EOG Artifact Propagation Estimation

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Load and normalize some eye-blinks

load ASCII-files into matrices

$B_1 := \mathrm{READPRN}(bl1) \quad B_2 := \mathrm{READPRN}(bl2) \quad B_3 := \mathrm{READPRN}(bl3)$

$B_4 := \mathrm{READPRN}(bl4) \quad B_5 := \mathrm{READPRN}(bl5)$

define channel labels

$P3 := 0 \quad P4 := 1 \quad F7 := 2 \quad F8 := 3 \quad EOGV := 4 \quad EOGH := 5$

remove DC-offsets channel- and epochwise

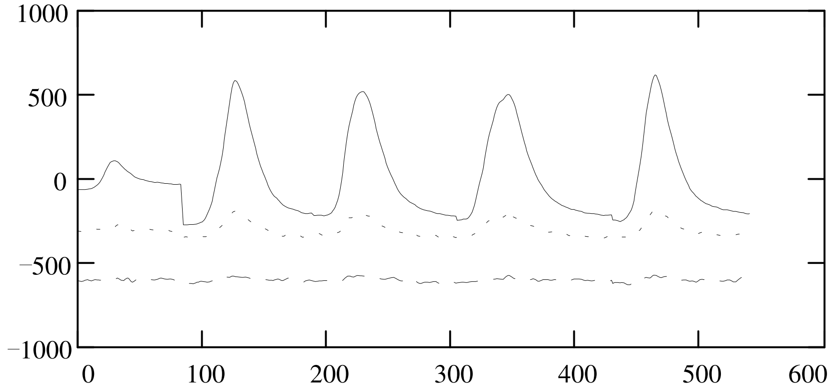
$c := 0 .. \mathrm{cols}(B_1) - 1$

$B_1^{\langle c \rangle} := B_1^{\langle c \rangle} - \mathrm{mean}\left(B_1^{\langle c \rangle}\right) \qquad B_2^{\langle c \rangle} := B_2^{\langle c \rangle} - \mathrm{mean}\left(B_2^{\langle c \rangle}\right)$

$B_3^{\langle c \rangle} := B_3^{\langle c \rangle} - \mathrm{mean}\left(B_3^{\langle c \rangle}\right) \qquad B_4^{\langle c \rangle} := B_4^{\langle c \rangle} - \mathrm{mean}\left(B_4^{\langle c \rangle}\right)$

$B_5^{\langle c \rangle} := B_5^{\langle c \rangle} - \mathrm{mean}\left(B_5^{\langle c \rangle}\right)$

$EEG := \mathrm{stack}\left(\mathrm{stack}\left(\mathrm{stack}\left(\mathrm{stack}\left(B_1, B_2\right), B_3\right), B_4\right), B_5\right) \quad i := 0 .. \mathrm{rows}(EEG) - 1$



We choose #2 and #4 as the blink prototypes used for factor estimation

$P := \mathrm{stack}\left(B_2, B_4\right) \quad i := 0 .. \mathrm{rows}(P) - 1$

Find two independent EOG components in EOGV and EOGH

perform a PCA - the matrix of eigenvectors of the covariance matrix rotates the original data vectors into linear independent components

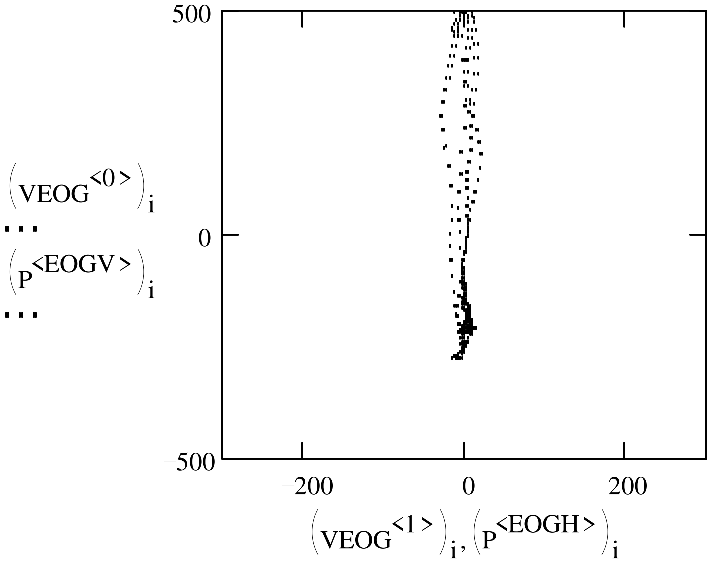
$$C := \begin{pmatrix} \mathrm{cvar}\left(P^{\langle EOGV\rangle}, P^{\langle EOGV\rangle}\right) & \mathrm{cvar}\left(P^{\langle EOGH\rangle}, P^{\langle EOGV\rangle}\right) \\ \mathrm{cvar}\left(P^{\langle EOGV\rangle}, P^{\langle EOGH\rangle}\right) & \mathrm{cvar}\left(P^{\langle EOGH\rangle}, P^{\langle EOGH\rangle}\right) \end{pmatrix}$$

$$R := \mathrm{eigenvecs}(C) \qquad R = \begin{pmatrix} 0.999922 & 0.012477 \\ -0.012477 & 0.999922 \end{pmatrix}$$

$$VEOG := \mathrm{augment}\left(P^{\langle EOGV\rangle}, P^{\langle EOGH\rangle}\right)\cdot R$$

check the EOG intercorrelation before/after

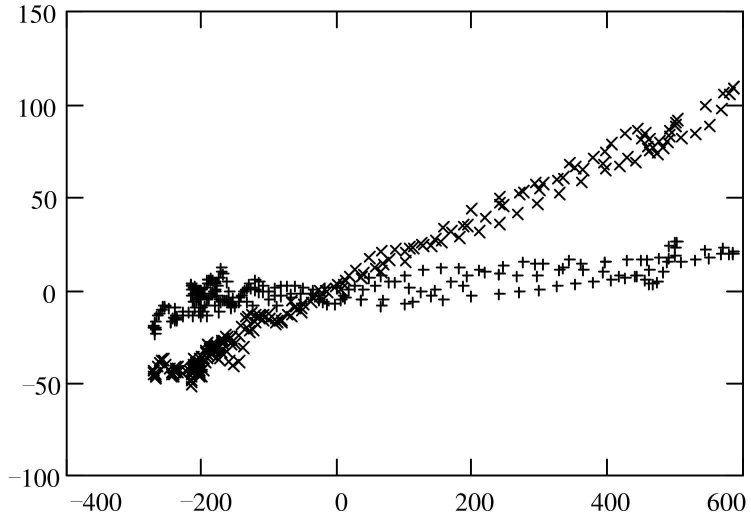
$$\mathrm{corr}\left(P^{\langle EOGV\rangle}, P^{\langle EOGH\rangle}\right) = -0.345 \qquad \mathrm{corr}\left(VEOG^{\langle 0\rangle}, VEOG^{\langle 1\rangle}\right) = 0$$



(in this case, the EOG electrodes are applicated nearly orthogonal and exactly in the blink direction - so there is nothing to rotate)

Calculate propagation factors

The propagation factor is defined to be the slope of the regression line between a EOG component and a EEG signal.



$eog := 0..1$

$F_{c,eog} := \text{slope}\left(VEOG^{\langle eog \rangle}, P^{\langle c \rangle}\right)$

$$F = \begin{bmatrix} 0.030685 & 0.429457 \\ 0.028385 & 0.461172 \\ 0.177540 & -0.181990 \\ 0.185897 & 0.454233 \\ 0.999922 & 0.012477 \\ -0.012477 & 0.999922 \end{bmatrix}$$

Some of the factors in detail:

$F_{EOGV,0} = 0.999922$ EOGV is nearly the main EOG component - propagation near 1

$F_{F7,0} = 0.178$

$F_{P3,0} = 0.031$

The propagation naturally decreases with the distance to the eyes.

$F_{F7,1} = -0.182$

$F_{P3,1} = 0.429$

A second EOG component is not present - the factors are nonsense but doesn't harm anything since they are applied to a nearly zero signal only.

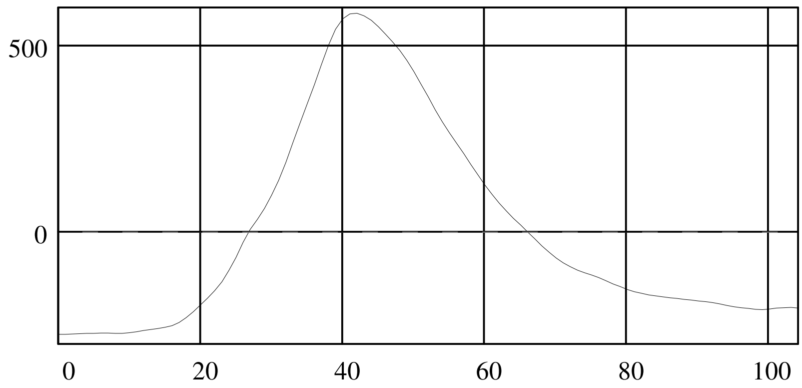
Apply the factors to the blink data

a prototypic one

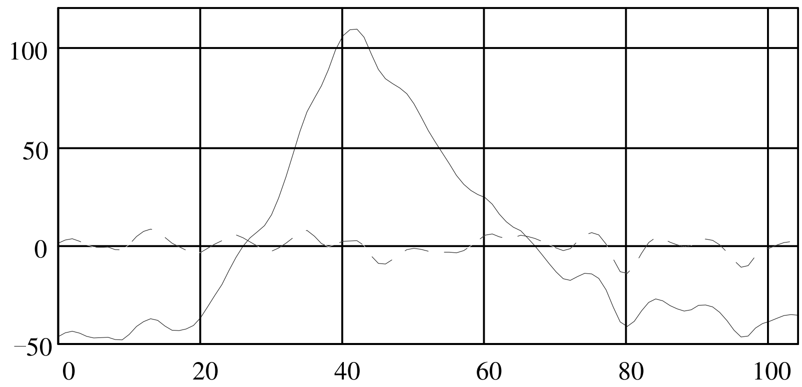
$M := B_2 \qquad VEOG := \mathrm{augment}\left(M^{\langle EOGV \rangle}, M^{\langle EOGH \rangle}\right) \cdot R$

$MC^{\langle c \rangle} := M^{\langle c \rangle} - VEOG^{\langle 0 \rangle} \cdot F_{c,0} - VEOG^{\langle 1 \rangle} \cdot F_{c,1} \qquad i := 0 .. \mathrm{rows}(M) - 1$

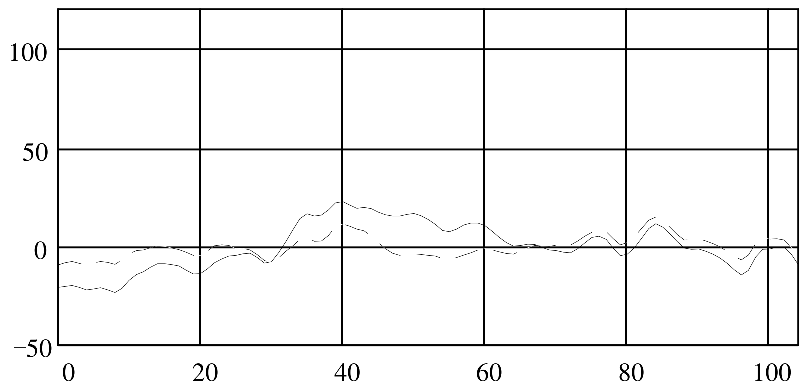
chan := EOGV



chan := F7



chan := P3

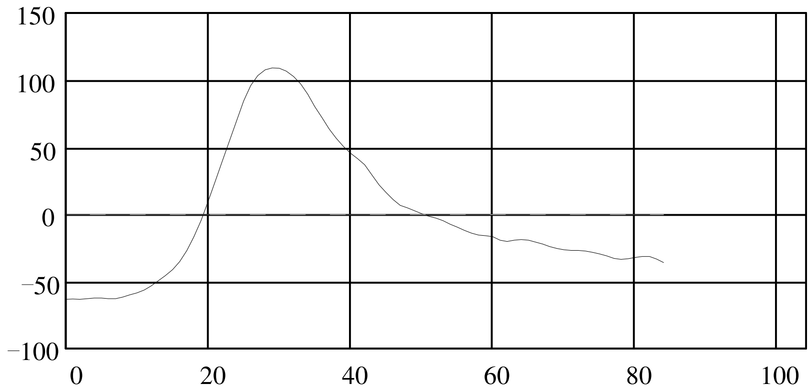


a non-prototype blink (less amplitude)

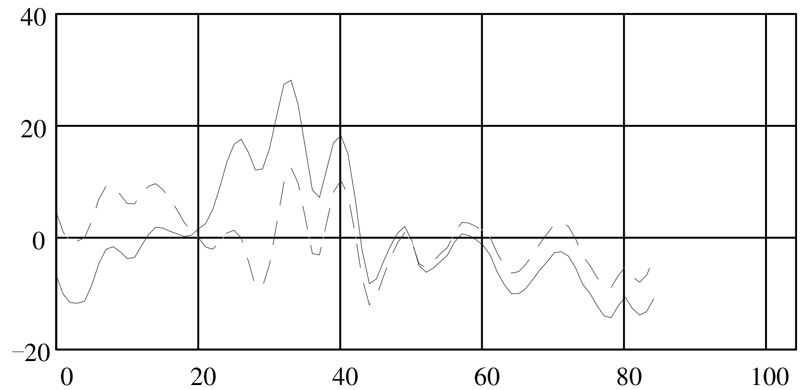
$M := B_1 \quad VEOG := \text{augment}\left(M^{\langle EOGV \rangle}, M^{\langle EOGH \rangle}\right) \cdot R \quad i := 0 .. \text{rows}(M) - 1$

$MC^{\langle c \rangle} := M^{\langle c \rangle} - VEOG^{\langle 0 \rangle} \cdot F_{c,0} - VEOG^{\langle 1 \rangle} \cdot F_{c,1}$

$chan := EOGV$



$chan := F7$



$chan := P3$