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A Reply to Krauth's Comments* on Möller et al. "Single-case Evaluation of Sleep Deprivation Effects by Means of Time-series Analysis According to the HTAKA Model"**, ***

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In several papers Krauth (1980, 1986) has strongly critized the application of all types of time-series analyses in psychology. In particular, this holds true for our use (Möller et al. 1989) of the HTAKA procedures proposed by Kleiter (1986). Krauth bases his critique on the violation of three major assumptions: (a) biased parameter estimation due to the restricted length of the time series obtainable in psychology; (b) serial correlation or non-stationarity of residuals (after whitening of the stochastic process); (c) lack of time continuity and equidistance of the time scale in classical time-series analyses.

With respect to these problems Krauth expressed specific objections to the HTAKA model. These are dealt with shortly briefly as follows.

Objection 1

(a) Cluster analyses will always provide a partition of a time series, even in a stationary process.

(b) These segmentations will consequently lead to significant level differences between segments.

Response

(a) This critique holds true for any type of cluster analysis but cannot be maintained for the HTAKA procedures in a global fashion. Only for a naive application of the cluster analysis procedure without using a segmentation improvement criterion is a formation of clusters enforced.

As numerous simulation studies have shown, the clustering procedure only generates a segmentation under white noise conditions if no segmentation improvement criterion has been used at all or if it has been set to zero. In the HTAKA procedures the clustering criterion takes into account the consecutive nature of time points. That is to say no arbitrary sets of elements from a time series will be clustered but only those continuous in time. This restriction can have important consequences such that the optimization criterion SAQ (within) (sums of squares within) will be reduced substantially if there are deviant values (outliers). The inadequate element would be sorted out with unrestricted clustering and attached to another cluster. With time clustering the odd element must remain within some potential time segment. In combination with a segmentation improvement criterion this leads to an efficient rejection of clusterings. Thus, it is not true, as Krauth maintains, that even stationary processes will lead to a segmentation of the time series. Problems, however, arise with the arbitrary choice of the segmentation improvement criterion and the possibility of higher-order trends leading to an (artificial) clustering.

(b) The fact that with segmentations via clustering ABC phases are obtained a posteriori and not a priori in an experimental fashion and that significance tests are not strictly valid is a problem for all types of cluster analyses and also for other divisive time-series analyses (Schmitz 1987):

Objection 2

Only linear trends are modeled, not those of higher order (quadratic, cubic, ...).

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*** Some arguments provided in this paper are to a large extent based on an unpublished manuscript of Kleiter (1989)

Response

This property is definitely an advantage of the HTAKA procedure considering simplicity of modelling and parsimony in parametrization for the representation of a time series. The systemic part of the time series is represented only by means of a dummy variable coding the time segments and by means of linear trend parameters within these segments. Higher-order trends are taken care of by the segmentation. In addition, empirical time series containing quadratic or other higher-order trends are very rare, especially if cumulative processes are concerned. This objection is not a principle one anyway. There is no difficulty in including trends of higher order within the segments. According to Kleiter (personal communication) up to quadratic trends were included in a preliminary version of the HTAKA program. But these higher than linear trends were removed from the model because they did not prove useful at all in any of the test applications of the HTAKA model.

Objection 3

a) The time series studied – in particular the time segments – are too short for proper parameter estimation.

(b), (c) Consequently, the introduction of pseudo-scores and the use of significance tests are not justified.

Reponse

(a) Simulation studies for the HTAKA procedures have shown that it is not generally true that these time series are too short. Time series of about NT = 30 points could be considered sufficiently adequate with respect to tests of stationarity, error percentage and assumed length of the time segments. Additionally, adequate estimability of parameters is dependent on several factors, such as length of the time series, number of segments as well as on the relation of the range and length of the residuals to the size of the parameter values.

(b) The computation of corrected scores within segments – critized as "pseudo-values" by Krauth – is a direct consequence of the application of the segment-identification approach. This objection is incomprehensible and can only be taken to be a misunderstanding.

(c) In a first step of the HTAKA procedure, the observed scores are partitioned into a deterministic model part and a residual part assumed to follow a multivariate normal distribution. Only if the check for stationarity indicates non-stationarity are the residuals whitened within an AR model. After elimination of these autoregressive parts new scores are computed as the sum of systematic model parts and modified residuals. These pseudo-scores are then subjected to significance tests (Kruskal-Wallis H-test, analyses of variance) for the detection of significant differences between time segments with respect to different aspects of the score curves. Model parameters are thus examined implicitly via the pseudo-scores. Because of small numbers o the time points only non-parametric Kruskal-Wallis tests are mentioned in the paper. The HTAKA program also provides ANOVA results. Three cases have to be discerned:

1. The check for stationarity indicates non-stationarity even for the whitened residuals. In this case an iterative procedure tries out various AR parameters until stationarity is obtained. If stationarity cannot be achieved, different values can be tried out for the segmentation improvement criterion at a restart of the analysis procedures.

2. Stationarity can be assumed to hold even without whitening. In this case proper estimation of parameters can be assumed to hold. The pseudo-values can be taken to be original scores minus a certain model part and can be entered into the subsequent significance tests without problem. As in our paper, this is mostly the case.

3. Whitening is required. In this case the residuals no longer contain the model part of the assumed AR process. The model now contains one additional component which is, however, lacking in the pseudo-values. Similar partitions are known for ARIMA models. In these models trend parameters are relaced by first-order differences and the time segmentations could be coded via a dummy variable.

Objection 4

One cannot exclude the possibility that even after whitening the residuals do not follow a multivariate normal distribution.

Response

There is no field of science and no procedure in an empirical science for which one can exclude errors and erroneous conclusions with absolute certainty. The HTAKA procedure, however, contains a very rigorous check for non-stationarity for the following reasons. In a first step trends are eliminated per time segment and only then is the residual time series tested for stationarity without consideration of the segmentation.

Problems related to the scale properties assumed in our study are as follows: The time-series analysis procedure assumes a continuous equidistant time scale, since time is involved as one of the two variables in a regression analysis. In applying the HTAKA procedures it is important to provide equidistant examinations or recordings. The random variable recorded, i.e. test scores or subjective ratings, is assumed to have interval scale properties. In general, the following assumptions must be made for proper application of the HTAKA model:

(a) The T-scale (time scale) must be continuous and equidistant.
(b) The Y-scale (observations) must have at least interval scale properties.
(c) The time series should have no less than 30 observations.
(d) A single segment should consist of no less then 5 time points.

(e) The segmentation improvement criterion should not lie below 10%.
(f) The simulated assumed length of the time segmentations in HTAKA-SIM should not be too large, the expected error percentage not too high, and the expected stationarity larger than 0.90.
(g) The residuals from an HTAKA analysis must be approximately stationary.

In our view all these requirements were met in the study by Möller and coworkers. The Y-scale represented total scores of a thoroughly constructed mood scale (von Zerssen 1976), the psychometric properties of which are well known. For a total score from a large number of items interval scale properties can be assumed to be present. To our knowledge, parametric statistical procedures have been used throughout for statistical analyses of these mood scores. Along the same line of argument Bullinger and Keeser (1985) did not find any problems in applying ARIMA models to data from mood scales. As to the T-scale, we recorded mood scale scores daily, thus providing time-continuous data. Moreover, in our study we used at least 30 therapy sessions.

We chose the HTAKA procedure because of its advantages for clinical applications even if not every implication of the procedure can be considered adequate when viewed very strictly. Whereas the alternative procedures proposed by Krauth are either multiple-subject procedures (Krauth 1973) or require a randomization of the therapeutic interventions along the randomization arguments of Edgington (1975, 1987), which precludes their clinical applicability for ethical and practical reasons, the HTAKA procedure of Kleiter offers the following advantages:

1. The procedure can model and analyse non-stationary processes. These processes can be cumulative and take place in intervals of unknown and variable length. The procedure is thus particularly useful for the analysis of non-stationary growth processes such as therapy processes found in psychology and psychopathology.

2. The procedure provides a segmentation of the time series via cluster-analysis methods.

3. The non-stationary part is partitioned into segments and within these segments into segment-specific linear trends. These linear trend parameters are then converted into a sequence of time-ordered linear trend parameters. Thus, trends in later segments are analysed independently of previous ones. The residuals obtained are tested for stationarity, which is the major prerequisite for proper use of the procedure. This stationarity check is particularly rigorous compared with other time-series procedures because, on the one hand, the non-stationary parts have been removed per segment beforehand and, on the other, the residuals are tested for stationarity across the whole series in a final step.

In the case of non-stationarity of the residuals, the residual part is subjected to an additional AR analysis, thus augmenting the model part. The model is particularly economical, since only segments and linear trends are required for the time-series modelling.

The extended version of the HTAKA procedure now also comprises the additional HTAKA-SIM routine, which allows computation of the segmentation interval length parameter via direct simulation.

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