Description of the Fokker-Planck algorithm (FPE) WT, 15.4.2020

FPE computes the attractors of one-dimensional time series x(t) by the potential function V(x). V(x) is assessed by the mean slopes at all realizations of x. Additionally, the entropy is assessed by the standard errors (or standard deviation) of the slopes at all realizations of x. In a .txt-file to be uploaded, the time series are in columns, the single measurements are lines. Variable names can be in the header line. It is assumed that the processes are sampled at high frequency, 1 Hz (1/s) or higher, as common in physiology ratings or motion capture. If you use other sampling rates (e.g. measures per minute), simply read the units 'seconds' of the input page as 'minutes'.

(1) **Causation**: The deterministic component of the time series is derived from the average change at each $x(t)$, assessed by linear regression slopes with <window size> in seconds (or 'minutes', respectively). Beginning with the smallest value, the local slopes of the temporal evolution are computed in all realizations of x throughout the time series. The 'slope function' $K(x)$ exactly describes the deterministic part of the Fokker-Planck equation (Tschacher & Haken, 2019).

(2) The empirically estimated slope function $K(x)$ can be transformed into the potential function $V(x)$ of a system by incremental summing up the (negative) slope values. The plot of the potential function provides an illustration of the attractor of the system. $V(x)$ is the free energy of the system.

(3) **Chance**: The standard errors of the slopes, again for all values of x, yield the function $Q(x)$. $Q(x)$ informs on the local amounts of entropy/stochasticity (output: standard error and standard deviation) at any position of the potential landscape. $Q(x)$ shows where sources of entropy are located in state space.

Pre-processing: The input page demands a parameter <Bucketsize>: how many values of $x(t)$ are to be compressed in one bucket (bin). Insert 1 if no bucketizing is necessary. If there are outlyers in the time series and thus gaps in the bucketized time series, step (1) will not work. Try to deal with outliers. <window size> is an integer of the sampling rate. Sometimes it is advisable to pre-process the data by multiplication with an appropriate 'blow-up factor' to better adjust the bucket size.

Note for **two-dimensional systems**: FPE computes the attractors of one-dimensional time series, thus 2D-systems may be reduced to 1D by computing their cross-correlation function (see SUSY).

Data requirements: the number of time-points measured (the length of the time series) must be considerably larger than the number of different x, or buckets, of the time series.

The FPE algorithm was coded using Python 3.6 by Nikolai Philipp Tschacher instructed by Wolfgang Tschacher and Hermann Haken.

If you use FPE, please cite: **Tschacher W & Haken H (2019). The Process of Psychotherapy – Causation and Chance. Cham: Springer Nature.**

a recent application: Tschacher W & Haken H (online 2019). Causation and chance: Detection of deterministic and stochastic ingredients in psychotherapy processes. *Psychotherapy Research*. doi.org/10.1080/10503307.2019.1685139