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A STATISTICAL OVERVIEW ON SLEEP SCORING

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ABSTRACT. In this study, sleep electroencephalography (EEG) which is frequently used in statistical modelling has been modelled with the autoregressive (AR) time-series model and what kind of a structure the variance of the term *white noise* included in the model represented in different sleep stages has been observed. Taking all of the stages scored in accordance with Rechtschaffen and Kales criterion into account separately, epoches in each stage have been modelled with the AR and the variance of the term white noise in this model has been monitored. The study has evaluated the sleep EEG variances of a subject. In accordance with the results, the heterogeneity at Stage 2 was thought to be the reason why the objective differences appeared in scoring. It is thought that this data pointed out a necessity that the period in Rechtschaffen and Kales scoring which is called Stage 2 must be revised.

1. INTRODUCTION

Data analysis on electrophysiological phenomenon: macro and micro. Sleep scoring also need these type of approaches. Sleep has been described as the brother of death since the beginning of human being. At the beginning of 20th century, electrophysiological recording methods had revealed that changes body functions

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could be recorded. Sleep studies based on basic electrophysiological methods. The first studies showed that brain functions have been changed during sleep. Rapid Eye Movement (REM) sleep discovered at 1953. after than sleep evaluated REM and NonREM (NREM) sleep. And than classification systems were described criteria to score sleep. After than Scientists have developed new and special methods. Especially, in the second part of 20th century, scientists have concentrated on microanalyses. Actually, high technology invited scientist to discover well known basic phenomenon. Actually, basic studies on sleep and related phenomenon had been discovered. Well known physiological changes were recorded, data analyses methods revealed relationship between physiological changes. All these studies revealed that intrinsic phenomenon have very close interaction. Especially, sleep studies have shown unknown phenomenon and interaction modellings. These approaches and mathematical modellings invited scientists get together especially in basic scientific areas.

Sleeping literally is the resting state in which consciousness towards the external stimuli was fully or partially lost, all kinds of activities decreased on a large scale and response strength was reduced. In medical terms, one may also include in the description that it is a different state of consciousness.

When Hans Berger recorded the electrical activity of human brain and revealed the presence of different rhythms between sleep and awareness in 1923, a new dimension has been added to researches on sleep [1]. Aserinsky and Kleitman have identified the eye movements during sleep and indicated them as a separate period in sleeping state [2]. On the other hand, Dement and Kleitman have identified the periodic phases during sleep in polysomnography studies they made using different physiological parameters [3].

Sleep scoring is an important step for the classification of the sicknesses and proper treatment practices in researching the patterns of sleep. Currently, Rechtschaffen and Kales classification is valid [4].

The Rechtschaffen and Kales classification has made important contributions to researches on sleep in the last thirty years. Along with its positive sides, the practice of scoring by an expert in epochs requires an intense labor and time. Rapidlychanging micro structures and phase changes are unable to be evaluated in epochs lasting thirty seconds, and this leads to subjective differences in the evaluation. Making the classification with young and healthy subjects leads to an insufficiency in elderly subjects with sleep diseases, especially in those who have abnormal EEG structure caused by neurological diseases [5]. Looking at the disadvantages of the Rechtschaffen and Kales scoring criteria, studies on subgrouping the sleep phases have been made [6, 7]. To be able to make sleep scoring more objectively, data on EEG have been tried to be modelled with time series and the results of these models in different stages have been examined [8].

In this study, sleep EEG which is frequently used in statistical modelling has been modelled with the autoregressive (AR) time-series model and what kind of a structure the variance of the term *white noise* included in the model represented in different sleep stages has been observed.

Taking all of the stages scored in accordance with Rechtschaffen and Kales criterion into account separately, epochs in each stage have been modelled with the AR and the variance of the term white noise in this model has been monitored.

2. Method

A - Subject: A subject without any psychiatric complaints has been informed about the study and taken into polysomnographic examination for two nights in Sleep Researches Center of GATA Department of Mental Health and Diseases. In sleep records, the polysomnographer named Somnostar Alpha is used.

B - Polysomnographic examination: Each of the polysomnographic examinations has been scored in epochs lasting thirty seconds [4]. The EEG record (C3-A2) has been included in the evaluation at the second night.

C - Statistical method: Let it be considered that a dynamic system with the $\{y(t)\}$ output has been modelled with the linear difference equation of

$$y(t) = a_1 y(t-1) + a_2 y(t-2) + \ldots + a_n y(t-n) + v(t) .$$

Here, $\{v(t)\}$ shows the white noise process. The model above with the parameter vector $\theta^T = (a_1,..., a_n)$ and

$$\varphi(t)^T = \left(y(t-1),..., y(t-n)\right)$$

is written as

$$y(t) = \theta^T \varphi(t) + v(t) \quad (1)$$

Regarding one of the most important problems in system identification, several methods on the estimation of the unknown parameter vector have been developed. There are problems encountered in cases especially when the system parameters and the variance of white noise process change over time, and for this reason, the estimators must be upgraded [9]. Kalman Filter which is one of the methods used to estimate the model parameters has been addressed in this study.

If the parameter vector is considered as a random walk model in dynamic linear model given by the Equality (1), the equality may be written as

$$\theta(t+1) = \theta(t) + w(t) \qquad \mathrm{w(t)} \sim \mathrm{N(0,R_1}(t)$$

$$y(t) = \varphi(t)^T \theta(t) + v(t) \qquad v(t) \sim N(0, R_2(t)) \quad (2)$$

in state space model form. Here, state vector is the parameter vector and transition matrix is the unit matrix. In these circumstances, depending on $\hat{\theta}(0)$ and $\hat{\theta}(0)$ initial values, KF is given by

$$K(t) = [P(t|t-1)\varphi(t)][\varphi(t)^T P(t|t-1)\varphi(t) + R_2(t)] \quad (3)$$

$$P(t|t-1) = P(t-1|t-1) + R_1(t) \quad (4)$$

$$e(t) = y(t) - \hat{y}(t) \quad (5)$$

$$\hat{y}(t) = \varphi(t)^T \hat{\theta}(t|t-1) \quad (6)$$

$$\hat{\theta}(t) = \hat{\theta}(t|\ t-1) + K(t)e(t) \quad (7)$$

$$P(t|t) = P(t|t-1) - K(t)\varphi(t)^T P(t|t-1) \quad (8)$$

[10]. In dynamic linear models, state and measurement noise covariances and variances must be known, in order to calculate the system state and make covariance estimations. Since values of these are mostly unknown, sequential estimations are

used. Under the assumption that the state noise covariance matrix in the Equation (2) is $R_1(t) = qI$, the parameter q is calculated by

$$q = h\left(\frac{e(t)^2 - E[e(t)^2 | q \equiv 0]}{\varphi(t)^T \varphi(t)} \right).$$

Here, it is formed as

$$h(x) = \begin{cases} x, & x \geq 0 \\ 0, & \text{else} \end{cases}$$

and

$$E[e(t)^2 | q \equiv 0] = R_2(t) + \varphi(t)^T P(t| \ t-1)\varphi(t).$$

With α indicating the correction parameter, the sequential estimation of the measurement noise variance of $R_2(t)$ is given by

$$R_2(t) = \alpha R_2(t-1) + (1-\alpha) h\left(e(t)^2 - \varphi(t)^T P(t|t-1)\varphi(t)\right) \tag{9}$$

and the sequential estimation of q is given by

$$\begin{aligned} q(t) &= \alpha q(t-1) + (1-\alpha) h\left(\frac{e(t)^2 - E[e(t)^2 | q \equiv 0]}{\varphi(t)^T \varphi(t)} \right) \\ &= \alpha q(t-1) + (1-\alpha) h\left(\frac{e(t)^2 - R_2(t) - \varphi(t)^T P(t|t-1)\varphi(t)}{\varphi(t)^T \varphi(t)} \right) \end{aligned} \tag{10}$$

[11]. The standard deviation and sleep histogram estimated in accordance with this method is shown in Figure 1.

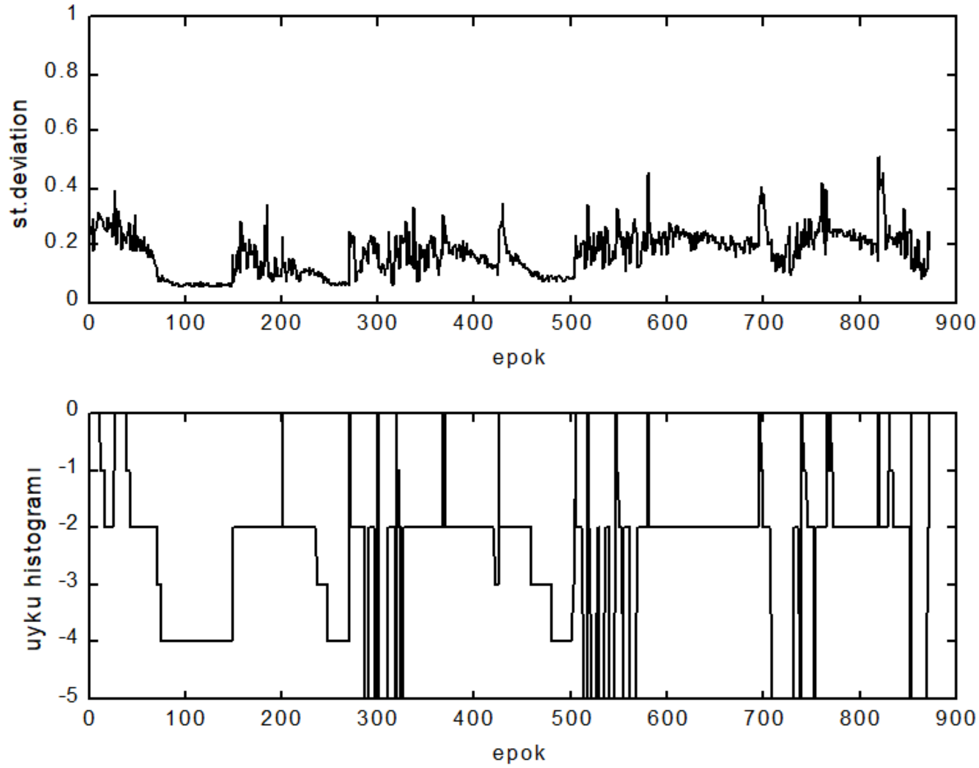

FIGURE 1. Sleep histogram and standard deviations

3. FINDINGS

In this study, the sleep EEG has been modelled as

$$y(t) = a_{1t} y(t-1) + e(t) \tag{11}$$

AR(1) process. a_{1t} in this model has been considered as parameter random walk process changing over time and calculated sequentially with the KF. The variance of white noise process in Equality (11) has been calculated adaptively by using (10) equality. In Figure 1, stages scored in accordance with the R-K criterion and the standard deviation of white noise variances in model corresponding to the stages have been shown.

At Stage 4, the variance was smaller than the other stages and it did not differ too much compared to varied epochs of Stage 4. At Stage 2, a big variance compared to Stage 4 has been encountered. When the variances of Stage 2 during the first half of the night and the Stage 2 during the second half of the night were observed, it is observed that the variance during the second half grew bigger.

4. Results

The study has evaluated the sleep EEG variances of a subject. In accordance with the results given in Figure 2, the heterogeneity at Stage 2 was thought to be the reason why the objective differences appeared in scoring. It is thought that this data pointed out a necessity that the period in Rechtschaffen and Kales scoring which is called Stage 2 must be revised.

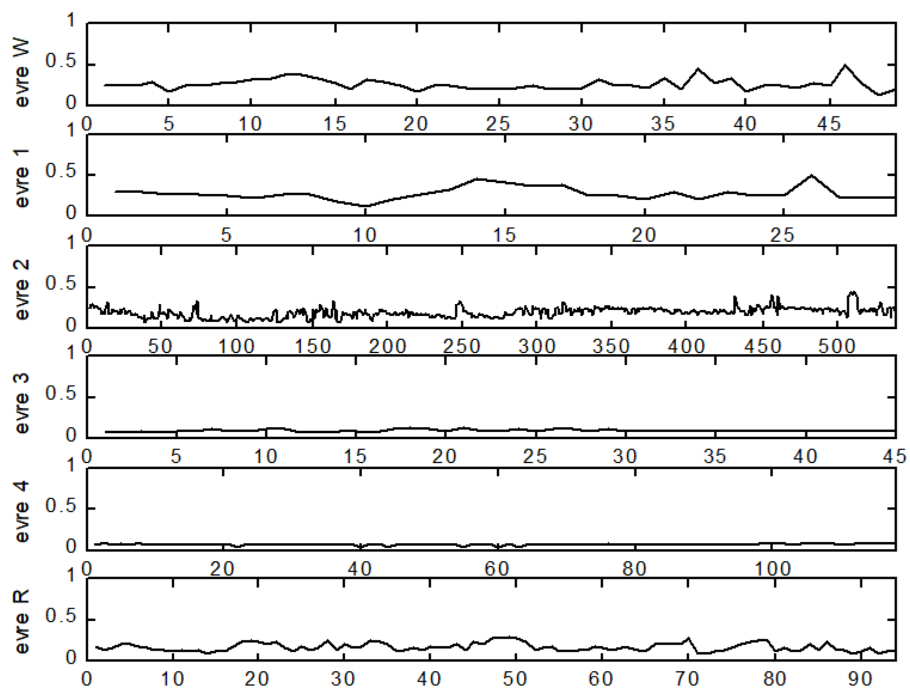

FIGURE 2. Standard deviations by stages

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