenge	MBI Cy	0.5082	0.0187
Left Alpha Peak Frequency Mean	Recovery	MBI Cy	0.4304	0.0515
Right Alpha Peak Frequency Mean	Baseline 1	MBI Cy	0.4637	0.0342
Right Alpha Peak Frequency Mean	Baseline 2	MBI Cy	0.3755	0.0934
Right Alpha Peak Frequency Mean	Challenge	MBI Cy	0.4662	0.0332
Left Alpha Peak Frequency Mean	Recovery	MBI Pe	-0.3733	0.0955
Left Alpha Peak Frequency CoefVar	Baseline 1	STAI Y1	0.4858	0.0256
Left Alpha Peak Frequency StdDev	Baseline 1	STAI Y1	0.3815	0.0879
Right Alpha Peak Frequency StdDev	Recovery	STAI Y1	0.3915	0.0792
Left Alpha Peak Frequency CoefVar	Baseline 1	STAI Y1 Pr	0.4185	0.059
Left Alpha Peak Frequency CoefVar	Challenge	STAI Y2 Pr	-0.3786	0.0906

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank,

6.3.19 EEG – Ratios

Table 6.39 Spearman ranked correlations between the EEG Ratio variables and the psychometric items. N=21

Variable Name	Step	Psychometric	Spearman r	p-value
Right Alpha/Theta CoefVar	(Ch-B2)/B2	MBI Cy	-0.516	0.0166
Right Alpha/Theta CoefVar	Ch-B2	MBI Cy	-0.4812	0.0272
Left Alpha/Theta Mean	Challenge	MBI Ex	-0.3898	0.0807
Right Alpha/Theta Mean	Ch-B2	MBI Ex	-0.4037	0.0696
Right Alpha/Theta Mean	Ch-B2	MBI Pe	-0.4029	0.0702
Left Alpha/Theta Mean	Baseline 2	STAI Y1	0.4822	0.0268
Right Alpha/Theta Mean	Baseline 2	STAI Y1	0.4724	0.0306
Left Alpha/Theta Mean	Baseline 2	STAI Y1 Pr	0.4911	0.0238
Right Alpha/Theta Mean	Baseline 1	STAI Y1 Pr	0.3704	0.0984
Right Alpha/Theta Mean	Baseline 2	STAI Y1 Pr	0.4995	0.0211
Right Alpha/Theta Mean	Challenge	STAI Y1 Pr	0.3775	0.0916
Right Alpha/Theta Mean	Recovery	STAI Y1 Pr	0.3918	0.079
Right Alpha/Theta StdDev	Baseline 2	STAI Y1 Pr	0.4255	0.0545
Right Alpha/Theta CoefVar	Baseline 2	STAI Y2 Pr	0.3815	0.0879
Left Theta/Beta1 CoefVar	(Ch-B2)/B2	MBI Ex	-0.3924	0.0785
Left Theta/Beta1 CoefVar	Ch-B2	MBI Ex	-0.3846	0.0851
Left Theta/Beta1 Mean	Baseline 1	MBI Ex	0.3763	0.0927
Left Theta/Beta1 Mean	Challenge	MBI Ex	0.4355	0.0485
Right Theta/Beta1 Mean	(Ch-B2)/B2	MBI Ex	0.485	0.0258
Right Theta/Beta1 Mean	Ch-B2	MBI Ex	0.4772	0.0287
Left Theta/Beta1 Mean	Baseline 2	STAI Y1	-0.3889	0.0814
Right Theta/Beta1 Mean	Challenge	STAI Y1	-0.3791	0.0901
Right Theta/Beta1 StdDev	Challenge	STAI Y1	-0.3739	0.095
Left Theta/Beta1 Mean	Baseline 2	STAI Y1 Pr	-0.3780	0.0911
Right Theta/Beta1 Mean	Challenge	STAI Y1 Pr	-0.3923	0.0786

Coefvar – coefficient of variation, StdDev – Standard deviation, MBI – Maslach Burnout inventory, Cy – Cynicism subscale, Pe – Professional efficacy subscale, Ex – Exhaustion subscale, STAI – State-Trait Anxiety Inventory, Y1 – State Anxiety, Y2 – Trait Anxiety, Pr – Percentile rank, Ch-B2 – Response, (Ch-B2)/B2 – Relative response

Coefficient of Variation of Right Alpha/Theta Ratio

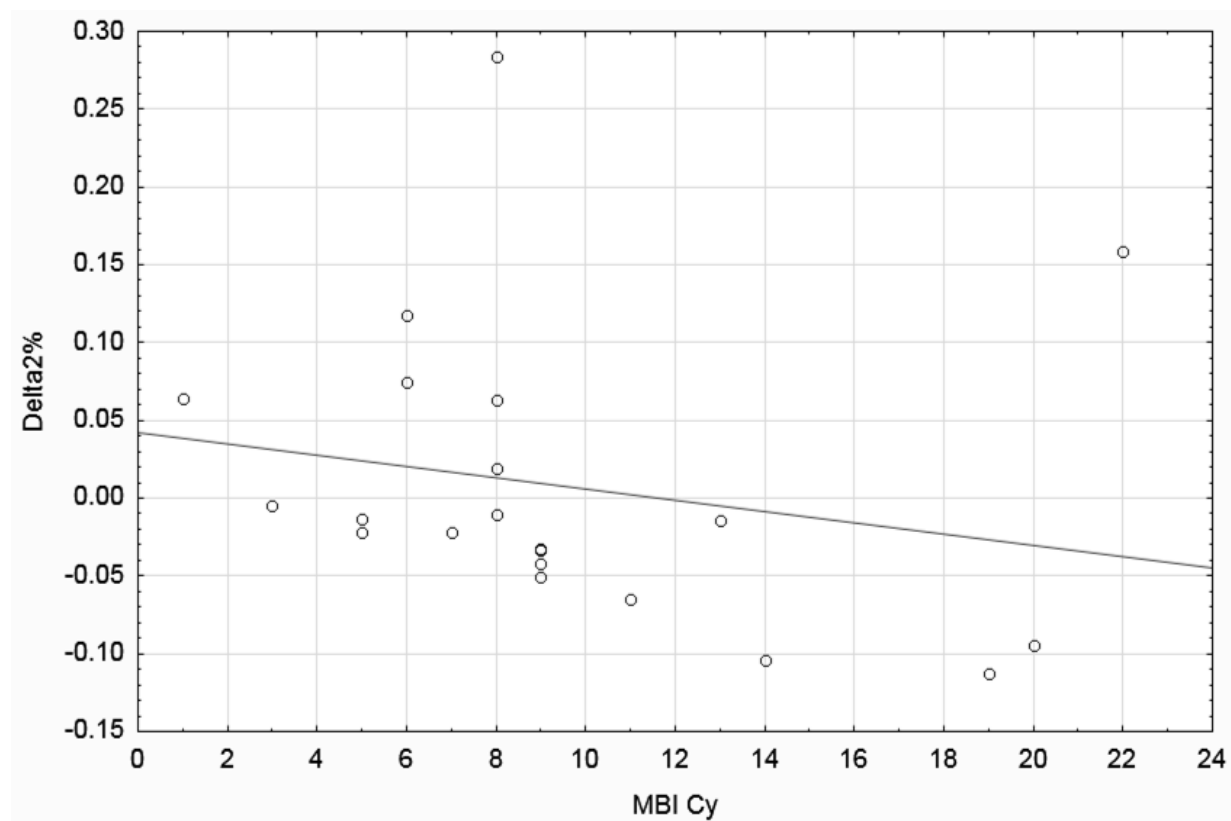
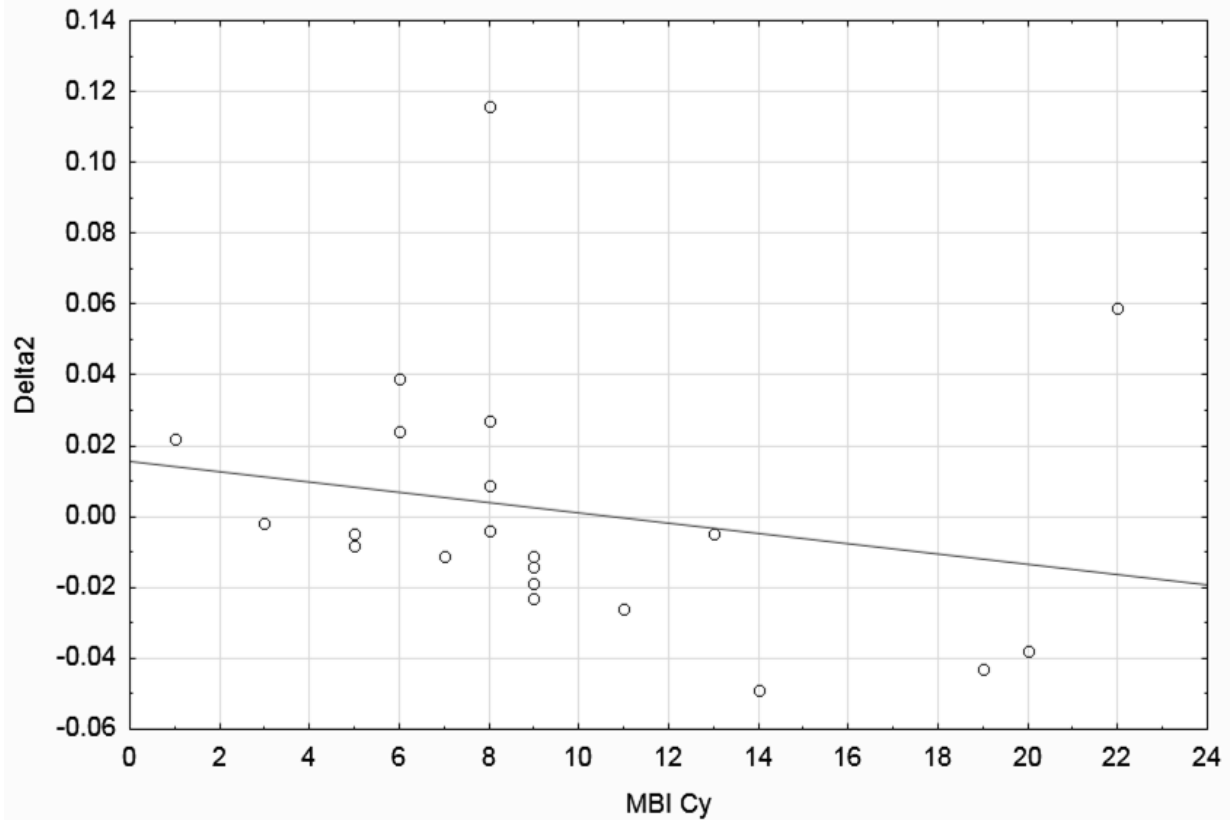


Figure 6.77 Scatterplots of the response of the Coefficient of Variation of the Right Alpha/Theta Ratio and MBI Cynicism scores.

Mean Right Theta/Beta1 Ratio

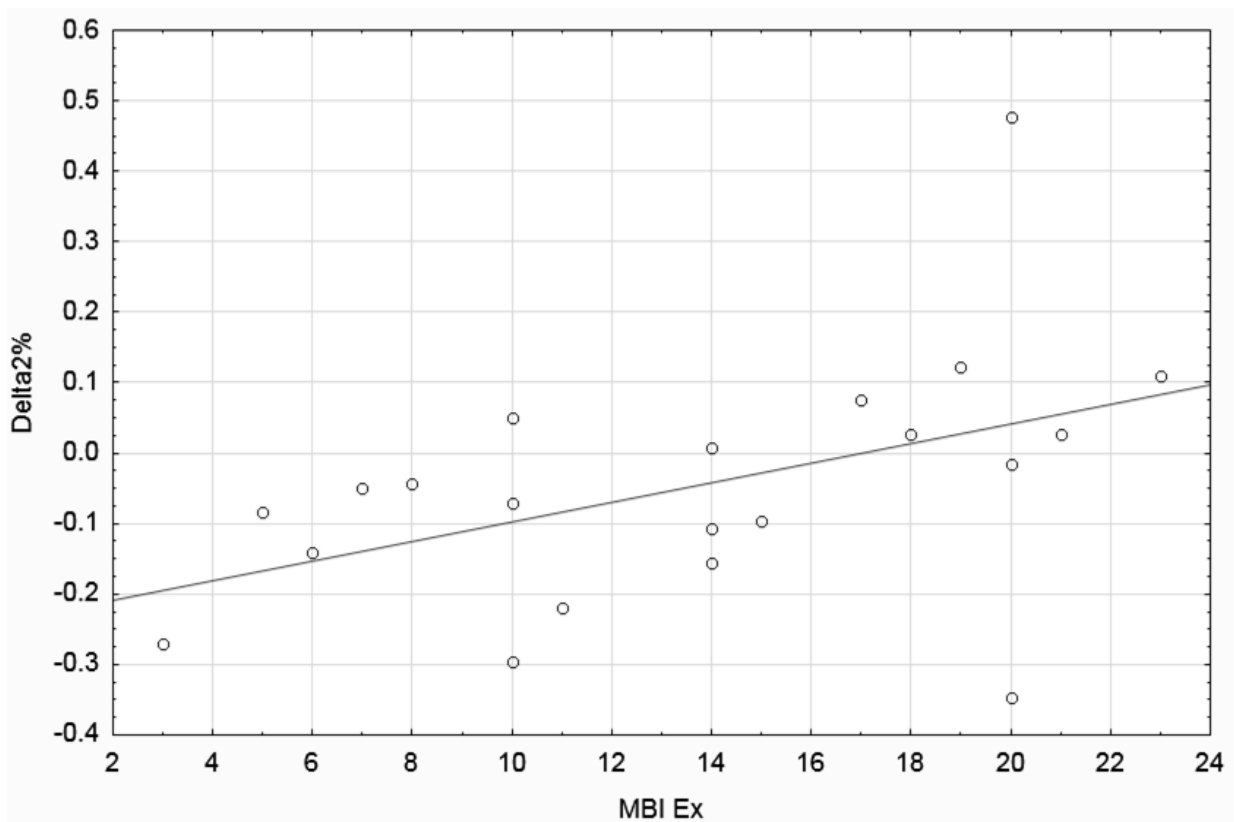
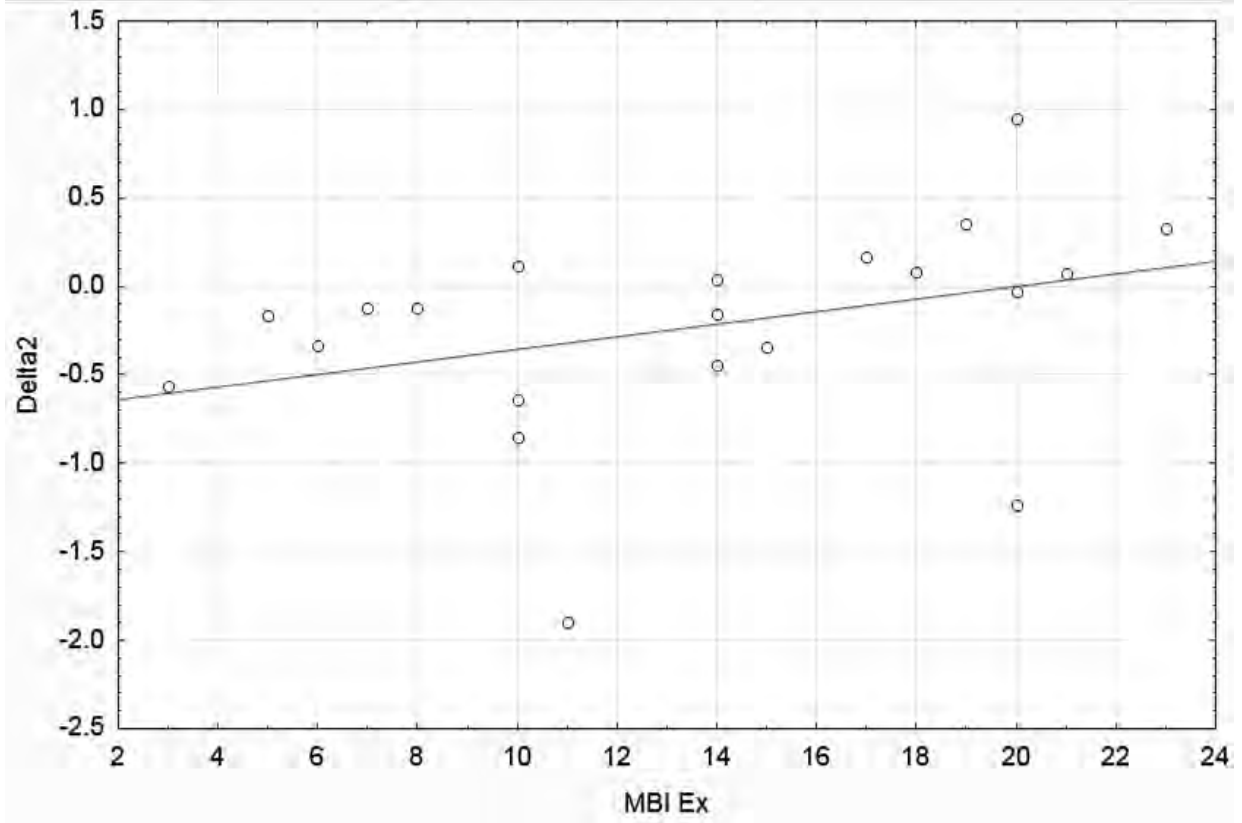


Figure 6.78 Scatterplots of the response of the Mean Right Theta/Beta1 Ratio and MBI Exhaustion scores.

6.4 Discussion

6.4.1 Blood-Volume-Pulse Amplitude

BVP Amplitude is not purely a measure of blood pressure; rather it is the magnitude of the pressure difference between systole and diastole. It is influenced by vasomotor responses to autonomic activity (6,7). Increased vasomotor tone as a result of alpha adrenergic stimulation would raise peripheral resistance and decrease the amplitude of the BVP. BVP is very sensitive to movement artefact, somewhat reducing its reliability in monitoring autonomic responses (6-8).

Although the value of BVP as stress marker appears to lie predominantly in its ability to assess HRV, indications for the use of BVP amplitude as emotional and autonomic indicator exist:

- Salimpoor *et al* (9) found a good correlation between decreased BVP amplitude and emotional arousal in response to music considered pleasing by subjects. The Procomp Infinity equipment from Thought Technology was also used in this study.
- Reduced BVP amplitude was found to be able to discriminate between baseline and stressful conditions, as well as between baseline and engaging conditions (10).

The consensus at present would be that a decrease in BVP amplitude would be indicative of stress. In the present study, several associations between BVP Amplitude and indicators of burnout and anxiety were found.

BVP Amplitude Coefficient of Variation correlated negatively with MBI Cynicism during the Challenge step ($r = -0.4946$, $p = 0.0226$), and positively with MBI Professional Efficacy during Baseline 1 ($r = 0.4387$, $p = 0.0466$). These results indicate that the variability of BVP amplitude, and therefore the variability of the autonomic stimulation, decreased with increases in cynicism and increased the more confident the individual felt about his own professional efficacy. This is in line with the consensus on BVP and stress.

The mean BVP amplitude had a negative correlation that approached significance ($r = -0.4145$, $p = 0.0617$) with Professional efficacy during Baseline 1 (Table 6.5). It points towards increased vasoconstriction with increases in feelings of efficacy.

With regard to anxiety, BVP Amplitude Coefficient of Variation had a negative correlation with state anxiety ($r = -0.4982$, $p = 0.0215$) during recovery (Table 6.5). In other words higher levels of state anxiety were associated with lower variability. This is in line with the assumption that stress conditions such as anxiety, in other words a lower psychological well-being, would result in lower variability (11-13).

Trait anxiety appeared to have had a very definite influence on the magnitude of the response of the BVP amplitude variability. Both the raw score and the percentile rank score of the STAI Y2 correlated positively with the response of the BVP amplitude variability to the cognitive stressor. This was seen in the Coefficient of Variation and Standard Deviation in Table 6.5. The correlations could be seen in both the response (difference between Challenge and Baseline 2 (Ch-B2)) and the relative response (% difference between Challenge and Baseline 2 $((Ch-B2)/B2 \times 100)$), with r -values ranging between 0.4518 and 0.5647, and p -values of 0.0076 to 0.0398. These correlations pointed towards a larger response in terms of variability to a cognitive stressor in individuals with higher trait anxiety. (Figure 6.1 and Figure 6.2) These results warrants further investigation as they are not necessarily in line with what can theoretically be assumed.

In summary, the biofeedback readings gave acceptable results in:

- Decreased BVP amplitude variability with increased levels of cynicism
- Increased BVP amplitude variability with increased professional efficacy
- Decreased BVP amplitude variability with higher levels of state anxiety

However, unacceptable results were found in the correlations between:

- BVP variability and trait anxiety
- BVP amplitude and professional efficacy

6.4.2 Heart rate variability

Heart rate variability (HRV) is a non-invasive technique for the assessment of autonomic balance. HRV refers to the change in the R-R interval of the electrocardiogram (ECG) (12,14). HRV is usually assessed from ECG. Besides ECG, a photoplethysmography or blood volume pulse (BVP) sensor can also be used to successfully determine the R-R interval (6,8). The BVP sensor uses infrared light reflection to calculate the changes in tissue saturation level associated with each cardiac cycle.

In chapter 4 and 5, comparisons were presented between HRV indicators obtained by biofeedback equipment and that obtained by Actiheart as a measure of anxiety and burnout. This was limited to eight candidates, in other words only those candidates where recordings were also obtained by Actiheart. In this part of the dissertation all candidates were included (N=21) and HRV assessed by means of both ECG- and BVP-based tachograms. The indicators of autonomic function were determined by the availability in the biofeedback software and the ability of the candidate to extract the relevant values. Equivalent indicators are used in this discussion.

High heart rate variability is usually associated with good cardiac health and a well-balanced ANS, whereas a decreased HRV is associated with stress (11,12). Some research findings suggest that when chronic stress becomes pathological, the ANS balance becomes less flexible, and autonomic stress responses are repressed (15-17).

The generally assumed stress response depicted by HRV is illustrated in a study on chess players by Troubat *et al* (18), who found that mental stress was associated with increased heart rate, increased LF/HF ratio and decreased mean HRV, with the changes attributed to increased LF but unchanged HF, pointing to increased sympathetic stimulation and unchanged parasympathetic tone. This is not necessarily applicable to stress in general as parasympathetic control of the heart may be reduced in certain states of stress. This was discussed in more detail in Chapter 5.

6.4.2.1 BVP Time-Domain HRV

The Blood Volume Pulse signal can be used to determine the inter-beat-interval of the cardiac cycle, and is, as mentioned above, one of methods used for HRV analysis (6,8).

Mean heart rate measured from the BVP sensor correlated positively with a higher MBI Professional efficacy score for all four recording steps ($r=0.4217$ to 0.4347) (Table 6.6). For Baseline1 the correlation was significant ($p=0.0489$) and the other steps all closely approached significance ($p<0.06$). Professional efficacy is generally viewed as a positive affective trait, but if there is a connection between personality features and baseline heart rate, it cannot be expected to be a simple one. Although one would expect lower heart rates with high levels of self-efficacy, other published results also show increases in heart rate with increases in professional efficacy (19).

The variability of the HR was negatively correlated with State Anxiety percentile rank scores, with significant correlations for the recovery step ($r= -0.4924$ to $r= -0.4607$, $p=0.0234$ to 0.0356) (Table 6.6). The results thus showed variability to be decreased in individuals with higher levels of state anxiety. This was also the result of other studies done on anxiety and HRV (11,12).

The Trait Anxiety scores were positively correlated to the response of the variability of HR, with p values from weak to approaching significant ($r=0.3821$ to 0.4054 , $p= 0.0683$ to 0.0874) (Table 6.6). These results indicate that subjects with higher trait anxiety had a greater increase in the variability of their heart rate during the challenge than those subjects with lower trait anxiety. The clinical significance, and therefore the value in stress assessment, is not quite clear. Although one would, in theory except the opposite this assumption is not necessarily correct and needs further investigation.

The Trait Anxiety percentile rank scores had negative correlations with NN50 and pNN50, i.e., indicators of parasympathetic activity. The correlations ranged from weak to approaching significance ($p=0.0563$ to 0.081). This is in line with previous findings of lower parasympathetic activity in individuals with trait anxiety (20).

In summary, the acceptable correlations with BVP time-domain variables were:

- Higher Professional efficacy with increased mean heart rate
- State anxiety and decreased variability of the heart rate
- Trait anxiety and decreased parasympathetic indicators (NN50 and pNN50)

Unacceptable results were found in the correlations between the Trait anxiety scores and the response of the variability of heart rate.

6.4.2.2 BVP Frequency-Domain HRV

As discussed in Chapter 5, exhaustion and burnout are classically assumed to be reflected by decreased parasympathetic tone (represented by HF) and/or increased sympathetic tone (represented by LF) (17,21), but that view is under increasing attack from results that suggest otherwise (15,16).

MBI Cynicism score correlated significantly with lower mean HF% during Baseline 2 ($r = -0.4513$, $p = 0.0400$) (Table 6.7), meaning that persons with higher cynicism had lower parasympathetic activity. There have been previous indications of suppressed parasympathetic activity with higher levels of cynicism (22).

MBI Professional efficacy scores correlated significantly with higher mean HF% ($r = 0.4511$, $p = 0.0401$) and approaching significance with lower mean LF% ($r = -0.4099$, $p = 0.0649$) at recovery. The LF/HF ratio supports these findings; a higher professional efficacy score correlated to a lower LF/HF ratio during Recovery with a p-value approaching significance ($r = -0.4274$, $p = 0.0533$) (Table 6.7). These results suggest that individuals with greater feelings of professional efficacy had more parasympathetic and less sympathetic power while recovering after the mental challenge. These results are supported by the results of other studies (23), and differ from the time domain results.

The LF% standard Deviation and LF/HF standard deviation both had significant negative correlations with professional efficacy score ($r = -0.4995$ to -0.4413 , $p = 0.0211$ to 0.0452) (Table 6.7) during the Recovery step. This indicates that the variability of LF power and LF/HF ratio were lower during recovery from the challenge in individuals with greater efficacy scores. These results reflect a decrease in sympathetic and autonomic nervous system balance variability with higher levels of perceived professional efficacy. These are not in line with what would be expected,

but, as previously mentioned, several factors may influence the perception of an individual about his own professional efficacy and it is quite possible that his perception may be based on a need to be highly efficient and as such be a stressor in itself.

Cynicism correlated with an ANS balance favouring sympathetic and professional efficacy correlated with a balance leaning toward parasympathetic modulation. It can again be speculated that these results represent the influence of outlook on coping, in turn affecting the physiological response to stress.

Exhaustion scores on the MBI had a negative correlation to HF% variability (illustrated by standard deviation and coefficient of variation) that approached significance at Baseline 2 ($r = -0.4289$ to -0.4025 , $p = 0.0523$ to 0.0705) (Table 6.7). Exhaustion also had significant positive correlations with the response of HF power variability to the challenge, as shown by coefficient of variability ($r = 0.4733$ to 0.4876 , $p = 0.025$ to 0.0302) and standard deviation ($r = 0.4316$ to 0.4628 , $p = 0.0346$ to 0.0508) (Figure 6.3 and Figure 6.4). In other words, higher levels of exhaustion were associated with less variability of HF power, but when presented with the cognitive challenge, subjects with high exhaustion had greater increases in the variability of their HF power than non-exhausted subjects. The first result points toward a decline in parasympathetic variability with increases in vital exhaustion at baseline. This is in line with the general assumption of a decline in variability in conditions with either psychological or physical stress (11-13). Implications of the second finding, that individuals with higher vital exhaustion responded to the challenge with greater increases in variability is not completely clear and may not be correct.

A similar pattern can be seen for MBI Exhaustion scores and LF% variability, with lower Baseline 2 values ($r = -0.5189$ to -0.5197 , $p < 0.02$) and larger response magnitudes ($r = 0.3950$ to 0.4147 , $p = 0.0616$ to 0.0763) associated with higher levels of exhaustion. This was also supported by the results of the LF/HF variability. Higher exhaustion was associated with lower variability of the LF/HF ratio ($r = -0.4146$, $p = 0.0617$) and with greater increase in variability of LF/HF when challenged ($r = 0.3911$, $p = 0.0796$). The findings of decline in baseline variability with increases in exhaustion, as before, correlates with decreased variability with a decline in wellness

(11,12), but the implications of the finding of increased variability during the mental stressor is not clear.

The STAI Y1 (state anxiety) Pr scores correlated with lower mean HF% ($r = -0.4209$, $p = 0.0574$), HF% Coefficient of Variation ($r = -0.4378$, $p = 0.0472$) and HF% Standard deviation ($r = -0.4235$, $p = 0.0557$) during the Challenge step. These results indicate that subjects with higher state anxiety had lower HF power and lower variability of HF power during the challenge than the less anxious subjects. The fact that state anxiety correlates with lower HF% mean and variability during the challenge step suggests vagal withdrawal rather than increased sympathetic stimulation in persons with high state anxiety. This is in line with findings of other laboratories using other techniques (24).

The Trait Anxiety scores didn't have any significant correlations with the BVP frequency domain HRV indicator values.

In summary, the BVP frequency-domain indicators that had acceptable correlations with the psychometric scores were:

- Lower HF % power with cynicism
- Higher HF % power with professional efficacy
- Lower LF % power with professional efficacy
- Lower LF/HF ratio with professional efficacy
- Lower variability of HF % power with exhaustion
- Lower HF % power with state anxiety
- Lower variability of HF % power with state anxiety

6.4.2.3 ECG Time-Domain HRV

MBI Cynicism score had a positive correlation with the ECG NN50 response ($r = 0.4635$, $p = 0.0343$) (Table 6.8). Scatterplots indicate that a lower Cynicism score was associated with a greater *decrease* in NN50 count in response to the challenge, whereas higher Cynicism scores correlated with a greater *increase* in NN50 count in response to the challenge. In other words, persons with more cynicism responded to the challenge with increased parasympathetic activity. This result is counter to the results obtained with BVP, and counter to that of the literature. The correlation might

have been influenced by an extremely outlying datapoint, as illustrated in the scatterplot of relative response (Delta2%) vs. MBI Cynicism (Figure 6.5).

MBI exhaustion and the response of ECG NN50 count also had a positive correlation ($r=0.5223$, $p=0.0182$) (Table 6.8), indicating that individuals with high levels of exhaustion responded to the challenge with increased parasympathetic activity, but once again an outlying datapoint could have influenced the finding (Figure 6.6).

Exhaustion also correlated with the response of the variability of the heart rate ($r=0.4389$, $p=0.0466$), with high Exhaustion scores associated with an increase in heart rate variability in response to the challenge (Figure 6.7). This result is not in line with other studies which found decreased heart rate variability in subjects with high exhaustion (23).

Professional efficacy correlated with a higher mean heart rate during baseline and challenge ($r=0.4629$ to 0.491 , $p=0.0238$ to 0.0346) (Table 6.8). The same result was reported before for BVP, and other studies have found similar results (19).

State Anxiety had a correlation approaching significance with decreased baseline heart rate variability ($r= -0.4177$, $p=0.0596$), in line with the literature (11,12).

Trait Anxiety also followed expectations, correlating with lower indices of parasympathetic modulation. NN50 and pNN50 had negative correlations with trait anxiety that ranged from significant to approaching significant ($r= -0.3972$ to -0.526 , $p=0.0143$ to 0.0746). These results obtained with ECG are in line with the findings of other studies (20).

To summarize, the acceptable correlations between ECG time-domain indices and psychometric indices were:

- Higher mean hear rate with professional efficacy
- Decreased heart rate variability with state anxiety
- Lower parasympathetic indices (NN50 and pNN50) with increased trait anxiety

6.4.2.4 ECG Frequency-Domain HRV

MBI exhaustion scores correlated consistently with the response of the variability of LF%, HF% and LF/HF ($r=0.3874$ to 0.6336 , $p=0.002$ to 0.0828) (Table 6.9). Lower

Exhaustion scores were associated with a greater *decrease* in the variability of LF%, HF% and LF/HF in response to the challenge, and higher Exhaustion scores correlated to a greater *increase* in the variability of LF%, HF% and LF/HF in response to the challenge (Figure 6.8 to Figure 6.11). These results suggest that the variability of autonomic activity increased in response to the cognitive stressor in subjects with high levels of exhaustion. These findings reflect those found with BVP, but are counter to the mainstream literature.

MBI Exhaustion correlated strongly to lower variability of LF, HF and LF/HF during baseline 2 ($r = -0.3776$ to -0.7236 , $p = 0.0002$ to 0.0915) (Table 6.9, Figure 6.12 and Figure 6.13). The reductions in baseline variability of autonomic modulation were also seen in the BVP findings, and are in line with the literature (13).

Exhaustion correlated to a lower mean LF/HF ratio during baseline 2 ($r = -0.04524$, $p = 0.0395$) (Table 6.9) (Figure 6.14). This indicates more baseline parasympathetic activity in persons with higher exhaustion, which is not in line with the literature.

Exhaustion correlated positively with the response of the mean LF/HF ($r = 0.4511$, $p = 0.0401$) (Table 6.9). Higher Exhaustion scores were associated with a greater *increase* in mean LF/HF (Figure 6.15). These results show that individuals with higher exhaustion responded to the challenge with increased sympathetic and/or decreased parasympathetic stimulation. This is also the finding of other studies (13).

State anxiety correlated with lower baseline levels of HF variability ($r = -0.4352$ to -0.4633 , $p = 0.0344$ to 0.0486), while trait anxiety correlated with higher LF variability during recovery ($r = 0.4597$ to 0.4617 , $p = 0.0351$ to 0.036) (Table 6.9). Reduced baseline variability is in line with the literature, but the implications of greater variability while recovering after a cognitive stressor is not generally supported by the findings of others (11,12).

In summary, the ECG frequency-domain indices that had acceptable correlations to the psychometric scores were:

- Reduced HF % power variability with exhaustion
- Lower LF % power variability with exhaustion
- Lower LF/HF ratio variability with exhaustion

- A greater increase in the LF/HF ratio in response to the challenge with exhaustion
- Lower HF % power variability with state anxiety

6.4.3 Trapezius Surface Electromyography

EMG measurements reflect the electrical activity in muscle tissue. Greater tension in the muscle involves recruiting more motor units, resulting in greater electrical activity. Cognitive challenges like the Colour-Word interference task can be correlated with increased trapezius muscle activity (25). Anxiety and worry are also associated with greater tension in muscles of the shoulders and neck, as well as the face (26,27).

Nilsen *et al* (28) measured muscle tension in trapezius and frontalis muscles, and found that muscle activity increased in both muscles in response to a stressful task. The muscular activity could be correlated with the heart rate response measured simultaneously.

While generalized anxiety disorder is associated with increased muscle tension (26,27), there are indications that striate muscle activity also exhibits reduced variability, just like the decreased flexibility of other autonomic indices in generalized anxiety disorder (17,26). Skeletal muscle can be said to be a somatic reflection of feelings of tension and anxiety.

In short, the consensus is that one would find increased EMG in association with stress. In line with the literature, it would be interesting to see if the variability of EMG was decreased.

There was no correlation between baseline EMG levels and MBI Exhaustion scores. However, exhaustion correlated negatively with the response of mean EMG to the cognitive challenge ($r = -0.4291$), with a p value closely approaching significance ($p = 0.0523$) (Table 6.10). This means that the higher the Exhaustion score, the greater the *decrease* in muscle tension in response to the challenge. The lower Exhaustion scores correlated to responses close to zero (Figure 6.16). The observed decrease in muscle tension in response to a cognitive challenge is counter to the findings of others, but there are cases where an association between lower EMG activity and high emotional exhaustion scores have been found (29).

MBI Professional efficacy was associated with higher levels of mean EMG during Baseline 2 and Challenge ($r=0.4967$ to 0.5496 , $p=0.0099$ to 0.022), and with higher variability of EMG during Baseline 2 and Challenge ($r=0.4439$ to 0.5080 , $p=0.0187$ to 0.0438) (Table 6.10). This would be appropriate if the burden of perceived professional efficacy became an additional stressor.

State Anxiety correlated significantly with lower levels of EMG during Baseline 2 ($r= -0.4974$, $p=0.0218$), and closely approaching significance during Baseline 1 ($r= -0.4248$, $p=0.0549$) (Table 6.10). State anxiety percentile rank scores (STAI Y1 Pr) also correlated with lower EMG during Baseline 2 ($r= -0.4841$, $p=0.0262$). These results indicate lower muscle tension in anxious persons, which is not in line with the literature on anxiety.

State Anxiety raw and percentile rank scores correlated significantly with EMG Response values ($r=0.5415$ to 0.6015 , $p=0.0039$ to 0.0179). In other words, higher State Anxiety scores correlated to greater *increases* in mean EMG in response to the challenge (Figure 6.17). In contrast to the baseline results, this is in line with previous literature (28).

State anxiety raw and percentile rank scores correlated significantly with lower variability in EMG activity during Baseline 2 ($r= -0.4696$ to -0.5261 , $p=0.0143$ to 0.0317), and less significantly with lower EMG variability during Baseline 1 ($r= -0.4170$ to -0.4339 , $p=0.0494$ to 0.0600). This is also in agreement with previous publications, which found reduced variability in skeletal muscle activity in persons with anxiety and stress (17,26).

State Anxiety correlated significantly to the response of EMG variability ($r=0.5031$ to 0.6353 , $p=0.002$ to 0.0201). Lower State Anxiety scores were associated with a *decrease* in EMG Standard Deviation in response to the challenge, while higher State Anxiety scores correlated to an *increase* in EMG Standard Deviation in response to the challenge (Figure 6.18). As before the implications of variability changes during the response to a cognitive stressor is not quite clear and further in depth analyses are required. That is, however, beyond the scope of this dissertation.

Trait Anxiety raw and percentile rank scores correlated with lower EMG variability during Baseline 2 and Challenge ($r= -0.4832$ to -0.5234 , $p=0.0149$ to 0.0265).

Reduced variability of EMG activity in anxious individuals is in agreement with expectations and published literature (17,26).

In summary, many of the observations were not in line with what is generally expected. However, biofeedback readings gave acceptable/expected results between:

- Greater increases in EMG in response to the challenge with state anxiety
- Lower variability with increased state anxiety
- Lower variability with increased trait anxiety

6.4.4 Fingertip Temperature

Vasomotor responses that influence the flow of blood to the skin influence the temperature of the skin surface, and provide an additional method to monitor these responses (6,30). Sympathetic adrenergic stimulation generally leads to increased peripheral vascular resistance, and subsequently a decrease in blood flow to the skin surface. The variability of the temperature has been shown to be a sensitive indicator of vasomotor responses to stress (6,30). Cognitive challenges, like the Colour-Word Interference test, have been shown to increase vasoconstriction (25). Fingertip temperature is sometimes used to investigate sleep disorders, and as a biofeedback protocol for the treatment of sleep disorders, as progressive relaxation is characterized by an increase in fingertip temperature (31).

MBI Cynicism had significant negative correlations with the variability of fingertip temperature during Baseline 2 ($r = -0.4478$ to -0.458 , $p = 0.0368$ to 0.0418) (Table 6.11). This suggests less variability in the sympathetic autonomic stimulation that modulates peripheral vasoconstriction. As seen in the HRV results, others have found indications of suppressed parasympathetic activity with higher levels of cynicism (22). Less parasympathetic stimulation could possibly result in a more unvarying sympathetic tone, but this possibility would have to be pursued in future work.

MBI Professional efficacy had significant negative correlations with the Response of the temperature ($r = -0.5754$ to -0.6087 , $p = 0.0034$ to 0.0064) (Table 6.11). Lower Professional efficacy scores were associated with an *increase* in the mean

temperature in response to the challenge, while higher Professional efficacy scores were correlated to greater *decreases* in mean temperature in response to the challenge (Figure 6.19). In other words, persons with feelings of professional efficacy had greater vasoconstriction in response to the cognitive stressor. This pattern of increased arousal in individuals with high efficacy scores was also seen in the EMG results and the finding of increased mean heart rate, but the implications in terms of stress indicators are not clear yet.

Trait Anxiety (STAI Y2) raw and percentile rank scores correlated significantly with lower variability in fingertip temperature during Baseline 2 ($r = -0.4758$ to -0.5705 , $p = 0.0069$ to 0.0293) (Table 6.11). This result is in agreement with work that suggested that the variability of fingertip temperature might be more indicative of sympathetic stimulation than mean temperature itself (6).

Trait Anxiety also correlated with the Response in the variability of fingertip temperature ($r = 0.3997$ to 0.4712), the correlations ranged from significant to merely approaching significant ($p = 0.0311$ to 0.0726) (Table 6.11). Lower Trait Anxiety scores correlated with a *decrease* in Temperature standard deviation in response to the challenge, and higher Trait Anxiety scores were associated with *increased* Temperature standard deviation in response to the challenge (Figure 6.20). This is counter to the literature that suggests anxiety and sympathetic activation leads to reduced variability of temperature.

In summary, the biofeedback readings gave acceptable results in:

- Decreased temperature variability with increases in cynicism
- Decreased temperature variability with increased trait anxiety

Unexpected results were found in the correlations between Professional efficacy mean fingertip temperature. However, it cannot summarily be accepted that these results are wrong, as similar disparities has previously been seen with professional efficacy. No correlations were found between mean fingertip temperature and other psychometric indicators.

6.4.5 Pulse Transit Time

Pulse transit time (PTT) represents the time interval between systole and the arrival of the surge of blood at a given location in the circulatory system (32). It is sensitive to changes in blood pressure, and lengthens during inspiratory blood pressure drops (33). It is shown to have a high inter-person variability, but within a person changes in PTT is a good indicator of changes in blood pressure (34). Payne *et al* found the relationship between blood pressure and PTT not to be linear, but still a good indicator of blood pressure variability (35).

Many factors influence pulse transit time, but an increase in sympathetic stimulation of the vessels are a major contributor (36).

The MBI Exhaustion scores had negative correlations approaching significance with lower variability of pulse transit time during Baseline 2 ($r = -0.4044$ to -0.4263 , $p = 0.054$ to 0.069) (Table 6.12). This suggests less blood pressure variability in exhausted individuals, and in turn less variability of sympathetic autonomic activity, which is in line with the findings of others (11-13).

MBI Professional efficacy correlated significantly with increased variability of pulse transit time during Baseline 1 ($r = 0.4879$, $p = 0.0248$) (Table 6.12). This means that individuals with high levels of professional efficacy had more autonomic variability, which is also seen in the literature (23).

State Anxiety (STAI Y1) percentile rank scores had negative correlations approaching significance with the variability of pulse transit time during Baseline 2 and Challenge ($r = -0.3884$ to -0.4094 , $p = 0.0654$ to 0.0818) (Table 6.12). This would suggest that anxious individuals have less autonomic variability, in line with the work of others (11-13).

Trait Anxiety (STAI Y2) raw and percentile rank scores had significant negative correlations to the variability of pulse transit time during Baseline 2 ($r = -0.4600$ to -0.5169 , $p = 0.0164$ to 0.0359), and a negative correlation approaching significance during Baseline 1 ($r = -0.4205$, $p = 0.0576$) (Table 6.12). As with the state anxiety, this result is in agreement to the literature.

In summary, no correlations were found between pulse-transit-time and anxiety or burnout. The only acceptable correlations found were between the variability of PTT and the psychometric scores:

- Lower variability of pulse transit time with increased exhaustion
- Increased PTT variability and professional efficacy
- Lower variability with increases in state anxiety
- Lower variability with increased trait anxiety

6.4.6 Respiration Rate and Amplitude

Breathing rhythms are complicated as they result from the interplay between various autonomic feedback systems as well as somatic control. Respiration rate and depth change drastically during a fight-or-flight response (27,37,38). Because of the complexity of the control of respiration, the correlation to sympathetic and parasympathetic activity is beyond the scope of this dissertation. The discussion of the results of this study was limited to the ability of the respiratory parameters to identify features of stress.

Studies have found an increase in respiration rate under mental stress, which was positively correlated to Trait Anxiety measures (39). Variability in respiration rate and depth was decreased in anxious women at baseline and during anxious imagery (40). In contrast, increased respiratory variability was observed in fearful imagery (40) and in panic disorder (41), making it important to discriminate between trait anxiety and fear or panic.

MBI Cynicism correlated with increased variability of respiration rate during Recovery ($r= 0.4306$ to 0.5756 , $p=0.0063$ to 0.0513) (Table 6.13). Increased respiration rate variability was seen in association with panic (40,41), but the link between cynicism and respiration variables are not well documented.

MBI Exhaustion correlated with increased respiration rate during Baseline 2 and Recovery ($r=0.4172$ to 0.5124 , $p=0.0176$ to 0.0599), and it correlated with reduced variability of respiration rate during Baseline 2 ($r= -0.4226$, $p=0.0563$) (Table 6.13). This result is similar to the literature on trait anxiety correlated to increased

respiration rate and decreased rate variability (39,40). If exhaustion accompanies chronic anxiety, this result would be in line with the findings of others.

MBI Professional efficacy had negative correlations approaching significant with respiration amplitude during Baseline 1 and Challenge ($r = -0.4067$ to -0.4165 , $p = 0.0604$ to 0.0673) (Table 6.13). In other words, persons with greater feelings of self efficacy had shallower breathing than the other subjects. The implication of this result is not clear.

State Anxiety (STAI Y1) raw and percentile rank scores correlated significantly with increased respiration amplitude during Challenge ($r = 0.4807$ to 0.5259 , $p = 0.0143$ to 0.0274), and had correlations approaching significant with increased variability of respiration rate during Challenge ($r = 0.3711$ to 0.432 , $p = 0.0505$ to 0.0977) (Table 6.13). The increased variability is in line with the literature findings on fear and panic (40,41).

Trait Anxiety (STAI Y2) raw scores had significant negative correlations with the variability of respiration amplitude during Baseline 2 and Recovery ($r = -0.4390$ to -0.4923 , $p = 0.0234$ to 0.0465) (Table 6.13). This was also the finding of another study on respiratory variability and trait anxiety (40).

Trait Anxiety also correlated with the Response in the variability of respiration amplitude ($r = 0.4513$, $p = 0.0400$) (Table 6.13). Lower Trait Anxiety scores were associated with a *decrease* in Respiration amplitude variability in response to the challenge, while the highest Trait Anxiety scores correlated to smaller responses (Figure 6.21). This result could be explained by a flattened response to stressors in chronic anxiety mentioned previously, but as before, the meaning of the response of variability is not clear yet.

As seen in other studies, the variability of respiration amplitude was able to distinguish between state anxiety (fear and panic) and trait anxiety, and could possibly be an indicator of the reduction in overall variability and flexibility of the autonomic nervous system seen after prolonged stress. As the associations with panic and fear indicate, too much variability is not desirable either.

Significant correlations were found between:

- Exhaustion and increased respiration rate
- Exhaustion and decreased variability of respiration rate
- State anxiety and increased variability of respiratory amplitude
- Trait anxiety and decreased variability of respiratory amplitude

6.4.7 Skin Conductivity

Merocrine (eccrine) sweat glands are innervated by the sympathetic nervous system and respond to stimulation by secreting watery sweat over most of the body surface (42), which reduces the electrical resistance of the skin and increases the skin conductivity.

Skin conductivity (SC), or galvanic skin responses (GSR) accurately reflect the emotional autonomic reaction to nociception or pain, and are often used in anesthetised and post-operative patients (43) as the reaction is immediate and independent of hemodynamics (43,44).

As demonstrated by Jacobs *et al* (44), skin conductivity levels rise in response to mental stress, and the effect was not influenced by β -blocking medication, making it clinically very useful to study autonomic arousal in cardiovascular patients (44). Research by Kilpatrick in the 1970's (45) indicated that changes in skin conductivity could fall into phasic and tonic classes; with phasic changes being a more sensitive indicator of the psychophysiological reaction to stress. Tonic fluctuations reflect emotional arousal, but are mediated through increased cognitive and perceptual processes that accompany an emotional stress response (45).

It is also possible for some individuals to have repressed or low skin conductivity in response to a stressor, as seen in work done by White *et al* (15), who attributes it to the autonomic suppression seen in some patients with Generalized Anxiety Disorder (16,17).

MBI Exhaustion had a positive correlation that approached significance with skin conductivity during Baseline 1 ($r=0.3859$, $p=0.084$) (Table 6.14). Exhaustion also correlated significantly with increased variability of the skin conductivity during Baseline 1 ($r=0.5797$ to 0.6363 , $p=0.0019$ to 0.0059) (Figure 6.22). This suggests greater sympathetic input that fluctuated more than non-exhausted individuals, which

would agree with the literature on exhaustion and HRV that suggests that burnout is accompanied by more sympathetic activity (17,21).

MBI Professional efficacy had significant negative correlations with skin conductivity during Recovery ($r = -0.5257$, $p = 0.0144$), and the correlation approach significance during Challenge ($r = -0.4152$, $p = 0.0613$) (Table 6.14). This suggests lower levels of sympathetic activity in persons with professional efficacy, a result that is supported by studies that found evidence of decreased sympathetic stimulation in individuals with greater feelings of self-efficacy (46).

MBI Professional efficacy also correlated significantly to decreased variability of skin conductivity during Challenge and Recovery ($r = -0.5597$ to -0.5664 , $p = 0.0074$ to 0.0083) (Table 6.14). Phasic fluctuations in skin conductivity were found by others to be a reflection of emotional stress (45). If professional efficacy is a resilience factor, it would be expected to buffer the fluctuations seen in such a response to stressors.

State Anxiety (STAI Y1) raw and percentile rank scores correlated with increased variability of skin conductivity during Baseline 2 ($r = 0.3697$ to 0.4888 , $p = 0.0245$ to 0.0990) (Table 6.14). This is in line with the findings of others (45).

State Anxiety also correlated significantly with the Response of skin conductivity levels ($r = -0.4796$ to -0.545 , $p = 0.0106$ to 0.0278) (Table 6.14). The correlation is negative, meaning that lower State Anxiety scores are associated with increased mean Skin conductivity in response to the challenge, while the higher State Anxiety scores are associated with smaller magnitude changes (Figure 6.23). This is supported by the findings of others that the response of indicators of arousal is flattened in those experiencing anxiety (15-17).

State Anxiety correlated with the Response of the variability of skin conductivity ($r = -0.3738$ to 0.4296 , $p = 0.0328$ to 0.0951) (Table 6.14). Lower State Anxiety scores were associated with a greater *increase* in the variability of the skin conductivity in response to the challenge, while higher State Anxiety scores correlated with a *smaller* increase or a *decrease* (Figure 6.24). While the significance of the response of the variability is not yet clear, this finding also seems to point to a flattened response in anxious individuals.

Trait Anxiety (STAI Y2) raw and percentile rank scores correlated significantly with increased levels of skin conductivity during all four steps ($r=0.4571$ to 0.5739 , $p=0.0065$ to 0.0372) (Table 6.14). High Trait Anxiety scores also correlated significantly with increased standard deviation of the skin conductivity levels during Baseline 1 (Figure 6.25) and Baseline 2 ($r=0.4912$ to 0.6788 , $p=0.0007$ to 0.0237). These results point to higher levels of tonic sympathetic stimulation in those with anxiety, in line with the findings of other studies (15-17).

Trait Anxiety correlated significantly with the Response of the variability of the skin conductivity levels ($r= -0.448$ to -0.5269 , $p=0.0141$ to 0.0417) (Table 6.14). Lower Trait Anxiety scores were associated with an *increase* in the variability of skin conductivity in response to the challenge, higher Trait Anxiety scores correlated to a *smaller increase* or a *decrease* in variability of the skin conductivity in response to the challenge (Figure 6.26 and Figure 6.27). As with state anxiety, this result is cautiously interpreted as a sign of decreased responsiveness in anxious persons.

Significant correlations were found between:

- Higher levels of skin conductivity with exhaustion
- Higher variability of skin conductivity with exhaustion
- Decreased skin conductivity with higher levels of professional efficacy
- Decreased variability of skin conductivity with higher professional efficacy
- Higher variability of skin conductivity and state anxiety
- High levels of skin conductivity and trait anxiety
- Higher variability of skin conductivity and trait anxiety
- A lower skin conductivity response and state anxiety
- A lower response and trait anxiety
- A muted response of the variability of the skin conductivity and both state and trait anxiety

Skin conductivity, as in other work by the same laboratory, showed excellent results in association with stress (47).

6.4.8 Quantitative Electro-Encephalography

The use of quantitative EEG in the assessment of stress levels is a relatively new field, riddled with uncertainties. Although all correlations found in this study are reported and briefly discussed, many of the findings could not be corroborated by evidence from previous literature. Should the reader not be interested in all he or she is advised to go directly to the summary of findings that could be compared to existing literature (p. 6-176).

Electroencephalography (EEG) is a technique used to measure the electrical activity of the brain. An advancement in the EEG technique is the digitized quantitative EEG (QEEG). The power of QEEG lies in the ability to quantify findings and compare them to normative databases (48-50). The power spectrum of a normal, healthy brain appears to be very stable across individuals with diverse backgrounds, and patterns of deviation from the norm exist that can be associated with mental and psychiatric disorders, but the exact functional correlates of all the electrophysiological features is still a work in progress (50,51).

The underlying components of the EEG are generally classified into frequency bands called rhythms, each associated with different levels of arousal and different cortical processes (Table 6.40).

Table 6.40. Classic interpretation of the main rhythmic components of the analogue EEG trace. Compiled from (50,52)

Designation	Frequency Range	Main Features & Functional Correlates
α (Alpha)	8 to 13 Hz	Highly rhythmic, sine-shaped waveform generated by pacemaker cells in the thalamus. Dominant rhythm in normal, wakeful adults with eyes closed. Mainly found over posterior parts of the cortex and parietal lobes, diminishes anteriorly, rarely found prefrontally. Abolished by concentration or imagery, or by opening the eyes.
θ (Theta)	4 to 7.5 Hz	Prominent in sleep and drowsy recordings, and in children. Limited in the wakeful adult EEG trace to sporadic bursts over the frontal-temporal areas
δ (Delta)	≤ 3.5 Hz	While normal in infants and adults in deep sleep, finding slow, high amplitude Delta waves in the wakeful adult EEG is strongly indicative of pathology.
β (Beta)	13 to 30 Hz	Low amplitude, asymmetric waves common to wakeful, eyes-open adult EEG traces, especially in frontal-central regions. The frequency of Beta activity appears to be related to the level of arousal.
γ (Gamma)	>30 Hz	The appearance of high frequency activity has been experimentally correlated to visual binding and integrative cortical processing.

Digital QEEG also allows the inter-hemisphere comparison of activity; like amplitude asymmetry, coherence and phase (3,4).

Neurophysiological research suggests that the left hemisphere is more involved in the processing of positive emotions and approach-behaviours, while the right hemisphere is more involved with negative emotions and withdrawal behaviours (53,54). Positive moods or reactions are associated with greater left prefrontal activity and negative moods or reactions with greater right prefrontal activity (55).

The Delta band is electrocortical activity in the range of 0.5 to 4 Hertz. It dominates during deep sleep or coma and is considered abnormal in the EEG of an awake adult (50,52). When QEEG is used, Delta is present in awake adults, but reduced in power

relative to the other frequencies. Because Delta power becomes relatively lower with increased arousal, it was expected that anxiety and hypervigilance would correlate to lower Delta levels.

Theta activity is found between 4 and 8 Hz, and is generally associated with drowsiness and onset of sleep. Hippocampal activity is hypothesized to contribute to Theta activity seen over the temporal regions (50,52). Since Theta increases with progressive relaxation, overall Theta power can be expected to decline with increased arousal, and to be even lower in those subjects considered to be more anxious. On the other hand, frontal Theta has been shown to increase with intensive thinking and mental calculation (56), and to play a role in spatial navigation (57).

The Alpha frequency band ranges from 8 to 12 Hz and is the dominant rhythm in awake, relaxed adults with eyes closed (50,52).

The QEEG profiles of depressed patients show that they often exhibit an asymmetry in alpha activity in their frontal cortex, and that they have decreased left frontal activation (58-61). Investigators found a relative right hemisphere parietal over-activation in patients with spider phobia, which correlated to self-reported levels of phobia, while also finding a correlation that approaches significance between right frontal over-activation and avoidance behaviour, as measured in alpha band (62).

It was expected that an Alpha asymmetry favouring the right hemisphere and lower overall Alpha power would be associated with higher scores on the anxiety and burnout scales (27,62).

The sensorimotor-rhythm (SMR) is between 12 and 15 Hz, and is sometimes referred to the mu rhythm (52). It is associated with quiet, relaxed wakefulness with eyes open, and since it is abolished by movement or motor planning or even imagery, can be associated with the inhibition of movement. Much focus has been placed on SMR neurofeedback in ameliorating hyperactivity in children suffering from ADHD (63,64).

Beta waves are irregular and low amplitude activity higher than 15 Hz. It increases with cognitive effort, higher frequencies generally indicating progressive intensity (50,52,57). Reduced alpha power and increased High Beta has been associated with tension and anxiety (27), as well as chronic stress (65,66).

The Gamma rhythm is found at the upper part of the EEG spectrum, and is generally centred at about 40Hz (52). It is speculated to be produced by integrative cortical processing activities like visual binding (50). A study (N=15) using a set of images from the International Affective Picture system found reduced Gamma power in negative emotional states, as compared to calm, neutral states (67).

Peak frequency indicates the frequency with the most power in the overall spectrum of the EEG. Changes in peak frequency reflect the shift to faster or slower cortical activity. Similar to EEG peak frequency, Alpha peak frequency identifies the frequency in the alpha band with the most power. Changes indicate shifts to faster or slower alpha activity.

Calculating the ratio between two rhythms illustrates the behaviour of those relative to each other. When a certain frequency band increases in power, the adjacent bands would often decrease in power, or vice versa (49).

The literature suggests that an underlying QEEG signature for high stress levels do exist, but it is certainly not clearly defined yet. Much of the conflicting findings could be due to persons caught in different stages of the chronic stress burnout pathway. The three features that are most commonly agreed upon are:

- A general hyperarousal, which could present as more power in the beta band and/or a higher peak frequency (48,62,68,69), or as less alpha or “idling” activity (27)
- An asymmetry between the left and right hemisphere activity, where increased right hemisphere activity is associated with a negative emotional bias and avoidance behaviour (27,58-62,70)
- A blunted response to acute stressors, as seen in ERP suppression and less reactivity in the high beta range. It is even possible that an acute stressor disturbs the ruminative processing and results in a decrease of high beta activity (15,71).

6.4.8.1 EEG – Delta Rhythm

The Delta band is electrocortical activity in the range of 0.5 to 4 Hertz. It dominates during deep sleep or coma and is considered abnormal in the EEG of an awake adult

(50,52). When QEEG is used, Delta is present in awake adults, but reduced in power relative to the other frequencies.

Delta Power

MBI Exhaustion correlated with the response of Mean Delta% power in both hemispheres ($r=0.4628$ to 0.5072 , $p=0.0189$ to 0.0346), (Table 6.15). Lower exhaustion scores correlated to a *decrease* in Delta power in response to the challenge, where higher exhaustion scores correlated to an *increase* in Delta power (Figure 6.28 and Figure 6.29). Non- exhausted individuals had increased arousal in response to the stressor, which was expected, but exhausted persons reacted in an anomalous way. Disruptions in slow-wave-sleep (when Delta power is strongest) has been implicated in fibromyalgia (72,73), and persons with increased frontal Delta report feelings of fatigue and “fogginess” (72). Vital exhaustion could be accompanied by disrupted and/or unrefreshing sleep, which in turn might manifest as abnormal Delta activity, but this is speculation.

During the challenge, state anxiety correlated to lower mean Delta power ($r= -0.4561$ to -0.4118 , $p=0.0377$ to 0.0998) and lower Delta power variability ($r= -0.4118$, $p=0.0637$) in the right hemisphere (Table 6.15). There are not much reference to waking Delta power anxiety in the literature, but since Delta is mainly found during sleep (50,52), one would intuitively expect it to be inversely related to arousal.

During recovery trait anxiety correlated to greater Delta power variability in the left hemisphere ($r=0.4376$ to 0.5065 , $p=0.0191$ to 0.0473) (Table 6.15). It is unclear what the interpretation of this is.

Delta Amplitude Asymmetry

Cynicism scores correlated with greater variability of Delta amplitude asymmetry during challenge and recovery ($r=0.4546$ to 0.5075 , $p=0.0188$ to 0.0384) (Table 6.16). In other words, the asymmetry between the left and right hemispheres fluctuated more in cynical individuals. The physiological implication of the variability of asymmetry is not clear.

MBI Professional efficacy correlated to less variability of Delta amplitude asymmetry at Baseline 1, Challenge and Recovery ($r=-0.4132$ to -0.4472 , $p=0.0421$ to 0.0626)

(Table 6.16). As mentioned before, the meaning of this is not clear, but it is worth noting that professional efficacy and cynicism have the opposite effect on the variability of the asymmetry.

Professional efficacy also correlated to the response of the mean Delta amplitude asymmetry ($r=-0.4453$, $p=0.0431$) (Table 6.16). The lower Professional Efficacy scores were associated with an *increase* in amplitude asymmetry in response to the challenge, whereas higher professional efficacy scores correlated to a *smaller increase*, or a *decrease* in amplitude asymmetry in response to the challenge (Figure 6.30). This means that subjects with low Professional efficacy scores responded to the challenge with relatively more *right hemisphere* Delta. The implications of the response of the Delta asymmetry are not clear.

Trait Anxiety had a correlation to the response of the variability of Delta amplitude asymmetry ($p=0.4505$ to 0.4596 , $p=0.0361$ to 0.0404) (Table 6.16). Low Trait Anxiety scores were associated with *decreases* in the variability of Delta amplitude asymmetry, where higher State Anxiety scores correlated to *smaller decreases* or *increases* in the variability of Delta Amplitude asymmetry in response to the challenge (Figure 6.31). The implications of this are unclear.

Delta Coherence

MBI Cynicism correlated with reduced Delta coherence at Baseline 2 and Recovery ($r=-0.4703$ to -0.4035 , $p=0.0315$ to 0.0697) (Table 6.17). There were less significant correlations between increased variability of Delta coherence and cynicism during recovery from the challenge ($r=0.3730$ to 0.3931 , $p=0.0779$ to 0.0958).

MBI Professional efficacy scores correlated weakly with higher Delta coherence during the challenge ($r=0.3779$, $p=0.0912$), and significantly to the magnitude of the response of the Delta coherence ($r=0.5133$ to 0.5211 , $p=0.0154$ to 0.0173) (Table 6.17). Higher Professional efficacy scores correlated to *greater increases* in Delta coherence in response to the challenge (Figure 6.32).

Higher MBI Professional efficacy scores correlated with reduced variability of Delta coherence at Baseline2, Challenge and Recovery ($r= -0.5002$ to -0.3753 , $p=0.0209$ to 0.0937) (Table 6.17).

There was a correlation approaching significant between MBI Exhaustion and reduced Delta coherence during the challenge ($r = -0.4068$, $p = 0.0672$) (Table 6.17).

The physiological interpretation of Delta coherence is not clear.

Delta Phase

MBI Exhaustion had correlations that approached significant with positive Delta phase (left leading) at Baseline 1 ($r = 0.4081$, $p = 0.0663$), and to reduced variability of the Delta phase during the challenge ($r = -0.4198$, $p = 0.0581$) (Table 6.18).

MBI Professional efficacy had correlations that approached significant to decreased variability of the Delta phase during the challenge and at Recovery ($r = -0.4041$ to -0.3929 , $p = 0.0693$ to 0.0780) (Table 6.18). The response of the phase variability correlated negatively with efficacy ($r = -0.3949$, $p = 0.0764$), meaning that subjects with greater feelings of efficacy responded to the challenge by favouring the right hemisphere in terms of Delta phase.

State Anxiety correlated negatively to Delta Phase at Baseline 1, Baseline 2 and Challenge ($r = -0.6132$ to -0.4 , $p = 0.0031$ to 0.0724) (Table 6.18). Lower State Anxiety correlated with a more *positive* Delta phase (Left leading), where higher State anxiety correlated with a more *negative* Delta phase (Right leading) (Figure 6.33).

Trait Anxiety correlated to the response of Delta phase ($r = 0.4343$ to 0.4961 , $p = 0.0222$ to 0.0491) (Table 6.18). Lower State Anxiety scores were associated with *decreases* in the Delta phase (Left-to-Right shift) while higher State Anxiety scores correlated to *smaller decreases* or *increases* in Delta Phase coefficient in response to the challenge (Figure 6.34). In other words, anxious individuals showed less change in Delta phase.

6.4.8.2 EEG –Theta Rhythm

Theta activity is found between 4 and 8 Hz, and is generally associated with drowsiness and onset of sleep. It is normal to find higher levels of Theta waves in children, but in awake adults it is limited to occasional bursts. Hippocampal activity is hypothesized to contribute to Theta activity seen over the temporal regions (50,52), and frontal Theta has been shown to increase with intensive thinking and mental calculation (56), and to play a role in spatial navigation (57).

Theta Power

MBI Exhaustion scores correlated to the response of the mean Theta % power in both hemispheres ($r=0.4303$ to 0.6363 , $p=0.0019$ to 0.0516) (Table 6.19). Higher Exhaustion scores correlated with greater *increases* in Theta power in response to the challenge (Figure 6.35 and Figure 6.36). This association was prominent for the right hemisphere, with Spearman correlations of $>60\%$. This suggests that the response of Theta power to a cognitive challenge was exaggerated in exhausted individuals. Research has shown that slow wave activity, including Theta, increases over the whole cortex as persons become fatigued (74).

There was a weak correlation between exhaustion and a decreased response of Right Theta variability ($r= -0.4081$, $p=0.0663$) (Table 6.19).

State Anxiety correlated with lower Left Theta power variability at baseline 2 ($r= -0.4443$ to -0.4235 , $p=0.0436$ to 0.0557) (Table 6.19). The response of Theta power variability in both hemispheres also correlated with State Anxiety scores ($r=0.4716$ to 0.4878 , $p=0.0249$ to 0.0309). Lower State Anxiety scores were associated with *decreases* in Theta power variability, while higher State Anxiety scores correlated to *increased* Theta power variability in response to the challenge (Figure 6.37 and Figure 6.38).

The interpretation of variability of Theta power and the response of the variability is not clear, and little reference is found in the literature, but the results of this study suggest a correlation between an increase in Theta variability in response to a cognitive stressor and state anxiety.

Strong correlations were also found between exhaustion and greater increases in Theta power in response to the cognitive challenge.

Theta Amplitude Asymmetry

MBI Cynicism scores correlated to increased variability of the Theta Amplitude Asymmetry at Baseline 1, Baseline 2, Challenge and Recovery ($r=0.4114$ to 0.5121 , $p=0.0176$ to 0.0639) (Table 6.20).

MBI Professional Efficacy correlated with the response of Theta Amplitude Asymmetry ($r= -0.5237$, $p=0.0148$) (Table 6.20). Lower Professional efficacy scores

were associated with an positive Theta Asymmetry (favouring Left Theta), and Higher Professional Efficacy scores correlated with a negative Theta asymmetry (favouring Right Theta) in response to the challenge (Figure 6.39). The changes in asymmetry that favour left can be due to increased left Theta and/or decreased right Theta, and the inverse is also true of asymmetry changes that favour right hemisphere Theta.

State anxiety had correlations that approach significant with more positive Theta asymmetry (greater Left Theta) during the challenge ($r=0.3876$ to 0.4177 , $p=0.0596$ to 0.0825) (Table 6.20).

State Anxiety scores correlated with the response of Theta Amplitude Asymmetry ($r=0.5099$ to 0.6662 , $p=0.001$ to 0.0182) (Table 6.20). Lower State Anxiety scores were associated with more negative (Left-to-right shift) Theta asymmetry, higher State Anxiety scores correlated with more positive (Right-to-left shift) Theta asymmetry in response to the challenge (Figure 6.40).

Trait Anxiety correlated less significantly to higher positive Theta asymmetry (more Left Theta) during recovery from the challenge ($r=0.4004$, $p=0.0721$) (Table 6.20). There was also a correlation approaching significant with the response in Theta asymmetry, once again favouring the left hemisphere ($r=0.4049$ to 0.4128 , $p=0.0629$ to 0.0686).

It is not clear how Theta asymmetry should be interpreted, but the results of this study implied that anxiety could be associated with more left hemisphere Theta and a greater magnitude change in Theta asymmetry (favouring the left hemisphere) during a cognitive challenge.

Theta Coherence

MBI Cynicism scores correlated to lower Theta coherence at baseline 2 and recovery ($r= -0.4814$ to -0.4447 , $p=0.0272$ to 0.0434) (Table 6.21). Cynicism correlated less significantly to increased variability of Theta coherence at Baseline 2 ($r=0.4033$, $p=0.0698$).

MBI Profession Efficacy correlated weakly with increased Theta coherence at Baseline 1 ($r=0.3975$, $p=0.0743$), and with decreased variability of Theta coherence at Baseline 2 and Recovery ($r= -0.4394$ to -0.3956 , $p=0.0463$ to 0.0759) (Table 6.21).

Once again the findings that are correlated to MBI Professional efficacy and Cynicism are inverse of each other.

Theta Phase

MBI Cynicism correlated with increased variability of Theta Phase at Baseline 2 and Recovery ($r=0.4297$ to 0.5651 , $p=0.0076$ to 0.0519) (Table 6.22 and Figure 6.41).

MBI Professional efficacy had a correlation approaching significant with decreased variability during the challenge ($r=-0.3916$, $p=0.0791$) (Table 6.22).

MBI Professional efficacy correlated to the response of Theta Phase ($r= -0.4662$, $p=0.0332$) (Table 6.22). Lower Professional efficacy scores were associated with an *increase* (Left ahead) in Theta Phase, while higher Professional efficacy scores correlated to a *decrease* (Right ahead) in Theta Phase in response to the challenge (Figure 6.42). There was, however, an extreme datapoint that might have influenced this correlation.

MBI Exhaustion correlated weakly with higher (Left ahead) Theta phase ($r=0.3794$, $p=0.0898$) (Table 6.22).

6.4.8.3 EEG – Alpha Rhythm

The Alpha frequency band ranges from 8 to 12 Hz and is the dominant rhythm in awake, relaxed adults with eyes closed (50,52). Low Alpha is from 8 to 10 Hz, High Alpha is from 10 to 12 Hz. Increased anxiety is associated with more power in the High Alpha band (75), whereas lower Alpha peak frequencies are associated with burnout (76). It was expected that an Alpha asymmetry favouring the right hemisphere and lower overall Alpha power would be associated with higher scores on the anxiety and burnout scales (27,62).

Low Alpha Power

MBI Exhaustion was weakly correlated to the response of Right Low Alpha power ($r=0.3794$, $p=0.0898$) (Table 6.23). Individuals with high exhaustion reacted to the cognitive challenge by increasing Low Alpha power in the right hemisphere.

Exhaustion also had correlations approaching significant with the response of the variability of Left Low Alpha ($r=0.3898$ to 0.4211 , $p=0.0573$ to 0.0806). This means

that exhausted subjects responded to the challenge with greater increases in the variability of their Left Low Alpha power.

State Anxiety correlated significantly with the Left Low Alpha% power at Recovery ($r=0.464$ to 0.4755 , $p=0.0294$ to 0.0341), as well as with the variability of the Left Low Alpha power at recovery ($r=0.4462$ to 0.4753 , $p=0.0294$ to 0.0426) (Table 6.23). In other words, anxious individuals had higher Left Low Alpha power during recovery from the stressor, and the power also varied more than non-anxious persons.

State Anxiety also had a weak correlation to the response of Right Low Alpha ($r= -0.3793$, $p=0.0899$) (Table 6.23). This implies that anxious individuals had less Right Low Alpha in response to the challenge than non-anxious subjects.

Trait Anxiety correlated with the response of Left Low Alpha power variability ($r=0.3763$ to 0.4591 , $p=0.0363$ to 0.0927) (Table 6.23). Lower State Anxiety scores were associated with a *decrease* in the variability of Left Low Alpha power, while higher State Anxiety scores correlated to *increases* in the variability of Left low Alpha power in response to the challenge (Figure 6.43).

High Alpha Power

MBI Professional Efficacy correlated with the response of the variability of Left and Right High Alpha power ($r=0.4165$ to 0.4813 , $p=0.0272$ to 0.0604) (Table 6.24). Lower Professional Efficacy correlated with a *decrease* in the variability of High Alpha power, while higher Professional efficacy scores were associated with an *increase* in the variability of Right High Alpha power in response to the challenge (Figure 6.44). Implications of the response of variability are not clear.

MBI Exhaustion had weak correlations to the response of the variability both Left and Right High Alpha ($r=0.3887$ to 0.3937 , $p=0.0774$ to 0.0985) (Table 6.24). Exhausted individuals had slightly higher increases in their High Alpha variability in response to the challenge.

State Anxiety correlated to more High Alpha power in both hemispheres at Baseline 1, Baseline 2 and Recovery ($r=0.3871$ to 0.5814 , $p=0.0057$ to 0.083) (Table 6.24). State Anxiety also correlated to increased variability of High Alpha% power in both hemispheres, at Baseline 1, Baseline 2 and Recovery ($r=0.4053$ to 0.4855 , $p=0.0257$

to 0.0683) (Table 6.24). There was a weak correlation between State Anxiety and increased variability of Right High Alpha power during the challenge ($r=0.3759$, $p=0.0931$). This result indicates that anxious individuals had higher levels of High Alpha power, which is in line with literature findings (75).

Whole Alpha Power

MBI Exhaustion correlated with the response of the variability of Whole Alpha power in both hemispheres ($r=0.4017$ to 0.4694 , $p=0.0318$ to 0.0711) (Table 6.25). Higher Exhaustion scores were associated with an increase in the variability of Whole Alpha power in response to the challenge (Figure 6.45 and Figure 6.46).

MBI Professional Efficacy correlated to the response of the variability of Right Whole Alpha power ($r=0.5538$ to 0.5695 , $p=0.007$ to 0.0092) (Table 6.25). Persons with higher Professional efficacy scores correlated with an increase in variability of Right Whole Alpha in response to the challenge (Figure 6.47).

State Anxiety correlated with higher levels of Whole Alpha power in both hemispheres at Recovery ($r=0.4339$ to 0.5096 , $p=0.0183$ to 0.0494). It also correlated to the variability of Whole Alpha power at Baseline 2 and Recovery ($r=0.4476$ to 0.3778 , $p=0.032$ to 0.0913) (Table 6.25).

State Anxiety had a correlation approaching significant to the response of Right Whole Alpha power ($r= -0.4014$ to -0.3982 , $p=0.0713$ to 0.0738) (Table 6.25). This result suggests that anxious individuals responded to the challenge with less Right Whole Alpha power than other subjects.

Trait Anxiety correlated to the response of the variability of Whole Alpha in both hemispheres ($r=0.3828$ to 0.4884 , $p=0.0247$ to 0.0867) (Table 6.25). This means that higher Trait Anxiety scores correlated with greater increases in the variability of Whole Alpha power in response to the challenge (Figure 6.48 and Figure 6.49).

Alpha Amplitude Asymmetry

MBI Cynicism correlated to increased variability of Alpha asymmetry at Baseline 1, Baseline 2, Challenge and Recovery ($r=0.3957$ to 0.4931 , $p=0.0231$ to 0.0758) (Table 6.26).

MBI Professional Efficacy correlated to the response of Alpha asymmetry ($r = -0.5741$, $p = 0.0065$) (Table 6.26). Higher Professional efficacy scores were correlated to a *decreased* (favouring Right Alpha) asymmetry in response to the challenge (Figure 6.50). This was not in line with the literature that led one to associate Alpha asymmetry favouring the right hemisphere with negative cognitive biases (53-55).

Professional efficacy also had a weak correlation to greater increases in the variability of Alpha asymmetry in response to the cognitive stressor ($r = 0.3858$, $p = 0.0842$) (Table 6.26).

State Anxiety correlated to higher Alpha asymmetry during the Challenge ($r = 0.4574$ to 0.4644 , $p = 0.0339$ to 0.0371). It also correlated to the response of the Alpha asymmetry ($r = 0.4891$ to 0.5723 , $p = 0.0067$ to 0.0244) (Table 6.26). These results indicate that anxious individuals had greater (favouring Left) Alpha asymmetry during the challenge than non-anxious subjects, and the magnitude of the increase in Alpha asymmetry was also larger in the anxious subjects. This is not in line with the literature findings that implicate Alpha asymmetry that favours the Right hemisphere in anxiety (27,62). A scatterplot (Figure 6.51) reveals that the correlation might have been influenced by an extreme datapoint.

Trait Anxiety was associated with increased variability of the Alpha asymmetry during the challenge ($r = 0.4376$ to 0.4453 , $p = 0.0431$ to 0.0473). Trait Anxiety also had a weak correlation to a greater increase in the variability of Alpha asymmetry in response to the challenge (Table 6.26).

Alpha Coherence

MBI Exhaustion had a correlation closely approaching significant with decreased Alpha coherence during Recovery ($r = -0.4211$, $p = 0.0573$). Exhaustion also correlated with increased variability of the Alpha coherence during the challenge ($r = 0.4589$, $p = 0.0364$) (Table 6.27). The exact significance of decreased Alpha coherence in exhausted subjects is not known, but others have demonstrated that normal subjects react to a frontal activation task with increased coherence in the Alpha band (77).

Trait Anxiety also had a correlation closely approaching significant with decreased Alpha coherence during the recovery period ($r = -0.4258$, $p = 0.0543$) (Table 6.27), as well as increased variability of Alpha coherence during the challenge.

Although the physiological implications of these findings are not completely understood, it is worth noting that exhaustion and trait anxiety exhibited the same pattern of disturbed Alpha coherence, perhaps supporting the association between chronic anxiety and exhaustion.

Alpha Phase

State Anxiety correlated to Alpha Phase at Baseline 1 ($r = -0.5403$ to -0.4359 , $p = 0.0115$ to 0.0483) (Table 6.28). Lower State Anxiety scores were associated with a positive (Left leading) Alpha Phase, while higher State Anxiety scores were correlated to negative (right leading) Alpha Phase (Figure 6.52).

Trait Anxiety correlated to greater variability of Alpha phase during the challenge ($r = 0.4583$ to 0.5015 , $p = 0.0206$ to 0.0367) (Table 6.28) (Figure 6.53).

Trait Anxiety also correlated to the response of the variability of Alpha phase ($r = 0.4115$ to 0.6172 , $p = 0.0029$ to 0.0638) (Table 6.28). Higher Trait Anxiety scores correlated to greater increases in the variability of Alpha phase in response to the challenge (Figure 6.54).

6.4.8.4 EEG - Sensorimotor Rhythm

The sensorimotor-rhythm is between 12 and 15 Hz, and is sometimes referred to the mu rhythm (52). It is associated with quiet, relaxed wakefulness with eyes open, and since it is abolished by movement or even motor planning or imagery, can be associated with the inhibition of movement. Much focus has been placed on SMR neurofeedback in ameliorating hyperactivity in children suffering from ADHD (63,64).

The challenge in this study was an exercised contingent on increasing SMR power, but how the rise in SMR would be affected by stress was not known.

SMR Power

MBI Exhaustion had a weak correlation to lower variability of Right SMR power at Baseline 1 ($r = -0.3834$, $p = 0.0862$) (Table 6.29 b).

MBI Professional Efficacy correlated to the response of the variability of Right SMR% power ($r = 0.5608$ to 0.5675 , $p = 0.0073$ to $p = 0.0082$) (Table 6.29 b). Higher

Professional efficacy scores were associated with increases in the variability of Right SMR power in response to the challenge (Figure 6.55).

State Anxiety is correlated to higher SMR power in both hemispheres during Baseline 1, Baseline 2, Challenge and Recovery. The correlations ranged from highly significant to weakly significant ($r=0.3774$ to 0.616 , $p=0.0029$ to 0.0917) (Table 6.29 a & b)(Figure 6.56 and Figure 6.57). SMR is associated with relaxed wakefulness and the inhibition of movement (63,64), which appear contrary to this result of higher SMR levels in anxious individuals.

The negative association between State Anxiety and the response of SMR in both hemispheres also ranged from significant to weak ($r= -0.443$ to -0.3765 , $p=0.0443$ to 0.0925) (Table 6.29 a & b), but these results suggested that higher State Anxiety possibly resulted in a reduced ability to increase SMR power in response to the challenge (Figure 6.58 and Figure 6.59).

State Anxiety was correlated strongly to increased variability of SMR power at Baseline 1, Baseline 2 and Recovery in the Left Hemisphere ($r=0.4488$ to 0.6833 , $p=0.0006$ to 0.0413), and at Baseline 1, Baseline 2, Challenge and Recovery in the Right Hemisphere ($r=0.4716$ to 0.6623 , $p=0.0011$ to 0.0309) (Table 6.29 a & b) (Figure 6.60 to Figure 6.62). This result means that the SMR power of anxious individuals fluctuated significantly more than non-anxious subjects.

State Anxiety was also correlated to the response of SMR power variability in both hemispheres ($r= -0.5331$ to -0.4396 , $p=0.0128$ to 0.0461) (Table 6.29 a & b)(Figure 6.63 and Figure 6.64).

SMR neurofeedback has been successfully used to increase SMR power, with a subsequent decrease in hyperactivity in ADHD patients (63,64), and increased seizure thresholds in epileptics (78,79). The literature suggests a correlation between beneficial neuropsychiatric effects and increased SMR, which makes this study's findings of higher SMR levels in anxious patients surprising, since the increased power was present before the feedback task that might have resulted in transiently increased SMR levels. The finding that anxious individuals had greater difficulty increasing their SMR during the challenge is more in line with expectations.

The significance of the variability of SMR is not clear, but the results of this study strongly suggest that increased SMR variability, and lower SMR variability in response to a challenge, could be used to identify anxious individuals.

6.4.8.5 EEG – Beta Rhythm

Beta waves are irregular and low amplitude activity higher than 15 Hz. It increases with cognitive effort, higher frequencies generally indicating progressive intensity (50,52,57). High Beta has been associated with tension and anxiety (27).

Beta 1 Power

MBI Exhaustion correlated with decreased variability of Right Beta 1 power at Baseline 1 ($r = -0.4394$, $p = 0.0463$) (Table 6.30).

MBI Professional efficacy had correlations approaching significant with decreased variability of Right Beta 1 at Baseline 1 and Recovery ($r = -0.4313$ to -0.4004 , $p = 0.0509$ to 0.0721) (Table 6.30).

State Anxiety correlated to increased Beta 1 power, at Baseline 1, Baseline 2, Challenge and Recovery in the Left Hemisphere ($r = 0.4079$ to 0.4969 , $p = 0.0219$ to 0.0664) and at Baseline 2, Challenge and Recovery in the Right Hemisphere ($r = 0.4385$ to 0.4885 , $p = 0.0247$ to 0.0467) (Table 6.30). This is in line with literature that finds increased Beta activity with increased arousal (27,50,52,57).

State Anxiety was correlated to increased variability of Beta 1 power in both hemispheres at Baseline 1, Baseline 2 and Recovery ($r = 0.3884$ to 0.558 , $p = 0.0086$ to 0.0818), and had a correlations between significant and approaching significant with decreased variability of Beta 1 in both hemispheres during the Challenge ($r = -0.4928$ to -0.3775 , $p = 0.0232$ to 0.0916) (Table 6.30). This result implies that anxious subjects had higher baseline Beta1 variability, but lower Beta 1 variability in response to the cognitive stressor.

State Anxiety correlated to the response of the variability of Left Beta 1 ($r = -0.5194$ to -0.5008 , $p = 0.0158$ to 0.0208) and weakly to the response of the variability of Right Beta1 ($r = -0.3837$ to -0.3733 , $p = 0.0864$ to 0.0956) (Table 6.30). In other words, Lower State Anxiety scores were associated with an *increase* in Beta 1 variability, while

higher State Anxiety scores were correlated with a *decrease* in Beta 1 variability in response to the challenge (Figure 6.65).

Beta 2 Power

Beta 2 is slightly higher in frequency than Beta 1, and has been associated with increased mental effort, but also with anxiety (27,50,52,57).

MBI Professional efficacy had a weak correlation with the response of the variability of Right Beta 2 ($r=0.3792$ to 0.3916 , $p=0.0791$ to 0.09) (Table 6.31). This would imply a greater increase in the variability of Right Beta 2 in response to the challenge by individuals with higher feelings of efficacy.

State Anxiety had a weak correlation with increased Right Beta 2 power during the challenge ($r=0.3902$, $p=0.0803$), and with lower variability of Right Beta 2 power during the challenge ($r= -0.4594$ to -0.3703 , $p=0.0362$ to 0.0985) (Table 6.31). These results are not highly significant, but are in line with the literature (27,50,52,57).

High Beta Power

High Beta encompasses all the high frequency activity between 18Hz and 38 Hz. High Beta is associated with increased cognitive effort, but in some individuals it is also a sign of hypervigilance and anxiety (27,50,52,57).

Cynicism had a correlation approaching significant with the power of Right High Beta ($r=0.4055$, $p=0.0682$) (Table 6.32). This is supported by the literature that finds negative moods associated with increased Right prefrontal activation (53-55).

MBI Exhaustion correlated negatively to the response of High Beta % power in both hemispheres ($r= -0.575$ to -0.4146 , $p=0.0063$ to 0.0617) (Table 6.32). Especially in the Right Hemisphere, lower Exhaustion scores were associated with an *increase* in High Beta power, while higher Exhaustion scores were correlated to a *decrease* in High Beta power in response to the Challenge (Figure 6.66 and Figure 6.67). This appears to be in line with the results of other studies that found decreased Beta power in burnout (76).

MBI Professional efficacy had correlations approaching significant with higher variability of High Beta at Baseline 1 ($r=0.3949$ to 0.4289 , $p=0.0524$ to 0.0764), and

with a greater increase in the variability of High Beta in response to the challenge ($r=0.3799$ to 0.4224 , $p=0.0565$ to 0.0894) (Table 6.32).

There was a borderline significant correlation between State Anxiety and lower Right High Beta variability at Recovery ($r= -0.4392$ to -0.4229 , $p=0.0464$ to 0.0562) (Table 6.32).

The High Beta results proved to be somewhat disappointing in terms of anxiety, but diminished increases in Beta in response to the challenge did correlate with exhaustion, a finding supported by the literature.

Beta Amplitude Asymmetry

The variability of Beta asymmetry at Baseline 2 was correlated to increased MBI Cynicism scores ($r=0.4533$, $p=0.0391$) (Table 6.33).

There was a weak correlation between MBI Professional efficacy and the response of Beta asymmetry ($r= -0.3929$, $p=0.078$). The result suggests that persons with high feelings of efficacy responded with an asymmetry that favoured the left hemisphere, a finding that is in accord with the literature that associates left activation with a positive outlook (53-55).

State anxiety correlated weakly to a Beta asymmetry that favoured the left hemisphere during Baseline 1, Baseline 2, Challenge and Recovery ($r=0.3883$ to 0.4131 , $p=0.0627$ to 0.082) (Table 6.33). This appears to be in conflict with the literature.

Beta Coherence

Trait Anxiety correlated to reduced Beta Coherence during the Baseline 2, Challenge and Recovery ($r= -0.3828$ to -0.4831 , $p=0.0265$ to 0.0868), and to higher variability of Beta Coherence during the Challenge ($r=0.4532$ to 0.5117 , $p=0.0177$ to 0.0391) (Table 6.34).

Beta Phase

MBI Cynicism correlated with a higher positive (Left ahead) Beta Phase at Recovery ($r=0.4716$, $p=0.0309$) (Table 6.35), but a scatterplot reveals that the apparent correlation could be due to an extreme datapoint (Figure 6.68). There is also a weak

correlation with a greater increase (Left ahead) in Beta phase in response to the challenge ($r=0.4016$, $p=0.0712$).

MBI Exhaustion was correlated to a higher positive (Left ahead) Beta Phase at Baseline 1 ($r=0.4863$, $p=0.0254$) and weakly at Recovery ($r=0.3755$, $p=0.0935$) (Table 6.35) (Figure 6.69).

Subjects with a high State Anxiety score were more likely to have a negative (Right ahead) Beta Phase at Baseline 1 ($r= -0.5266$ to 0.4222 , $p=0.0142$ to 0.0566) (Table 6.35) (Figure 6.70), but state anxiety also correlated with a more positive (Left ahead) response in Beta phase ($r=0.3982$ to 0.4294 , $p=0.0521$ to 0.0738).

6.4.8.6 EEG – Gamma Rhythm

The Gamma rhythm is found at the upper part of the EEG spectrum, and is generally centred at about 40Hz (52). It is speculated to be produced by integrative cortical processing activities like visual binding (50). A study ($N=15$) using a set of images from the International Affective Picture system found reduced Gamma power in negative emotional states, as compared to calm, neutral states (67).

Gamma Power

MBI Cynicism score was associated with reduced variability of Gamma % power in both hemispheres at Baseline 1 and Baseline 2 ($r= -0.5015$ to -0.3702 , $p=0.0206$ to 0.0986) (Table 6.36).

MBI Cynicism correlated weakly to the response of the variability of Left Gamma power ($r=0.3811$ to 0.3837 , $p=0.0859$ to 0.0883) (Table 6.36).

MBI Exhaustion correlated to the response of Gamma power in both hemispheres (Left $r= -0.5145$ to -0.5098 , $p=0.0169$ to 0.0182 ; Right $r= -0.5319$ to -0.5111 , $p=0.0131$ to 0.0179) (Table 6.36). Lower Exhaustion scores correlated to an *increase* in Gamma power in both hemispheres, while higher Exhaustion scores were associated with a *decrease* in Gamma power in response to the challenge (Figure 6.71 and Figure 6.72).

6.4.8.7 EEG – Peak Frequency

Peak frequency indicates the frequency with the most power in the overall spectrum of the EEG. Changes in peak frequency reflect the shift to faster or slower cortical activity.

MBI Cynicism correlated to higher variability of Right Peak Frequency at Baseline 2 and Challenge ($r=0.04449$ to 0.04481 , $p=0.0417$ to 0.0433)(Table 6.37).

MBI Exhaustion was correlated to the response of the Peak frequency in both hemispheres ($r= -0.5593$ to -0.4003 , $p=0.0084$ to 0.0722) (Table 6.37). Lower Exhaustion scores were associated with an *increase* in peak frequency in response to the challenge, while higher Exhaustion scores were correlated to *decreases* in peak frequency in response to the challenge (Figure 6.73).

MBI Exhaustion also correlated with the response of the variability of Right peak frequency, but the correlation only approached significant when the relative response was used ($r= -0.3807$ to -0.4785 , $p=0.0282$ to 0.0886) (Table 6.37). Lower Exhaustion scores correlated to an *increase* in the variability of Right peak frequency, while higher Exhaustion scores were associated with a *decrease* in the variability of Right peak frequency (Figure 6.74).

In opposition to the Exhaustion scores, State Anxiety correlated positively to the response of the variability of peak frequency in the left hemisphere ($r=0.5351$ to 0.5898 , $p=0.0049$ to 0.0124) and less strongly in the right hemisphere ($r=0.37$ to 0.5067 , $p=0.0191$ to 0.0988) (Table 6.37). Lower State Anxiety scores were associated with *decreases* in the variability of peak frequency, while higher State Anxiety scores correlated to *increases* in the variability of peak frequency in response to the challenge (Figure 6.75 and Figure 6.76).

6.4.8.8 EEG – Alpha Peak Frequency

Similar to EEG peak frequency, Alpha peak frequency identifies the frequency in the alpha band with the most power. Changes indicate shifts to faster or slower alpha activity.

MBI Cynicism was correlated to a higher Alpha peak frequency in both hemispheres for Baseline 1, Baseline 2, Challenge and Recovery ($r=0.3755$ to 0.5082 , $p=0.0187$ to 0.0934) (Table 6.38).

State Anxiety correlated with increased variability of Left Alpha peak frequency at Baseline 1 ($r=0.4858$ to 0.3815 , $p=0.0256$ to 0.0879) (Table 6.38).

6.4.8.9 EEG – Ratios

Calculating the ratio between two rhythms illustrates the behaviour of those relative to each other. When a certain frequency band increases in power, the adjacent bands would often decrease in power, or vice versa (68).

Alpha/Theta Ratio

MBI Cynicism correlated to the response of the variability of the Right Alpha/Theta ratio ($r= -0.5160$ to -0.4812 , $p=0.0166$ to 0.0272) (Table 6.39). Lower Cynicism scores correlated to *increases* in the variability of Right Alpha/Theta, whereas higher Cynicism scores correlated with *decreases* in the variability of Right Alpha/Theta in response to the challenge (Figure 6.77).

State Anxiety correlated to a higher Alpha/Theta ratio in both hemispheres at Baseline 1, Baseline 2, Challenge and Recovery ($r=0.3704$ to 0.4995 , $p=0.0211$ to 0.0984) (Table 6.39). The relatively less slow wave activity is in line with literature that associate Theta with relaxed states (50,52).

Theta/Beta1 Ratio

MBI Exhaustion correlated with a higher Left Theta/Beta1 ratio during the challenge ($r=0.4355$, $p=0.0485$) (Table 6.39).

MBI Exhaustion also correlated with the response of the Right Theta/Beta1 ratio ($r=0.4772$ to 0.4850 , $p=0.0258$ to 0.0287) (Table 6.39). Lower Exhaustion scores were associated with a *decrease* in Right Theta/Beta1 ratio (Theta has decreased and/or Beta1 has increased), while higher Exhaustion scores correlated to an *increase* in Right Theta/Beta1 ratio (Theta has increased and/or Beta1 has decreased) in response to the challenge (Figure 6.78). If the decline in the ratio is as a result of decreased Beta, then the result is in line with the study that found decreased Beta power in burnt-out individuals (76).

There was a weak correlation between State Anxiety and a decreased Left Theta/Beta1 ratio at Baseline 2 ($r= -0.3889$ to -0.378 , $p=0.0814$ to 0.0911), and with decreased Right Theta/Beta1 in during the Challenge ($r= -0.3923$ to -0.3791 ,

$p=0.0786$ to 0.0901) (Table 6.39). Relatively more fast Beta activity in comparison to slow Theta activity is in agreement with the literature that associate anxiety with greater levels of Beta power (27,50,52,57).

In summary, many correlations were found. However, the significance of the majority of the correlations is not clear and is not described in the literature. The latter may be partially due to the fact that QEEG are, large due to financial implications, not generally used in stress research. However, a small number of laboratories are now involved in trying to find associations between QEEG patterns and levels of stress.

The validity of the biofeedback QEEG measurements as stress indicators could be compared to the literature for a few of the correlations:

- Exhaustion and an increase in Delta power in response to the challenge. The literature on sleep disturbances and fibromyalgia report abnormal Delta activity (72,73)
- Exhaustion and increased Theta power in response to the challenge. Others have found more slow cortical activity in burnt out individuals (74)
- State anxiety and increased high Alpha power (75)
- Exhaustion with decreased alpha coherence in response to the challenge. Normal individuals respond to a stimulating task with increased Alpha coherence (77)
- Anxious subjects had less increase in SMR in response to the challenge
- State anxiety and increased Beta 1 power (27,50,52,57).
- Cynicism and increased Right hemisphere high Beta power (53-55)
- Exhaustion and a diminished increase in high beta power in response to the challenge (76)
- Exhaustion and reduced Gamma power in response to the challenge. Others have found decreased Gamma in negative emotional states (67), and a general tendency toward more power in the slower rhythms in burnout (74), which would correspond to less power in the high frequency bands
- A higher Alpha/Theta ratio with increased anxiety. Less slow wave activity with increase anxious arousal (50,52).
- Exhaustion and a higher right Theta/Beta 1 ratio in response to the challenge. Relatively more slow wave activity with more vital exhaustion (76).

6.5 Conclusions

The aim of the study was to determine if the Biograph Infinity biofeedback device could be used to accurately identify and measure biometric variables that are disturbed in stressed individuals. Not all the indicators tested had acceptable correlations with the psychometric items, and the significance of some of the other correlations is not yet known, but many of the measurements had good correlations to the psychometric stress indicators. Skin conductivity stood out as an effective modality to detect the levels of stress.

It is worth noting that while professional efficacy is usually thought of as a resilience factor, a correlation that approached significance was found with trait anxiety in Chapter 5, which could have played a role in the conflicting results between the biometric indicators and the MBI Professional efficacy scores.

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