On Correlation Between Single-Trial ERP and GSR Responses: a Principal Component Regression Approach

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Motivation

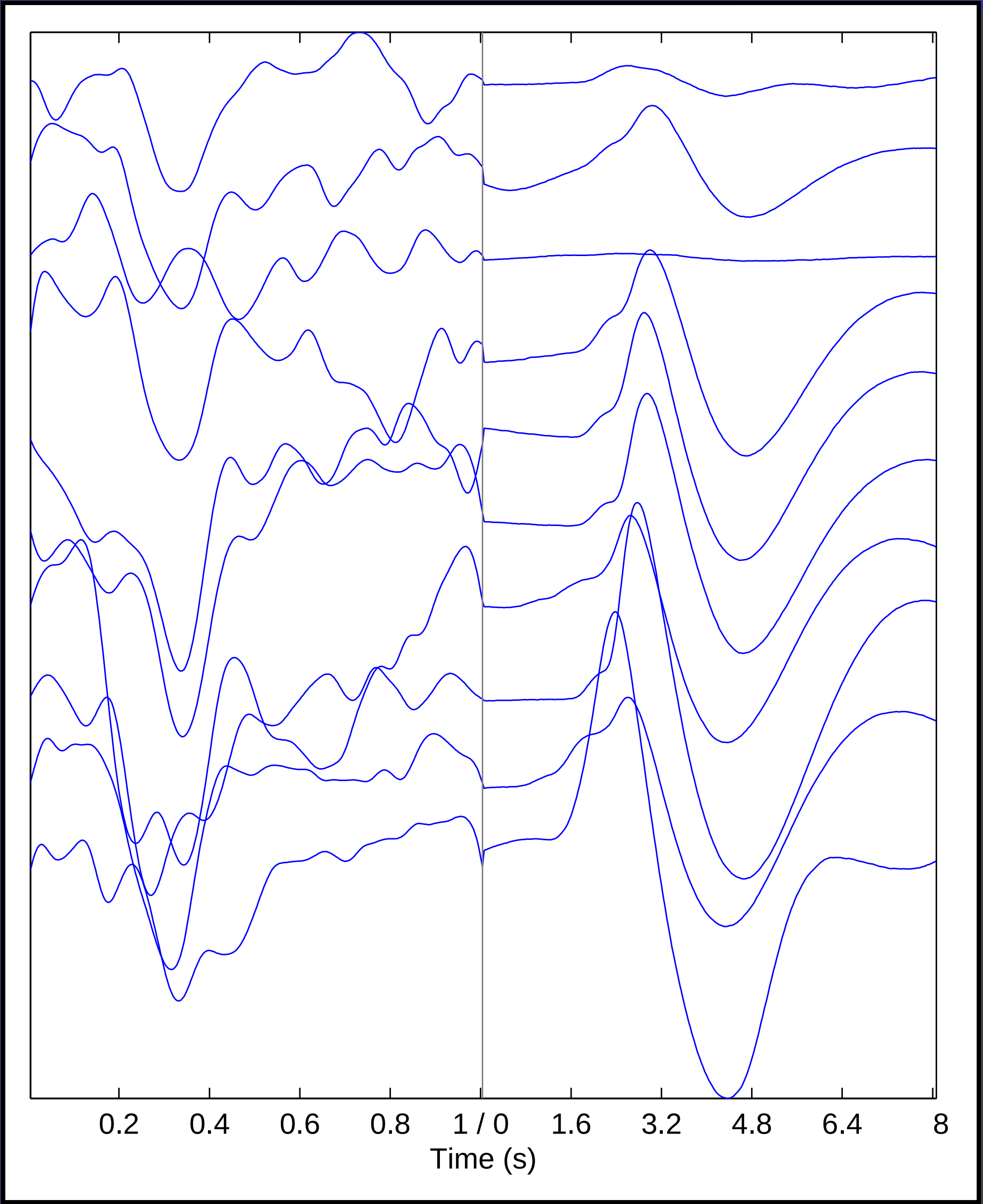
- Investigation of the dynamic features of the event-related potentials requires an estimation of single potentials.
- We have proposed subspace regularization based approach for estimation of single-trial ERP responses [**?**, **?**].
- The proposed methods take advantage of the second order statistics of the measured data.
- In some cases this can be problematic, for example when studying strong habituation like the orienting response.
- However, often some other signals such as galvanic skin response (GSR), also known as skin conductance response (SCR), are measured simultaneously with ERP measurements.
- Could these be used in the ERP estimation?

Galvanic Skin Response (GSR)

- The galvanic skin response is a simple, useful and reproducible method of capturing the autonomic nerve response as a parameter of the sweat gland function [**?**].
- Previous studies have shown that the amplitude of the late positive components of ERP and GSR measurements correlate.
- In studies investigating the quality of the ERP showing habituation of the orieting response, like [**?**, **?**, **?**], it has been shown that the amplitude of the both signals decrease when GSR habituates.
- In this study we investigate the correlation between the single-trial responses using principal component regression (PCR) based approach.

Measurements

- The galvanic skin responses were recorded from palm.
- For the analysis EEG signals were resampled to 250 Hz and GSR signals to 31 Hz.
- The auditory oddball paradigm was used for stimuli. It consisted of standard, deviant and 10 unique novel tones.
- After novel stimulus epochs of 8 second GSR response and 1 second ERP (channel Cz) were extracted for the analysis.
- The GSR resposes were rescaled to have equal maximum amplitude with the ERP responses.



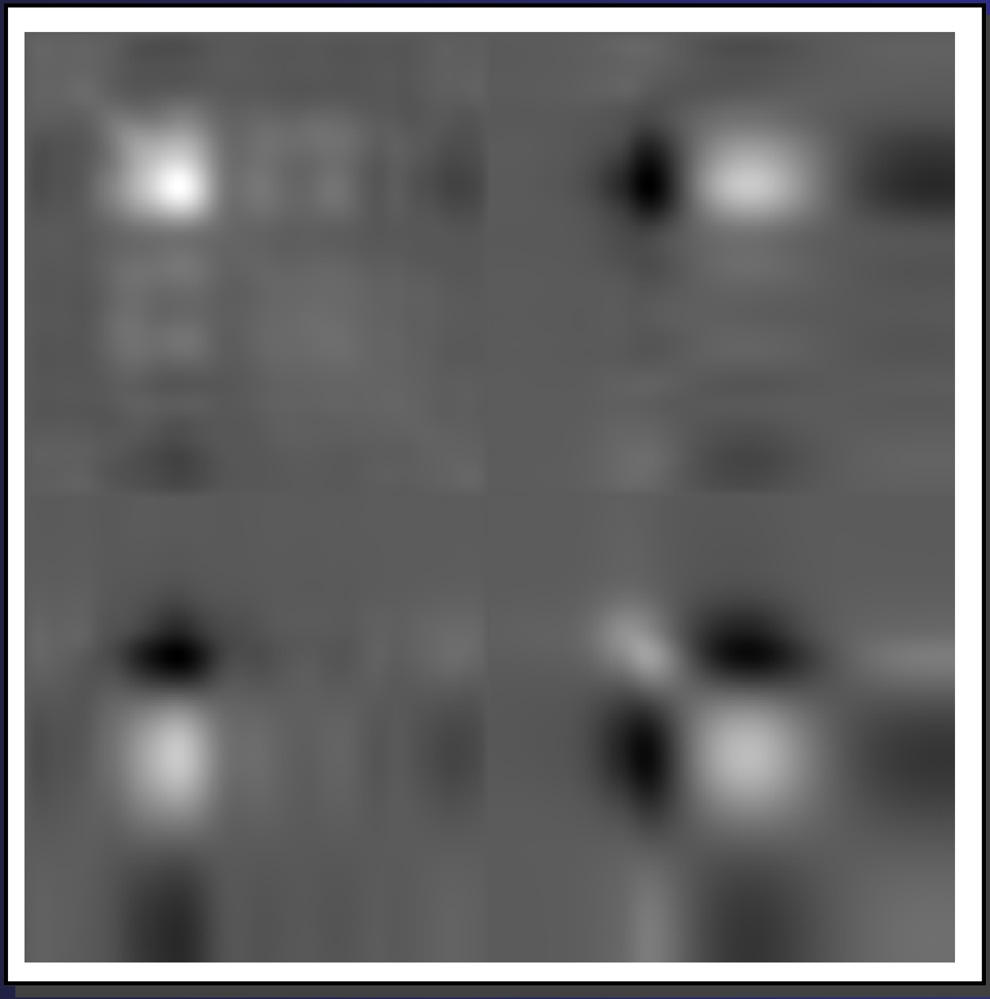
Analysis

- For the analysis the ERP and GSR responses were stacked together to form the data matrix.

$$z^{(j)} = \begin{pmatrix} z^{(j)}_{ERP}(1) \\ \vdots \\ z^{(j)}_{ERP}(T) \\ z^{(j)}_{GSR}(1) \\ \vdots \\ z^{(j)}_{GSR}(T) \end{pmatrix}. \quad (1)$$

- The top part of augmented Z, containing only the data of ERP channel, is denoted with Z_{ERP} and the bottom part containing the GSR responses is denoted with Z_{GSR}.

Correlation matrix



Principal component regression

- Let $H_{\mathcal{S}}$ be matrix $(2T \times K)$ containing K eigenvectors of the data correlation matrix $R_Z = \frac{1}{2*T} ZZ^T$.

$$H_{\mathcal{S}} = (\psi_1, \ldots, \psi_K) = \begin{pmatrix} H_{\mathcal{S}(ERP)} \\ H_{\mathcal{S}(GSR)} \end{pmatrix}.$$

- LS-solution for additive noise model

$$\begin{aligned} z^{(j)} &= s^{(j)} + v^{(j)} \\ Z &= H\theta + v \end{aligned}$$

is then

$$\begin{aligned} \hat{\theta}_{\mathrm{LS}} &= (H^T H)^{-1} H^T Z \\ \hat{\theta}_{\mathcal{S}_{\mathrm{LS}}} &= H_{\mathcal{S}}^T Z \quad \text{since} \quad H_{\mathcal{S}}^T H_{\mathcal{S}} = I \end{aligned}$$

and the estimates for observations can be calculated with

$$\hat{Z}_{\mathrm{LS}} = H\hat{\theta}_{\mathrm{LS}} = HH^T Z$$

Qualitative measure for correlation

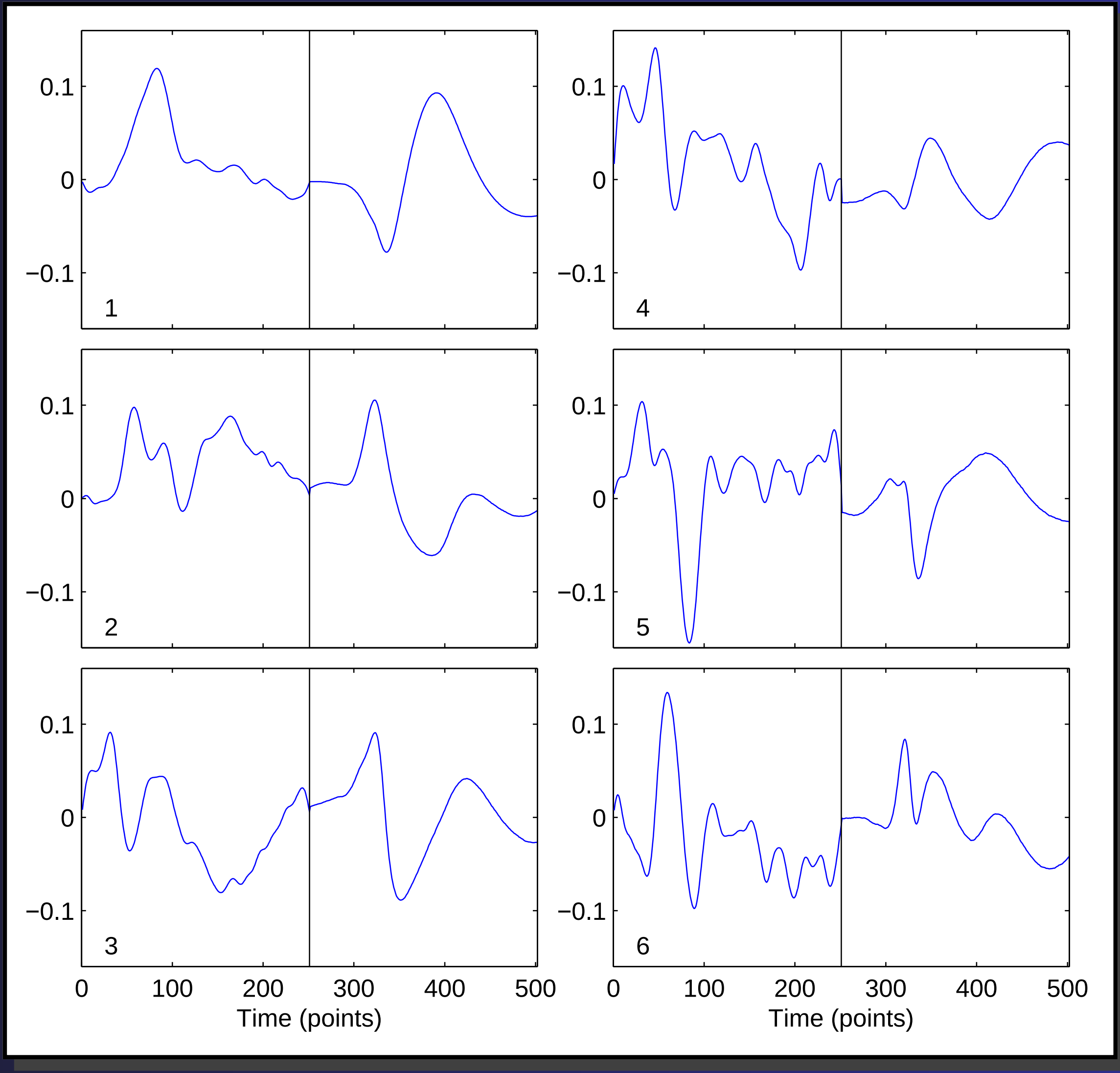
- The LS coefficients describing GSR responses can be solved from

$$\hat{\theta}_{GSR} = \left(H^T_{\mathcal{S}(GSR)} H_{\mathcal{S}(GSR)} \right)^{-1} H^T_{\mathcal{S}(GSR)} Z_{GSR}.$$

- Although $H_{\mathcal{S}}$ is orthonormal and thus $H^T_{\mathcal{S}} H_{\mathcal{S}} = I$, the $H_{\mathcal{S}(GSR)}$ is not necessarry orthonormal and the inverse of $H^T_{\mathcal{S}(GSR)} H_{\mathcal{S}(GSR)}$ has to be calculated.
- If signals correlate, ERP responses can now be estimated according by using parameters estimated from GSR measurements

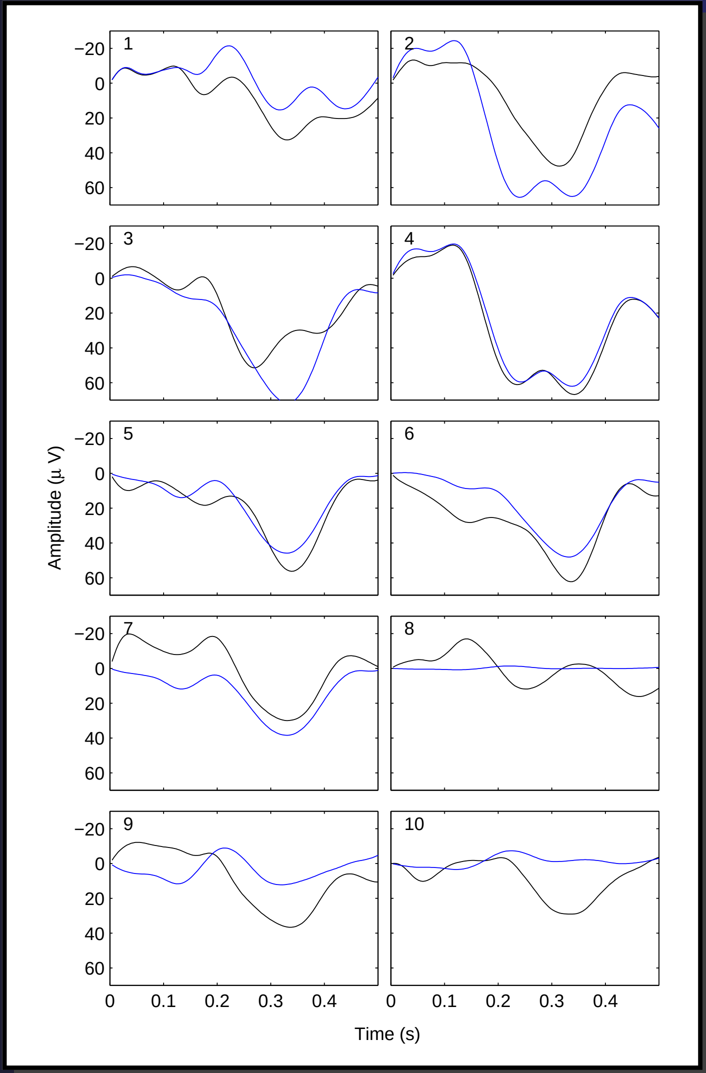
$$\hat{Z}_{ERP} = H_{\mathcal{S}(ERP)} \hat{\theta}_{GSR}.$$

Eigenvectors

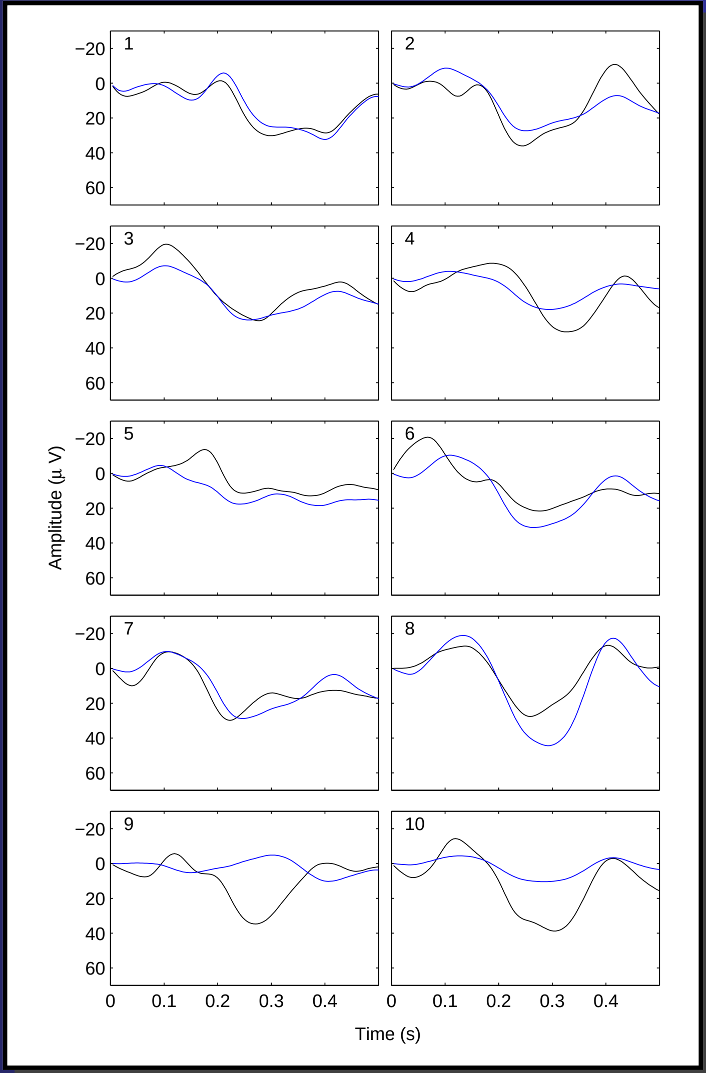


Estimates – GSR → ERP

Calculated using 3 eigenvectors.



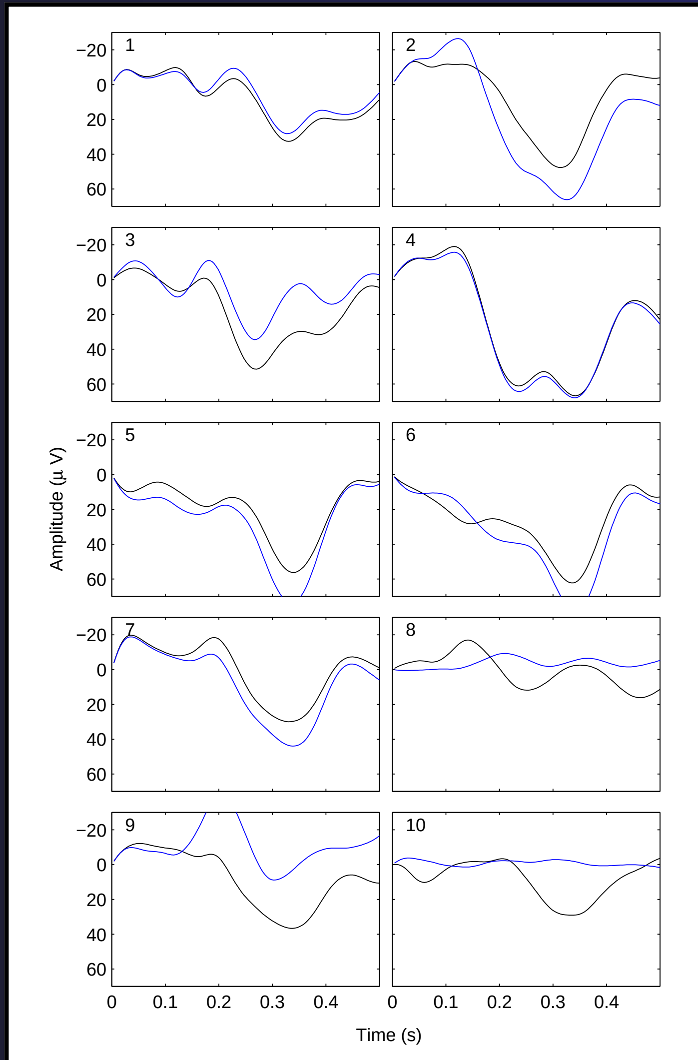
Test Person A



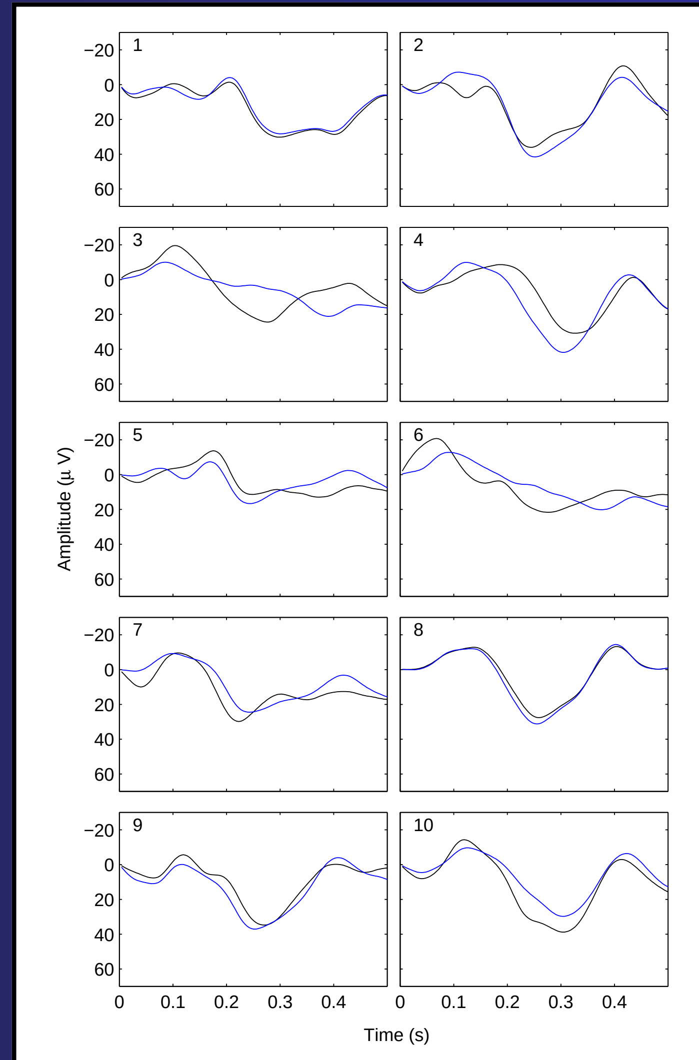
Test Person B

Estimates – GSR $\longrightarrow$ ERP

Calculated using 6 eigenvectors.



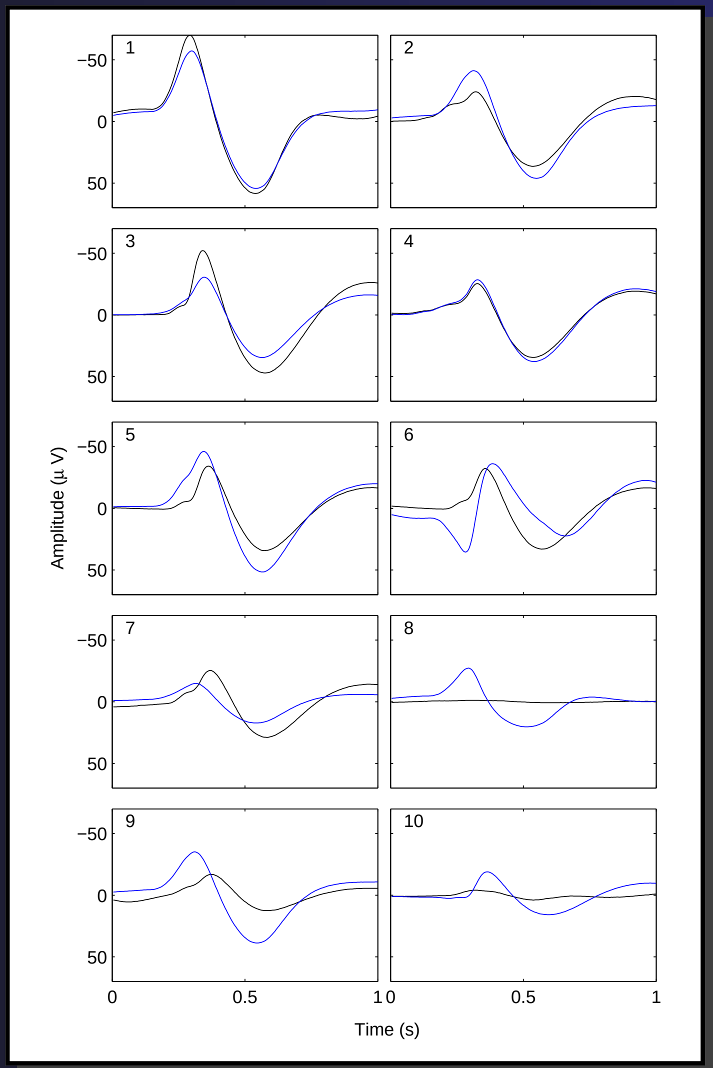
Test Person A



Test Person B

Estimates – ERP $\longrightarrow$ GSR

Calculated using 3 eigenvectors.



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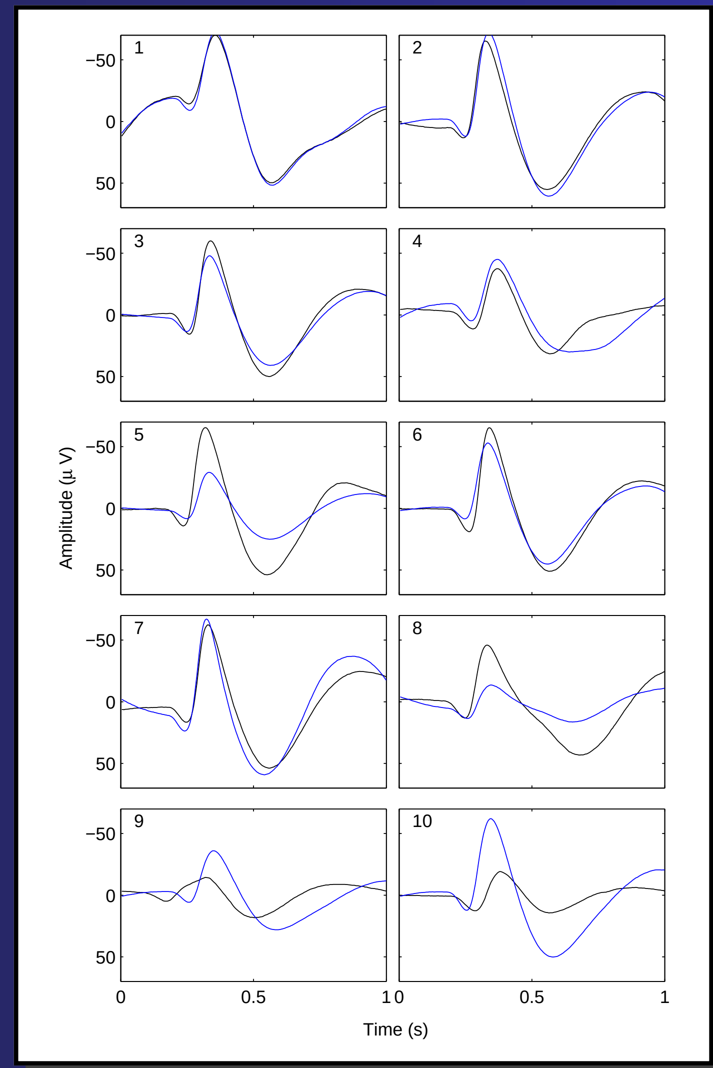
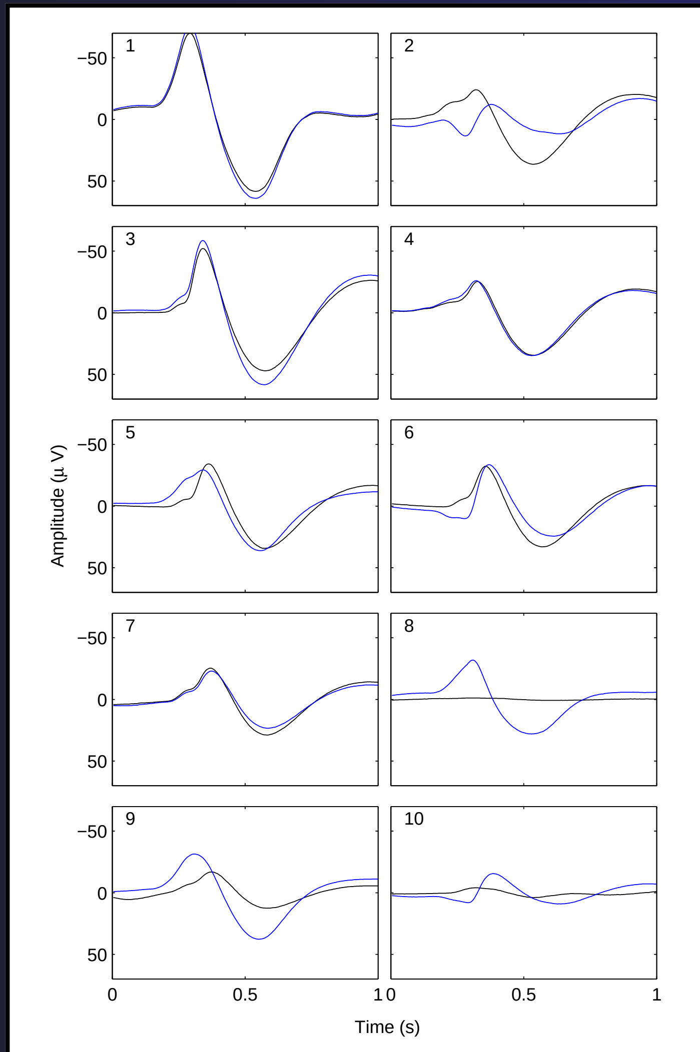


Test Person B

Estimates – ERP → GSR

Calculated using 6 eigenvectors.



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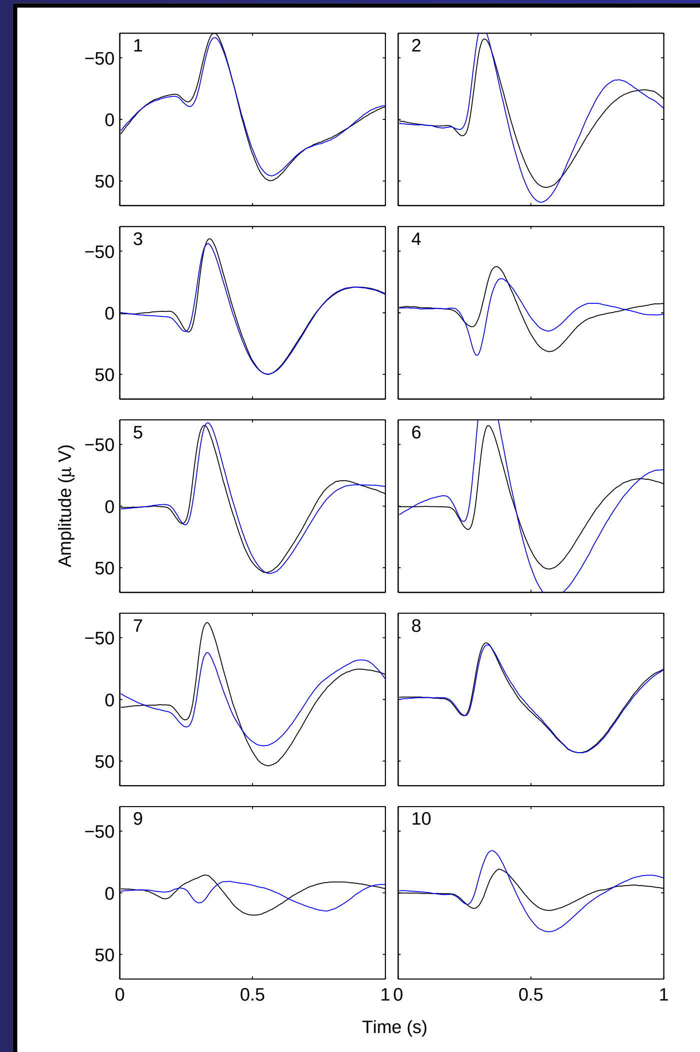

Test Person B

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Conclusions

- In this study we investigated the correlation between evoked brain response and GSR.
- Our findings are in line with the previous works and we were able to estimate the P3 response reasonably well from GSR measurements.
- Since the ERP and GSR responses seem to be correlated it should be investigated how the GSR responses can be utilized as a prior information in the single-trial estimation of ERP responses.

Qualitative measure for correlation

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