From polysomnography to sleep parameters indexing sleep quality and sleep related physiological and psychometric factors

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Objectives of the Study

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- How to balance objective and subjective measures of the sleep quality? Questionnaires versus PSG, behavioral testing ...
- How the subjective perception of sleep relates to the objective measures of the day-time behavior or subject's physiological changes? For example, does poorly rated and perceived sleep necessarily mean impaired cognitive ability, increased sleepiness or reduced vigilance?

Dataset

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- List of 22 tests and measured variables collected during the two consecutive days in the sleep lab:

Abbreviation	Explanation
age	Age of a subject
s_qua	Self-rating Questionnaire for Sleep Quality
a_qua	Self-rating Questionnaire for Awakening Quality
s_tot	Self-rating Questionnaire for Somatic Complaints
num_m	Numerical Memory Test (morning)
wb_e	Well-being Self Assessment Scale (evening)
wb_m	Well-being Self Assessment Scale (morning)
pul_m	Pulse Rate (morning)
pul_e	Pulse Rate (evening)
sys_m	Systolic Blood Pressure (morning)
sys_e	Systolic Blood Pressure (evening)
dia_m	Diastolic Blood Pressure (morning)
dia_e	Diastolic Blood Pressure (evening)
vas_drive	Visual Analogue Scale Test for Drive
vas_mood	Visual Analogue Scale Test for Mood
vas_aff	Visual Analogue Scale Test for Affectivity
vas_drows	Visual Analogue Scale Test for Drowsiness
ad_ts	Alphabetical Cross-out Test (total score)
ad_sv	Alphabetical Cross-out Test (variability)
ad_errp	Alphabetical Cross-out Test (percentage of errors)
fma_r	Fine Motor Activity Test (right hand)
fma_l	Fine Motor Activity Test (left hand)

Factor Analysis Towards Parsimonious Sleep Quality Indexing

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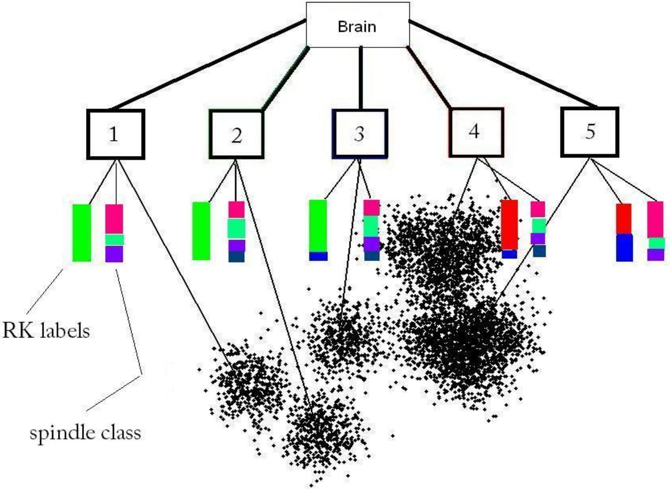
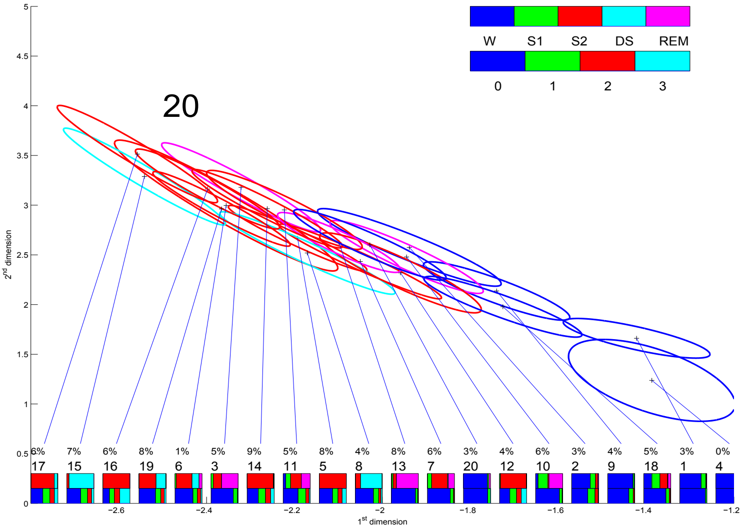
- Factor loadings (the first three factors):

Observed variables	**Factor 1** *subjective*	**Factor 2** *physiological*	**Factor 3** *psychometric*
age	-0.061	**+0.443**	**-0.601**
s_qua	**+0.240**	+0.097	-0.005
a_qua	**+0.538**	+0.066	-0.087
s_com	**+0.275**	+0.199	-0.017
num_m	-0.006	-0.222	**+0.437**
wb_e	**+0.439**	-0.061	+0.111
wb_m	**+0.705**	-0.019	+0.123
pul_m	-0.086	-0.074	-0.111
pul_e	-0.187	-0.110	-0.037
sys_m	+0.070	**+0.855**	-0.207
sys_e	-0.034	**+0.832**	-0.232
dia_m	+0.128	**+0.694**	-0.147
dia_e	+0.027	**+0.679**	-0.095
vas_drive	**+0.840**	-0.001	+0.019
vas_mood	**-0.751**	+0.038	+0.013
vas_aff	**-0.728**	+0.024	+0.143
vas_drows	**+0.810**	-0.107	+0.076
ad_ts	-0.043	-0.178	**+0.537**
ad_sv	+0.093	-0.028	-0.018
ad_errp	+0.010	-0.021	-0.007
fma_r	-0.059	-0.156	**+0.918**
fma_l	-0.016	-0.083	**+0.844**
Explained variance	17 %	17 %	7 %

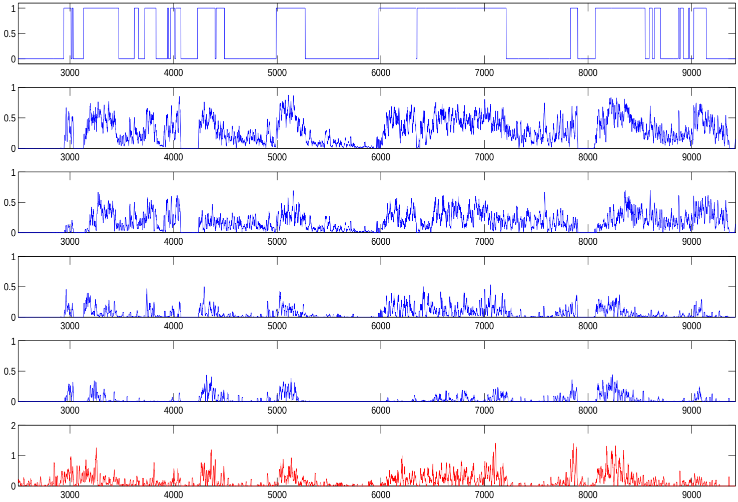
Probabilistic Separator Model (type of a Gaussian Mixture Model)



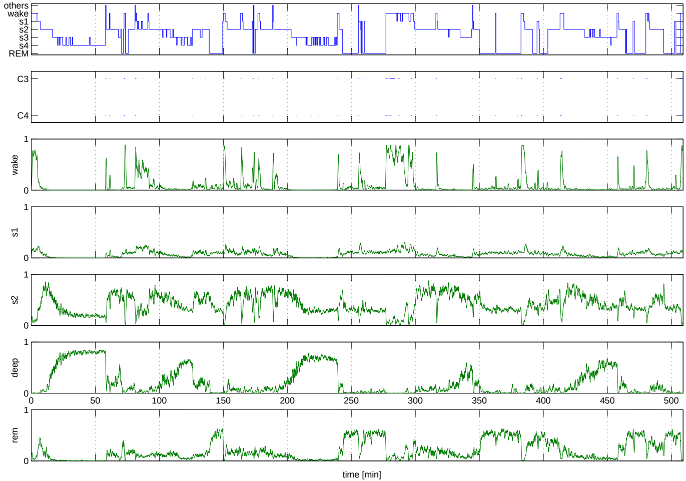
Probabilistic Separator Model



Example: S2-related Sub-states Plot



R&K Based Plot



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  1. R&K like PSM sleep model
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  1. R&K like PSM sleep model
  2. Combined sub-state curves model
- Spearman rank correlations between sleep parameters and three factor scores were computed

Factors vs. Individual Variables

- Correlations between sleep parameters for the second (*physiological*) and third (*psychometric*) factors were found to be higher or comparable with the correlations computed using the individual variables they consist of (two sample t-test)

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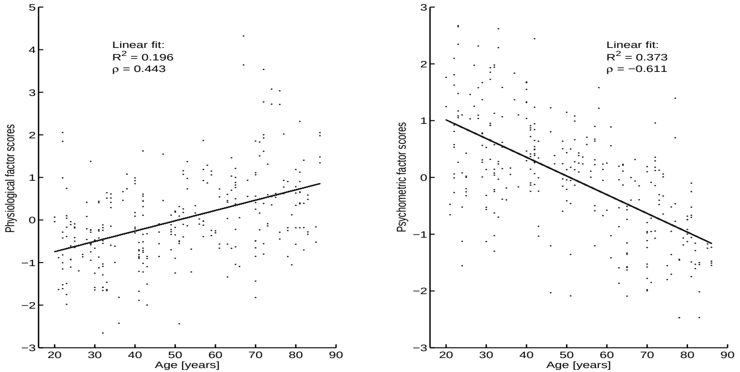
- Correlations between sleep parameters for the second (*physiological*) and third (*psychometric*) factors were found to be higher or comparable with the correlations computed using the individual variables they consist of (two sample t-test)
- This was not true for the first factor where *s_qua* was higher (*s_qua* - 7 questions self-rating sleep quality, Saletu et al. (1987))

Age Effect

- Strong age effect was found for the *physiological* and *psychometric* factors ⇒ restriction to age group 20 - 40 years where the effect is not significant



R&K versus PSM - s_qua

s_qua (subjective sleep quality questionnaire)

- Comparable results between R&K and PSM for general sleep parameters (e.g. *eff*, *tst*, ...), wake, S1 and REM
  $|\rho| \approx 0.3 - 0.36$

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- Comparable results between R&K and PSM for general sleep parameters (e.g. *eff*, *tst*, ...), wake, S1 and REM
  $|\rho| \approx 0.3 - 0.36$
- In addition, PSM shows significant correlations for S2 and SWS (*auc*, *entropy*)
  $|\rho| \approx 0.24 - 0.27$

R&K versus PSM - 2nd factor

physiological factor

- R&K: significant correlations for two general sleep parameters fw_q4, fs and two SWS parameters tst, tst_q2
  $|\rho| \approx 0.26 - 0.39$

R&K versus PSM - 2nd factor

physiological factor

- R&K: significant correlations for two general sleep parameters *fw_q4*, *fs* and two SWS parameters *tst*, *tst_q2*
  $|\rho| \approx 0.26 - 0.39$

- PSM: significant (and in comparison to R&K higher) correlations for general sleep parameters and also significant correlations for parameters representing all sleep stages and wake
  $|\rho| \approx 0.30 - 0.44$

R&K versus PSM - 3rd factor

psychometric factor

- R&K: only sleep latency to REM and average duration of REM cycles are significant
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psychometric factor

- R&K: only sleep latency to REM and average duration of REM cycles are significant
  $|\rho| \approx 0.31, 0.26$
- PSM: significant for parameters representing all sleep stages but not wake
  $|\rho| \approx 0.30 - 0.43$

Beyond R&K

- Higher correlation values of *auc* and *entropy* sleep parameters were observed for combined sub-states models (e.g. $\rho = 0.39$ vs. 0.42; for *auc_q*4 in wake; 2nd factor; 5.5 sub-states)

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- Number of sub-states varies with individual sleep stages but on average it is less than 1/4 of all sub-states
- This finding indicates that changes in substructures of the standard R&K sleep stages may better reflect important aspects of the sleep process related to subjective or objective evaluation of sleep

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- The proposed probabilistic approach allows to model finer micro-structure of sleep which increases the level of the studied correlations
- The clinical validation of these results remains the subject of the further study