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Investigations on the relaxation behaviour of vegetative parameters in the phase falling asleep

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Abstract

The mini-sleep (also called short sleep, power-nap) is a very effective means of restoring a disturbed basic rest-activity cycle (BRAC), increases performance and well-being. In a pilot study on 12 patients (3 fm, 9 m), the aim was to prove that relaxation processes of the parameters vegetative-nervous, vegetative-emotional, muscular and metabolic response before sleep stage 1 take place. A relaxation process is defined as the slowing down of regulatory processes of the aforementioned parameters. To verify this, the sleep stages were recorded polysomnographically using the system Somnoscreen Plus (Somnomedics GmbH) and the vegetative parameters were recorded using the smard-watch-system, fixed at the wrist. The data was analysed using chronobiological regulation diagnostics (CRD). The regulatory behaviour was analysed approx. 15 minutes before sleep stage 1 was reached. A relaxation process was detected for all persons and parameters analysed (12 Pat. x 4 parameters = 48 measurements) in approx. 91 % of the cases investigated. This was a first step towards validating the system smard-watch as a detection instrument for the occurrence of relaxation reactions. The investigations also confirmed that the regulatory states from the deactivation area of the periodic system of regulatory states 31, 42 and 43 in particular are typical of relaxation states. The shift in the regulatory activity of vegetative physiological functions

from the first phase of relaxation to the second phase of relaxation (as a mean value) in the deactivated state was analysed in detail for each patient using a significance test and revealed significant differences in approx. 61% of cases (Kolgomorov-Smirnov test, alpha = 0.05).

Keywords: mini-sleep, relaxation, smard-watch, fall asleep phase, vegetative

Introduction

The diane and ultradiane rhythms consist of a proportion of activation processes followed by a proportion of deactivation processes. Just sleep - as part of the circadian rhythm - is a necessary component of the regeneration of our vital functions, the deactivation phases of the ultradian 4-hour rhythm - BRAC (basic rest-activity cycle [8 , 9] - are necessary recovery phases. This consists of approx. 1.5 hours of activation of our life processes, such as concentration and attention, followed by a deactivation phase of approx. 20 - 30 minutes.

The regeneration processes affect all important functions of our organism and therefore physiological, biochemical including immunological processes as well as psychological processes. The mini-sleep (also known in english-speaking countries as a power nap) is a very effective means of restoring a disturbed BRAC.

A mini-sleep is a short sleep during the day lasting 10 to 20 minutes. Sleeping beyond this time usually leads to a trance state from which the person concerned has difficulty coming out again." (quoted from [1]), Health Information No. 7, Gesundbrunnen mini sleep during the day [7]). It is not always possible to achieve a state of sleep during relaxation. The time required to reach a state of sleep also varies and is between 7 - 8 minutes for inexperienced people, 3-4 minutes for experienced people and for people who falling asleep > 15 minutes have problems or relaxing.

There are numerous studies investigating various relaxation techniques in relation to improving sleep quality (e.g., Trihandayani, 2024). Changes in autonomic parameters are depicted, for example, by changes in heart rate variability. This is usually done using an ECG measurement (Rudics, 2025).

The aim of this study was to demonstrate the relaxation behavior in the falling asleep phase until reaching the first sleep stage using the vegetative parameters - vegetative-muscular

reaction (EMG), vegetative-nervous reaction (skin potential - SP), vegetative-emotional reaction (skin resistance - SR) and metabolic reaction (skin temperature - ST).

Method

The examination of sleep behaviour was carried out on 12 patients (3 f, 9 m) in a sleep laboratory (Centre for Sleep Medicine Schlafdoktor+de BAG Dr.Warmuth & Dr. Blau). The PAT.s examined had an average age of 53.92 years, a BMI of 32.11, an AHI of 22.44 and a PLMI of 41.77 (for exact details, see Table 3 in the results section). The sleep profile was recorded and the sleep stages reached were polysomnographically using the system Somnoscreen Plus (Somnomedics GmbH) determined on the basis of standard criteria (according to Rechtschaffen and Kales [10], analysis interval: 30 seconds). The evaluation was carried out as part of routine clinical practice and the data was anonymised and made available for further analysis. At the same time, the vegetative parameters EMG, SP, SR and ST were recorded using the measuring system smard-watch (Fig. 1 - **S**ystem for **M**onitoring and **A**nalysing using **R**egulation **D**iagnostics) on the wrist (sampling rate: 10Hz/parameter). biorhythmometric analysis of the vegetative parameters

A biorhythmometric analysis of the vegetative parameters ([1], [6]) makes it possible to check whether a mini-sleep has taken place and how good the relaxation achieved was. This utilises the fact that relaxation is accompanied by a slowdown in regulatory processes in correlation to systolic blood pressure [2]. Relaxation can occur either emotionally, nervously, or muscularly. In the best case, it occurs simultaneously in all three parameters. According to Boucsein [4], Bureš [5] and Balzer [2, 3], the skin resistance parameter correlates with sympathetic innervation and the skin potential parameter with parasympathetic innervation.

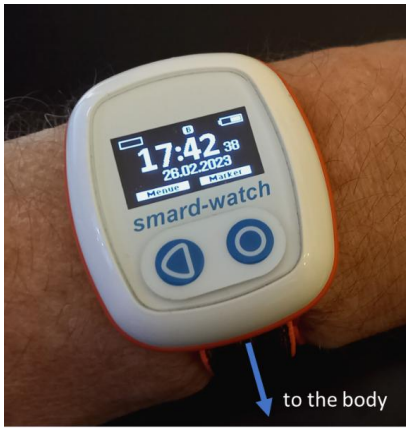

Fig. 1 Multi-parametric measuring system smard-watch

Data recording of vegetative parameters with the smard-watch

The physiological parameters were recorded for the EMG and SP parameters as bipolar recordings (1 reference electrode, 2 measuring electrodes). The SR parameter was measured by means between the reference electrode and the measuring electrode with measuring currents below 1µA. The skin temperature was measured using a temperature sensor integrated in the reference electrode. The measuring electrodes are made of titanium and do not cause any skin irritation. Movement activity (acceleration) was measured using acceleration sensors integrated in the device. All the parameters were measured without special cleaning of the skin surface or shaving of hair. Likewise, no electrode gel was used for measurement. This uncomplicated procedure was made possible by the analytical method used the Chronobiological Regulation diagnosis (CRD). Physiological drift phenomena (e.g. altered electrode pressure) or electronically induced drift phenomena (e.g. temperature influences on the measured value acquisition) and randomly occurring disturbances (electrode lifting or similar) are separated. This method also eliminates the need for standardisation when collecting measurement data.

Methodology

The biorhytmometric analysis is carried out in the form of a time series analysis for the vegetative parameters (Fritz [6], Balzer [3], software CRD ver. 1.3 Chronomar GmbH). The analysis for periodic processes was carried out in the range 20 sec... 130 sec. For this purpose, the original data were averaged blockwise (with 100 data) so that data with a "sampling rate" of 10 sec. were formed. Using the procedure described (among others in Fritz [5]), the period available for a data window of 200 seconds was determined slidingly for the measurement time time.

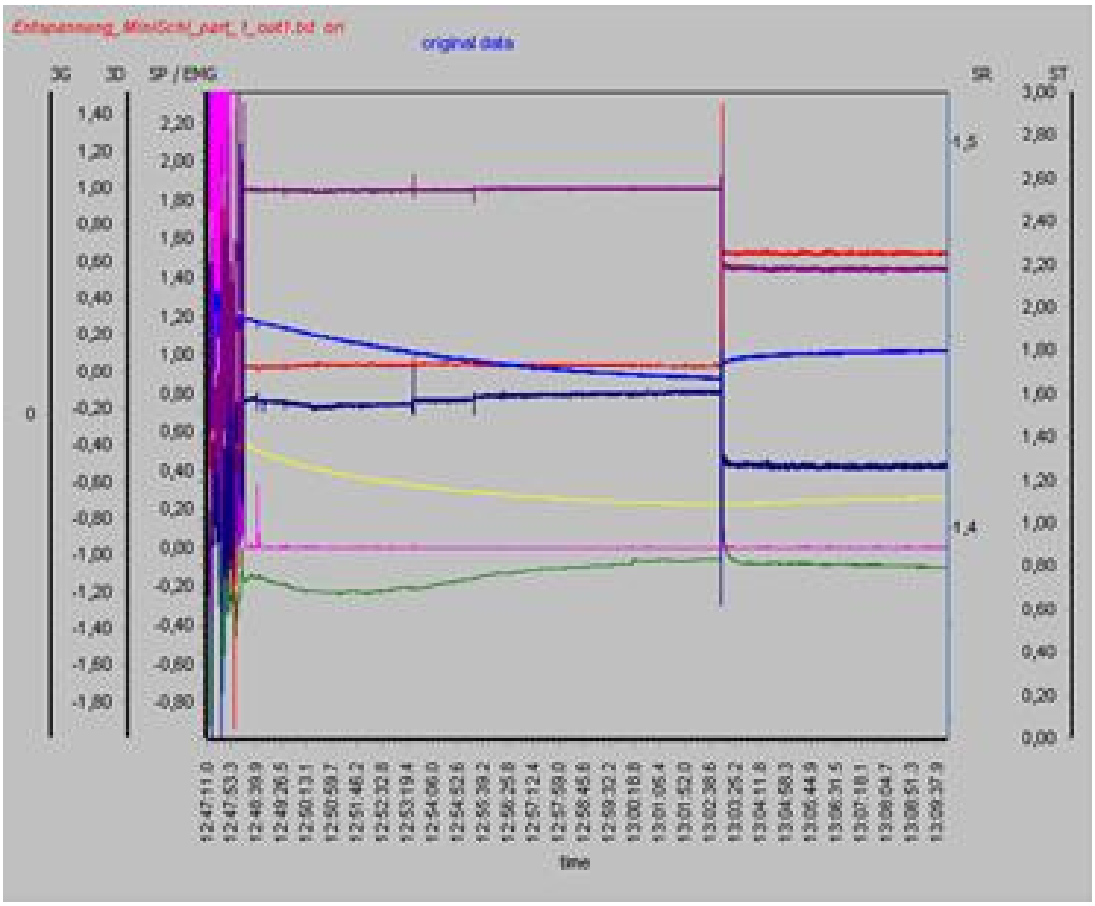

Fig. 2a Original measurement data during the performance of a mini-sleep of a Vol. during the day

Legend: blue - skin resistance, green - skin potential, pink - EMG, yellow - skin temperature, red, dark blue, purple 3d acceleration components x,y,z

Figure 2a shows the original measurement data from a mini-sleep study lasting approx. 20 minutes. During the relaxation process, the core body temperature rises and the skin temperature usually falls. The skin values resistance fall due to the increasing formation of the microclimate under the measuring electrodes. The measurement data, as expected, shows peaks when lying down and standing up. The acceleration sensor also reacts as expected when lying down and standing up (e.g. x-component - red curve). EMG trend influences such as the change in the microclimate under the electrodes or stochastic influences due to possible electrode movements are eliminated as part of the time series analysis. The evaluation of the regulatory processes will be described using the example of vegetative-emotional regulation (SR) (Fig. 2b).

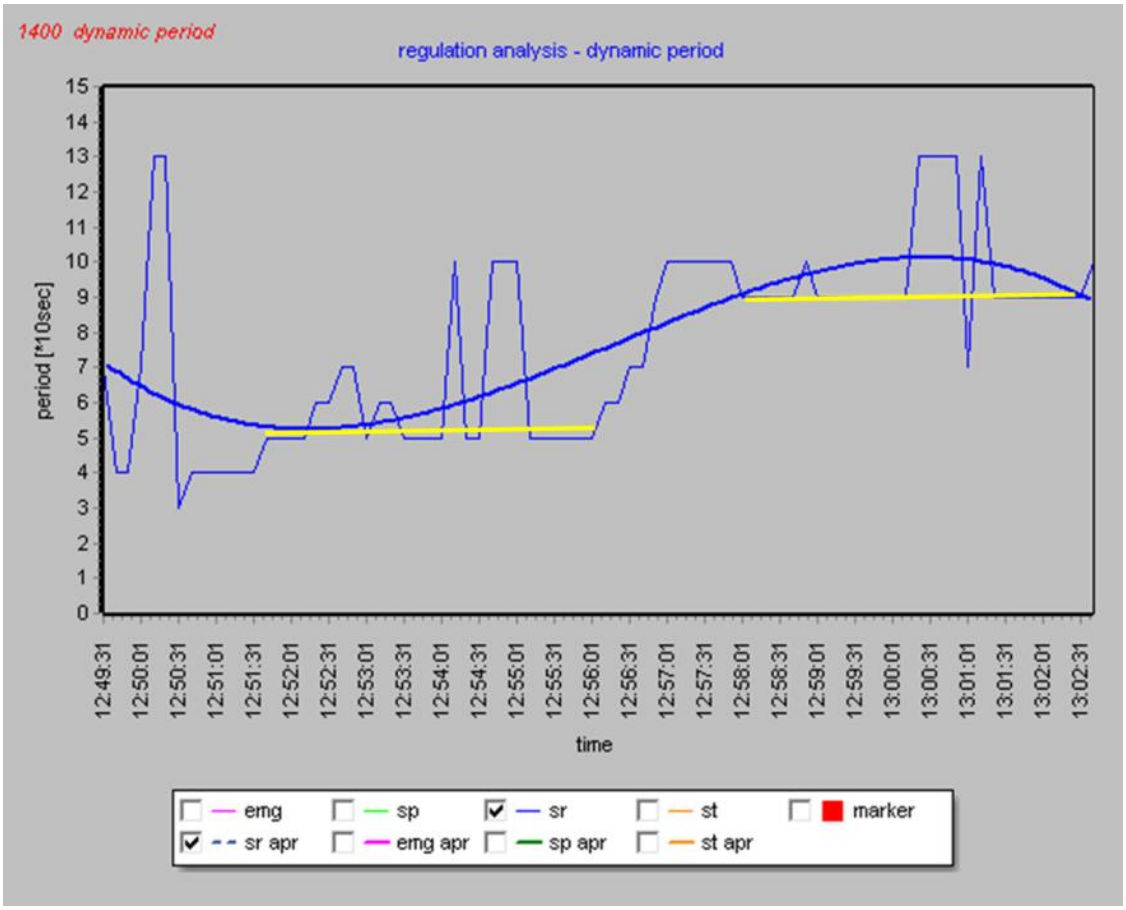

Fig. 2b Regulatory change in the vegetative-emotional response during the relaxation process at a Vol. during the day

The process starts at a period of 40..50 sec. and shows a gradual switch to the relaxed state in the 2nd phase in the range around 80..100 sec. (at approx. 12:56h). The thick blue curve represents the approximation function. The approximation function is used to determine the minimum and maximum (time of occurrence) as well as the minimum and maximum of the regulation period. Furthermore the slope (change in regulation period/time unit) is determined. In case of relaxation these values are positive. These analyses were carried out for all measured vegetative parameters.

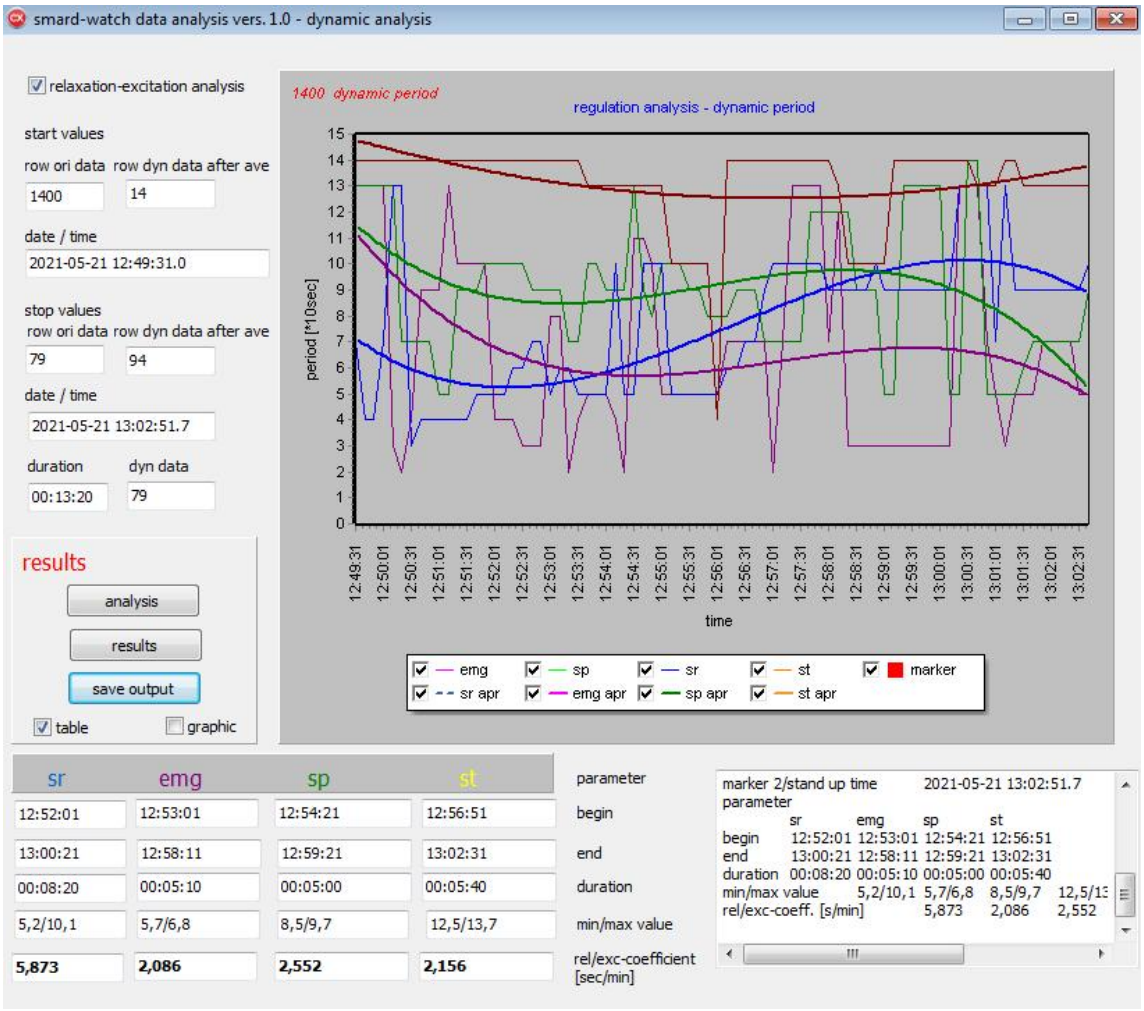

Fig. 2c Regulatory changes in the range from 20 sec. to 130 sec for the 4 parameters EMG, SR, SP and ST during mini-sleep daytime at a PAT.

The table at the bottom left of Fig. 2c shows the relaxation values achieved (rel/exc. coefficient). The min/max values are the corresponding fastest regulation periods (min) x 10 seconds and the slowest regulation periods (max) x 10 seconds. Sleep stage analysis is used to determine the change in sleep stages over time. The time immediately before reaching the first sleep stage N1 is essential for the relaxation process. This time can be determined by the sleep stage analysis.

Signal ID: SchlafProfil\profile

Start Time: 02.11.2022 21:49:00

Unit:

Signal Type: Discret

Events list: N4, N3, N2, N1, Rem, Awake, Movement

Rate: 30 s

21:49:00,000; Awake

.....; Guard

22:00:30,000; Awake

22:01:00,000; Awake

22:01:30,000; N1

22:02:00,000; N1

Table 1 Occurrence of the onset of sleep stage 1 of the examined patients and selection of the examination periods for the analysis of the vegetative data, measured with the system smard-watch

No.	Start time	Performance time N1	Start of analysis	Duration	End of analysis
1	21:49:00	22:01:30	21:49:00	00:12:30	22:04:30
2	22:12:00	22:47:00	22:32:00	00:15:00	22:50:00
3	21:30:30	21:50:00	21:35:00	00:15:00	21:53:00
4	22:24:30	22:57:30	22:42:30	00:15:00	23:00:30
5	21:22:00	22:27:00	22:12:00	00:15:00	22:30:00
6	22:27:30	22:50:00	22:35:00	00:15:00	22:53:00
7	21:24:30	22:05:30	21:50:30	00:15:00	22:08:30
8	22:09:30	22:45:00	22:30:00	00:15:00	22:48:00
9	22:05:00	23:07:30	22:52:30	00:15:00	23:10:30
10	22:00:30	22:09:30	22:00:30	00:09:00	22:12:30
11	21:54:30	21:59:00	21:54:30	00:04:30	22:02:00
12	21:57:30	22:34:30	22:19:30	00:15:00	22:37:30

As far as possible, an analysis duration of 15 minutes before the first occurrence of sleep stage N1 was selected. The duration of 15 minutes corresponds to the recommended duration for relaxation exercises. Trained persons reach the first sleep stage during a relaxation exercise (mini-sleep) in half the recommended time, i.e. after approx. 7 - 8 minutes or 3 - 4 minutes.

Based on the sleep stage analysis and using a large number of studies on humans, animals and plants the Periodic System of Regulatory States (PSR - Fig. 3) has been created (Balzer [1];

Fritz [6] and developed for stage analysis of physiological data. A regulatory state is understood to be a defined as a quasi-stationary distribution of regulatory periods over time. For this purpose, frequency distributions of analysed periods are determined and assigned to regulatory states as part of the time series analysis. The assignment is carried out with the help of an artificial neural network (Fritz [6]). The analysis and assignment of the regulatory states is carried out within the framework of a comprehensive complex time series analysis in which methods of trend elimination, autocorrelation, power density spectrum, modeling using Fourier synthesis, cross-correlation and an extensively trained neural network are used. A detailed description of the methodology analysisis not possible here for reasons of scope. Reference is made to the literature [1, 3] and Fritz [6].

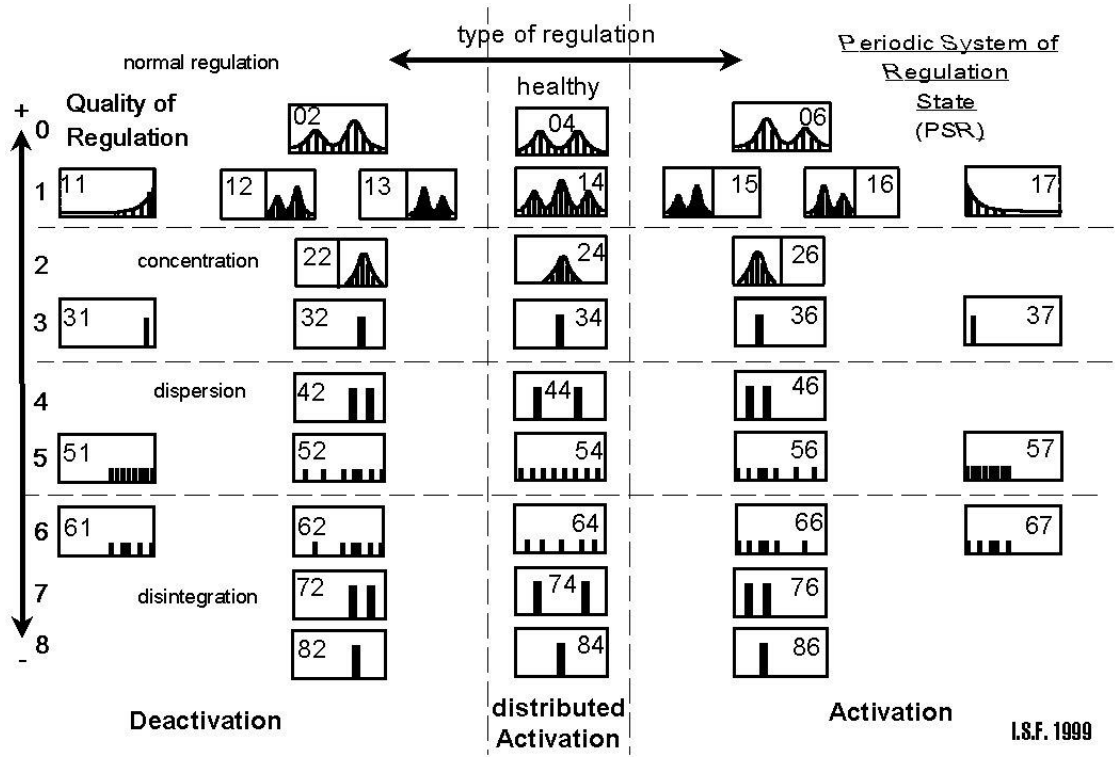

Fig. 3 Periodic system of regulatory states according to Balzer [1], Fritz [6]

The regulatory system describes regulatory processes in living systems, both in the ratio of activation to deactivation (horizontal change) and in the quality of regulation from normal adaptive to stressed dysregulated or the lack of regulatory properties (vertical change). The numbering of the individual states (frequency distributions) were arbitrary. According to previous studies, the deactivated states 11, 31 and 42 in particular are typical for deep relaxation, sleep, hypnosis and similar stages.

Table 2 Definitions of terms

Term	Definition of
Regulation	Periodic change in physiological, biochemical and other parameters in biological systems to maintain life processes
Dysregulation	Disruption and/or decay of regulatory properties of regulated systems (e.g. in depressive states)
Regulatory state	Frequency distribution of regulation periods over a defined period of time (e.g. waking state)
Activation	Regulatory state in which predominantly rapid regulatory processes occur (awake, REM...)
Deactivation	Regulatory state in which predominantly slow regulatory processes occur (deep sleep, trance....)
Relaxation	Slowing down regulatory processes
Circadian rhythm	24-hour rhythm, e.g. wake-sleep rhythm
ultradian rhythm	Regulatory processes in the range of e.g. hours, REM phase, BRAC (4-hour rhythm), basic rest-activity cycle

A 3D representation of the PSR was selected to analyse the states that occurred and their frequency, which shows the characteristic shift in the frequencies of the states. The study was divided into 2 sections - 1st half of the analysis time and 2nd half of the analysis time. A state comparison with the sleep stages was carried out not in this analysis.

In the further course of the analysis, these forms of evaluation were carried out for all patients examined.

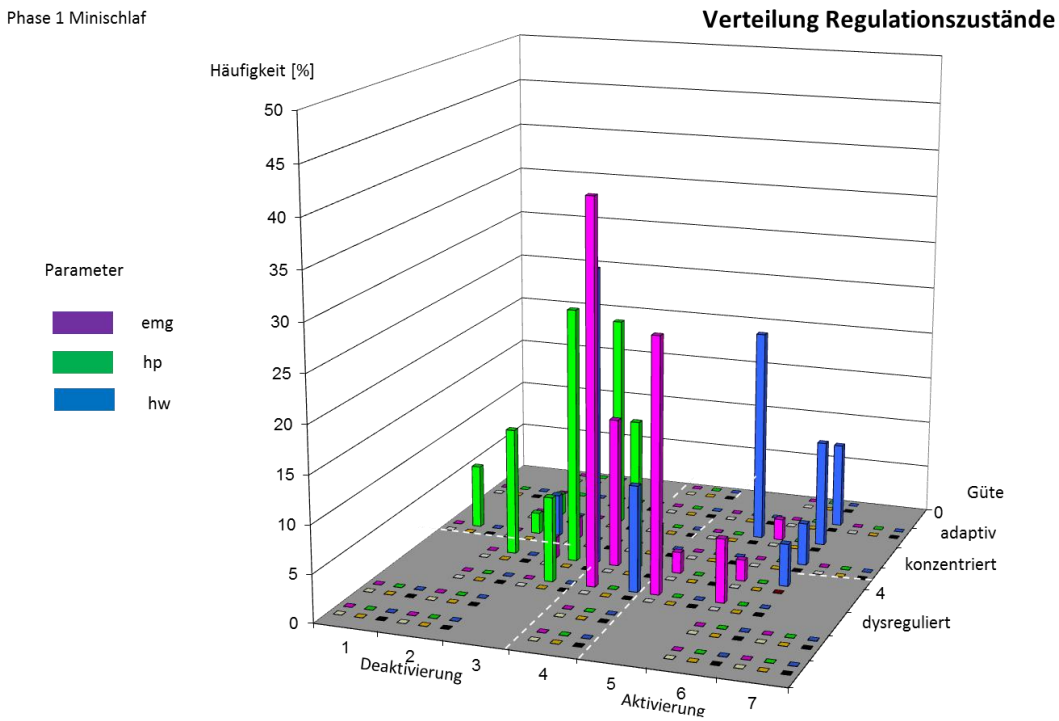

Fig. 4a Distribution of regulatory states in the first half of the relaxation process (mini-sleep) of a pat. during the day

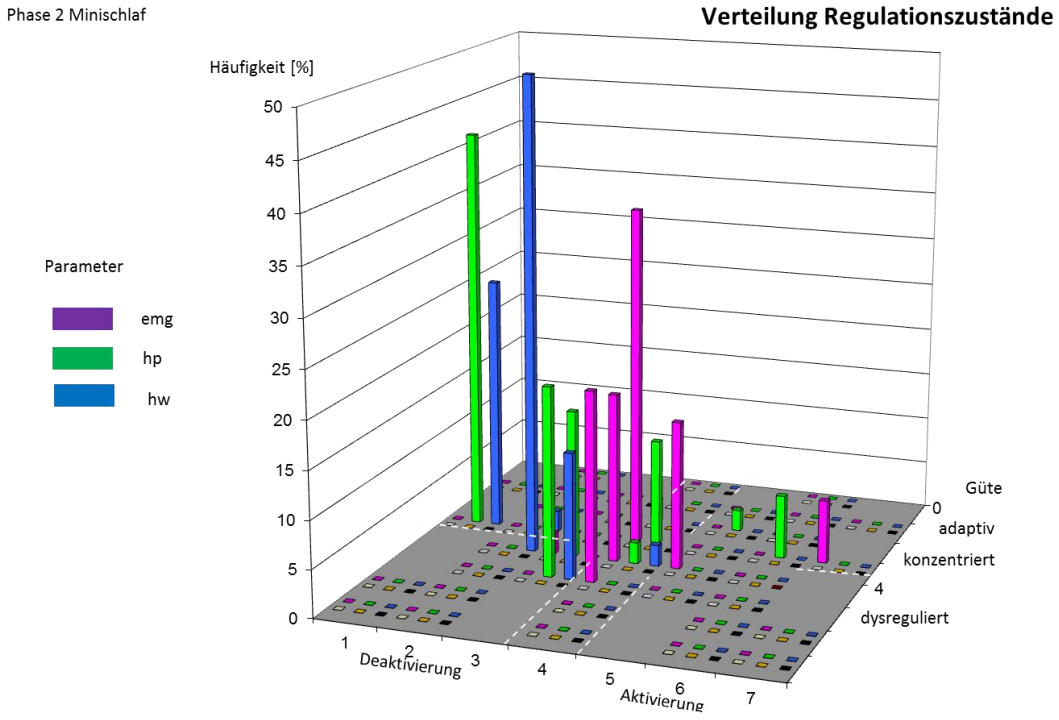

Fig. 4b Distribution of regulatory states in the 2nd half of the relaxation process (mini-sleep) of a pat. during the day

To analyze the states that occurred and their frequency, a 3D representation of the PSR was chosen, which allows to show the characteristic shift in the frequencies of the states. A clear shift and increase in the frequency of the regulatory states in the deactivated area can be recognised. The increase in the regulatory states 31 and 42 is particularly recognisable for both the vegetative-nervous regulation (green) and the vegetative-emotional regulation.

Results

The analysis of the characteristic of relaxation coefficientsshowed the following result:

Table 3 Demographic information on the analysed CPs

	Age	m/f	BMI	AHI	PLMI	CPAP
	65	1	30,1	5,1	43,5	0
	62	1	36,8	26,9	33,1	0
	55	0	29,1	1,2	47	0
	26	0	24,2	19,7	4,7	0
	51	0	36,3	6,5	68	0
	62	0	34,3	56,7	38,8	0
	58	0	27,8	5,2	34,4	0
	51	1	39,7	40,4	24,4	0
	39	0	25,2	3,8	4,6	0
	43	0	35,2	86,6	28,3	0
	52	0	29,4	10,7	37,4	0
	83	0	37,2	6,5	137	0
Ø	53,92		32,11	22,44	41,77	

1 - f, 0 - m

Table 4 Relaxation coefficients (positive - relaxation, negative - excitation)

No.	HW	EMG	HP	HT
1	-10,227	4,637	4,543	0,956

2	8,87	5,669	4,119	2,689
3	3,287	2,413	5,559	6,655
4	1,781	1,779	3,514	5,642
5	-8,922	-10,104	10,806	3,087
6	4,879	0,803	-10,064	3,407
7	10,908	2,792	9,774	3,738
8	3,147	5,233	1,59	5,362
9	2,379	2,165	2,824	4,515
10	9,131	2,415	8,829	5,766
11	6,72	8,887	6,348	6,21
12	10,908	2,792	9,774	3,738
Mean value	3,572	2,457	4,801	4,314
Median	4,083	2,604	5,051	4,127
Stand.abw.	6,643	4,334	5,339	1,607

Of the total of 48 analyses performed (12 patients x 4 parameters), 44 analyses showed relaxation processes, i.e. in 44 cases (91.67%) there was a slowdown in regulation during relaxation. This slowdown also occurred in different initial situations. For negative values, i.e., excitation, there was a very slow regulation for the respective parameter at the beginning of the analysis.

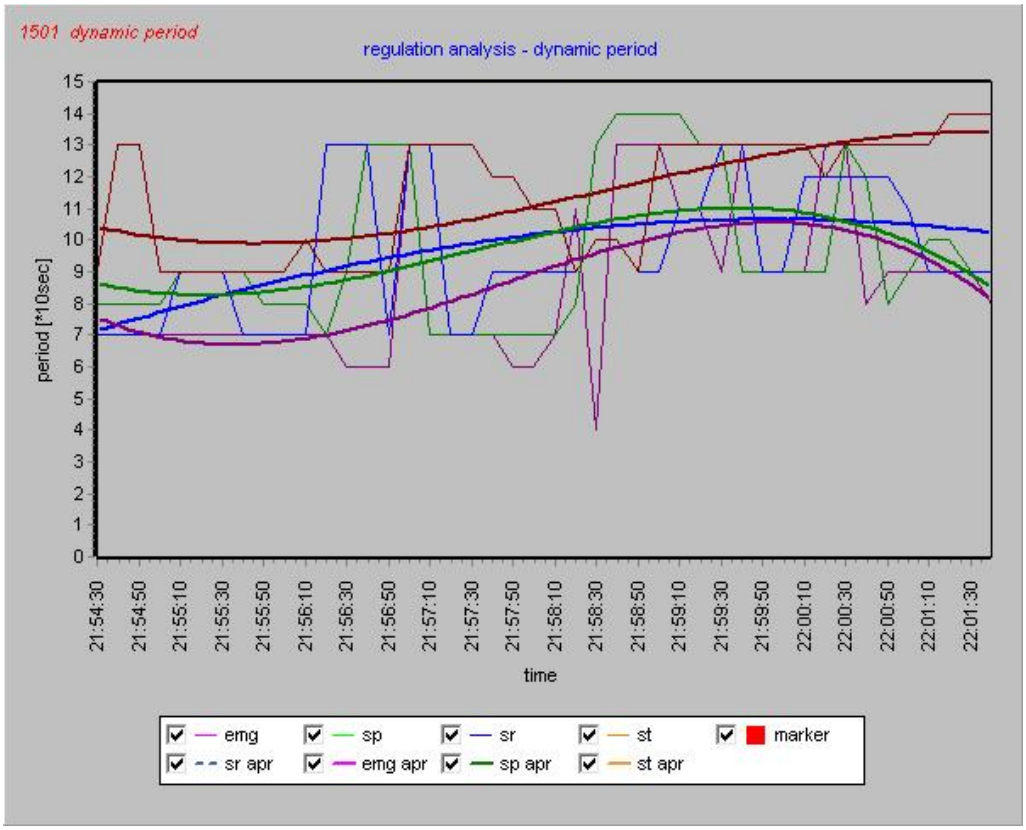

Fig. 5 Example of the relaxation process in the sleep phase of patient 11

During the process of falling asleep in the examined patients, various shifts in the distribution of regulatory states towards deactivation were observed. In the following Figure 6a, 6b an example of patient no. 10.

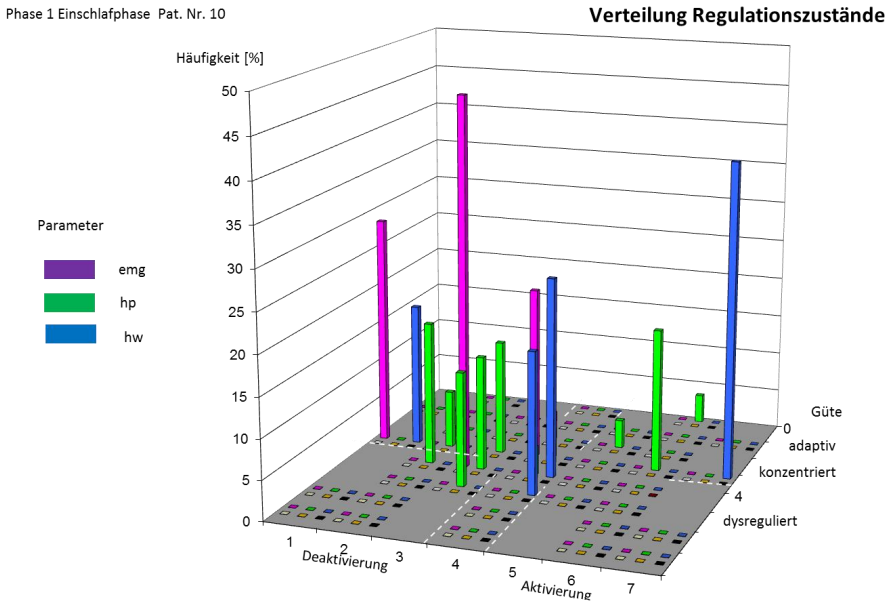

Fig. 6a Distribution of regulatory states in phase 1 (1st half) of the sleep phase of patient no. 10

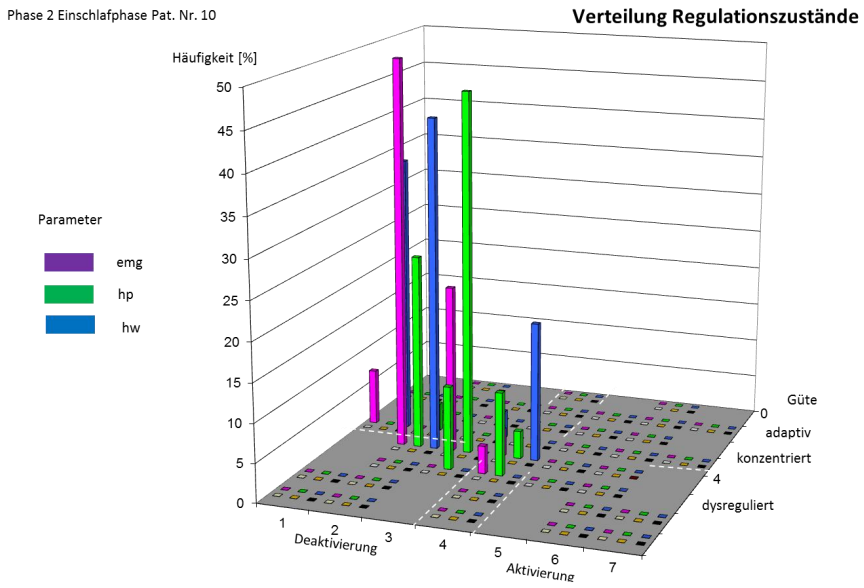

Fig. 6b Distribution of regulatory states in phase 2 (2nd half) of the sleep phase of patient no. 10

The analysis shows a clear shift of the vegetative-nervous regulation (green) and the vegetative-emotional regulation (blue) into the deactivation area. For the vegetative-nervous regulation, a clear increase in the regulatory states 42 and 43 is evident, and for the vegetative-emotional regulation, an increase in the regulatory states 31 and 42. The activation components have completely disappeared.

In order to obtain an overall view, the distributions of regulation states were averaged over all patients. The shift into the deactivated area is again recognisable, although not as pronounced as in the individual cases. What is striking, however, is the increase in the already mentioned regulatory states 31, 42 and 43 for both the vegetative-neural regulation and the vegetative-emotional regulation.

To verify the shift in regulatory states, the Kolmogorov-Smirnov test was carried out for significant differences in distributions for each patient examined.

Table 2 Significance test for the shift in the distribution of the regulatory states - parameter by parameter - for the falling asleep process of patients (comparisons of phase 1 to phase 2)

	alpha = 0.05		max D		n1/n2
No.	D(alpha)	emg	hp	hw	
1	0,33	0,92	1,31	1,12	26/46
		sign.	sign.	sign.	

2	0,28	0,50	0,30	0,39	46/46
		sign.	sign.	sign.	
3	0,28	0,35	0,28	1,12	46/46
		sign.	not sign.	sign.	
4	0,27	0,57	0,16	0,29	49/49
		sign.	not sign.	sign.	
5	0,28	0,41	0,37	0,28	46/46
		sign.	sign.	not sign.	
6	0,28	0,46	0,15	0,37	46/46
		sign.	not sign.	sign.	
7	0,28	0,26	0,26	0,35	46/46
		not sign.	not sign.	sign.	
8	0,28	0,52	0,24	0,13	46/46
		sign.	not sign.	not sign.	
9	0,28	0,33	0,26	0,33	46/46
		sign.	not sign.	sign.	
10	0,36	0,43	0,46	0,25	28/28
		sign.	sign.	not sign.	
11	0,51	0,29	0,57	0,50	14/15
		not sign.	sign.	not sign.	
12	0,28	0,26	0,63	0,20	46/46
		not sign.	sign.	not sign.	

Of the 36 tests performedsignificance, no significant differences could be detected in 14 cases. Significant differences were detected in 22 cases (61%).

Discussion

The investigations were carried out on a group of 12 patients during clinical routine polysomnography. To confirm the quality of mini-sleep during the course of the day, it would

be useful to determine the occurrence of a sleep stage. The occurrence of a sleep stage should be cross-checked with other sleep analysis systems and/or independent investigations. In addition, the investigations should be extended to patients with difficulty falling asleep vs. without difficulty falling asleep or PAT. during mini-sleep during the day.

Summary

An analysis of the relaxation behaviour of patients during the sleep phase confirmed that there is a slowdownin the regulation of the vegetative-nervous, vegetative-emotional, muscular and metabolic response. This behaviour occurred approx. 15 minutes before sleep stage 1 was reached and was in approx. 91 % of the cases examined (n = 12achieved 4 parameters). This was a first step towards validating the smard-watch system as a detection tool for the occurrence of relaxation reactions. The investigations also confirmed that the regulatory states from the deactivation range of the periodic system of regulatory states 31, 42 and 43 in particular are typical of relaxation states. The shift in the averaged regulatory activity of vegetative physiological functions from the first phase of relaxation to the second phase of relaxation in the deactivated state was in detail for each patient analysed and revealed significant differences in approx. 61% of cases. using a significance test.

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