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The evolution of brain waves in altered states of consciousness (REM sleep and meditation)

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Abstract. Aim: The aim of this study was to investigate the brain activity in REM sleep and meditation; it was also studied in which way an appropriate musical background would affect the evolution of brain waves in these altered states of consciousness. Material and Method: The recordings were done with a portable electroencephalograph, on a homogeneous group of human subjects (men aged 30-50 years). The subjects were monitored in their own bed, the length of sleep and how early they went to bed was up to them. This was made to avoid errors that could compromise the whole study. Results: It was shown that an appropriate musical background has a positive effect on brain activity and especially on alpha waves. There were no significant results regarding REM sleep, although a slight increase in the frequency by which the periods of REM sleep occurred was noticed. On the other hand, in meditation, the appropriate musical background had a major influence on the period in which the subjects entered the alpha state. This period was considerably reduced. Conclusion: An adequate type of music can help our brain entering in, and maintaining the alpha state.
Key words: brain waves, alpha waves, REM sleep, meditation, altered states of consciousness, alpha state, musical background.

Rezumat. Obiective: În acest studiu, s-a înregistrat activitatea cerebrală în timpul somnului REM şi a meditaţiei. De asemenea, s-a investigat modul în care un fond muzical adecvat, poate influenţa activitatea cerebrală pe parcursul celor două stări modificate de conştiinţă. Material şi metodă: Înregistrările s-au realizat cu ajutorul unui electroencefalograf portabil, pe un grup omogen de subiecţi umani (bărbaţi cu vârsta cuprinsă între 30 şi 50 de ani). Toate înregistrările s-au realizat în mediul obişnuit de trai al fiecărui subiect, conform programului fiecăruia, astfel eliminându-se anumite disconforturi ce ar fi putut să influenţeze buna desfăşurare a experimentului. Rezultate: S-a demonstrat că, un fond muzical adecvat, are un efect pozitiv asupra activităţii cerebrale şi în special asupra undelor alfa. În ceea ce priveşte somnul REM, nu s-au obţinut rezultate semnificative, dar s-a constatat o uşoară creştere a frecvenţei de apariţie a perioadelor de somn REM. Pe de altă parte, în cazul meditaţiei, fondul muzical folosit a avut o influenţă majoră asupra perioadei în care subiecţii intrau în stare alfa. Această perioadă a fost redusă considerabil. Concluzie: Un fond muzical adecvat ne ajută să intrăm mai repede în stare alfa şi să o menţinem o perioadă mai lungă de timp.
Cuvinte cheie: unde electrice cerebrale, unde alfa, somn REM, meditaţie, stări modificate de conştienţă, stare alfa, fond muzical.

Introduction. We all spend about one third of our life sleeping. But do we know what is happening in our brains after we close our eyes? The general tendency is to say that sleep is a relaxed state that includes a relaxed body and a peaceful mind. For most of the time that we are sleeping this is true, but for 90-120 minutes of our total period of sleep per night, this hypothesis is false. In these 90-120 minutes we experience what it is called 'the paradoxical sleep' or rapid eye movement sleep (REM), when our body undergoes muscle atony (Siegel 2005), rapid eye movement and the activity of our brain is similar to the one in the awaken state (Horne 2009). REM sleep is also characterized by the appearance of alpha waves (8-12 Hz) on the EEG recording (Borbély 2000). Such as sleep, meditation is also an altered state of consciousness in which the brain activity is characterized by alpha waves and the entire body is in a relaxed state.

REM sleep is a period of an irregular activity of the physiological functions of our body (Kalia 2006). We can say that this kind of sleep is far from being restful and regenerating. It was demonstrated that the neurons from certain parts of the brain, especially from the optic area, have periods when they are very active (Moorcroft 2005), but this is not happening only because this area is inducing REM sleep, but also because

there is a high brain activity during this stage of sleep. Most of the brain areas have an inflow of blood over 200% higher than in the awake state (Moorcroft 2005). REM sleep facilitates brain development. It was demonstrated that there is an internal source of stimulation that determinates the increase of the nervous tissue and its physiological maturity (Fagioli 2002). Also, the amount of neurotransmitters, especially catecholamines, is restored, because the activity in locus coeruleus is diminished and so, the receptors for catecholamines have a chance to adjust their activity. REM sleep deprivation causes a reduction of inhibitory processes in the brain stem triggered by noradrenaline (Moorcroft 2005). Another function of REM sleep is memory consolidation. Studies have shown that after intense learning processes, the periods of REM sleep occur after a shorter period of time and lasts longer (Born & Gais 2003; Ficca & Salzarulo 2004). It was also found that REM sleep changes the vision the subjects have on their emotional problems; these problems can be easily solved during REM sleep (Stickgold & Walker 2004).

After all these discoveries, we begin to wonder what if we could increase the duration of REM sleep? How could we do that? Music is known to be a relaxing factor and it is used in some relaxation techniques, meditation and in similar practices. Although there are many techniques of relaxation through music, the physiological process on which these techniques are based, is scarcely studied.

The experiments reported here were designed to highlight the major benefits of an appropriate musical background to the evolution of brain waves, especially to the activity of alpha waves. Thus, it was shown that an adequate music induces a relaxation state (alpha state) more rapidly.

Material and Method. In this research the evolution of alpha brain waves in two altered states of consciousness (REM sleep and meditation) was investigated, both with and without an appropriate musical background. The recordings were made with a portable EEG, on a homogeneous group of human subjects (men with age between 30 and 50 years old). The subjects were monitored in their own bed, the length of sleep and how early they went to bed was up to them. This was made to avoid errors that could compromise the whole study.

Subjects selection. Human subjects were men, aged between 30-50 years. For the accuracy of the recordings, the disposable electrodes had to have a perfect adhesion on the subject's head. This was the reason why men that agreed to shave their heads were chosen. It was also important the subjects to be mentally healthy. In order to investigate brain activity in meditation, the subjects had to be familiar with this practice. This was the reason why men that had experience in meditation practice were chosen.

Working techniques. The recordings were made with a portable electroencephalograph (30/25/5 cm), Hipocrat 1000, from CoMed. This was connected to a Dell Inspiron 1525 laptop, on the one hand and on the other hand to the electrodes placed on the head of the subjects, through the patient cable. Two types of disposable electrodes were used, with a diameter of 55 mm:

- electrodes with liquid gel from VivoMed – which were not good enough for a whole night recording (5-8 h) because of their weak adhesion;
- electrodes with solid gel from Clinical – which were good for monitoring both sleep and meditation.

EEG recordings were made using the Hipocrat software.

The subject once connected to the electroencephalograph is asked to relax and keep his eyes closed, meanwhile the EEG recording is verified to see if all the electrodes make contact.

It was monitored a homogeneous group of 7 men, each man being monitored 4 times: a meditation in silence, a meditation with a musical background, one night sleep in silence and one night sleep with a musical background. The subjects were informed about the aim of the study and they agreed with the whole procedure.

The period of the recording for the meditation was between 15 and 30 minutes, and for the sleep was between 4 and 8 hours (the subjects have kept their usual program).

Meditation is an altered state of consciousness characterized by a relaxed body and a clear mind. During the meditation, the subjects sat on a chair in a relaxed position; they attempted entering and mentaining a state in which there were no thoughts.

The music used in this experiment was: "L'Amour de l'Infini" (Indra: Whispers of Nature, 1999) – for the sleep musical background and "Conquest of Paradise" (Klaus Schulze: Conquest of Paradise, 1994) – for the meditation musical background. The music volume was set depending on the situation (sleep or meditation), and on the subject preferences. Regarding the sleep, the musical background was on repeat during the entire night.

Statistical analysis. The statistical analysis included the following steps:

- calculating the arithmetic mean of individual values;
- calculating the standard error;
- calculating the "t" Student's test of significance;
- determining the index of probability "p" using the usual tables, based on the value of "t" and the freedom degrees.

Variations that had the value of $p<0.1$, were considered significant, as follows:

$p<0.1$ partially significant - (*) ;
$p<0.05$ significant - * ;
$p<0.01$ distinctly significant - ** ;
$p<0.001$ very significant - *** ;

Results and Discussion. ***EEG in sleep.*** The results obtained in monitoring sleep without using a musical background are presented in Table 1.

Table 1

EEG in sleep without a musical background

Entry	Total duration of sleep (min)	Periods of REM	Average duration of a period of REM (min)	% REM from the total sleep	Frequency of REM (min)
1.	300	5	15	26	60
2.	330	6	14	26	55
3.	330	5	16	24	66
4.	330	5	12	17	66
5.	330	4	11.5	14	82.5
6.	270	4	13	20	67.5
7.	480	7	18	26	68.5
Average	338.5	5.14	14.21	21.85	66.5

For reducing any variations caused by certain individual characteristics, the same group of 7 subjects was monitored in the state of sleep both with and without a musical background.

The duration of sleep is not the same because the subjects were free to sleep according to their own program and necessities. The sleep period varies between 270 minutes and 480 minutes. This is the reason why the number of periods of REM sleep varies between 4 and 7. The average duration of one period of REM is 14.21 minutes. This matches the data present in literature, where it is said that a period of REM sleep is about 15 minutes (Longstaff 2005). Regarding the percentage of REM sleep from the total duration of sleep, this varies between 14% and 26%, with an average of 21.85%. The frequency of REM sleep is about 66.5 minutes which also matches the data present in literature, where it is mentioned that REM sleep occurs once every 60-90 minutes (Longstaff 2005).

Although the period of sleep varied, in the statistical processing of the data, all the parameters were reported to the same period of 330 minutes of sleep.
The results obtained in monitoring sleep using a musical background are presented in Table 2.

Table 2

EEG in sleep with a musical background

Entry	Total duration of sleep (min)	Periods of REM	Average duration of a period of REM (min)	% REM from the total sleep	Frequency of REM (min)
1.	300	5	13	23	60
2.	300	5	13	22	60
3.	360	6	12	21	60
4.	290	4	17	24	72.5
5.	240	3	12	14	80
6.	270	4	14	21	67.5
7.	480	7	17	25	68.5
Average	320	4.85	14	21.42	66.9

The duration of sleep varied between 240 and 480 minutes. The number of periods of REM sleep was between 3 and 7 and the average duration of one period of REM was 14 minutes. The percentage of REM sleep from the total duration of sleep had an average of 21.42%, it varied between 14% and 25% and the frequency of REM sleep was about 66.9 minutes.

Although the period of sleep varied, in the statistical processing of the data, all the parameters were reported to the same period of 330 minutes of sleep.

EEG in meditation. The results obtained in monitoring meditation without using a musical background are presented in Table 3.

Table 3

EEG in meditation without a musical background

Entry	Total duration of meditation (min)	Wave types (%)			Entering in α state (min)	Total duration of α waves (min)
		α	β	Δ		
1.	20	50	11.1	38.8	2	10
2.	20	48	2	50	0.33	9.6
3.	25	49	4	47	0.8	12.25
4.	20	63	16	21	1.8	12.6
5.	30	68	9	23	3	20.4
6.	20	49	5	46	1	9.8
7.	20	55	2	43	0.5	11
Average	22.14	54.57	7.01	38.4	1.34	12.23

To reduce any variations caused by certain individual characteristics, the same group of 7 subjects was monitored in the state of meditation both with and without a musical background.

The length of the meditation ranged between 20 and 30 minutes; the subjects maintained this state until they achieved a complete state of relaxation. In this EEG recordings, beta, alpha and delta waves were present, with an average percentage of 7.01%, 54.57% and 38.4% respectively. The period of time the subjects needed to enter the alpha state varied between 0.33 and 2 minutes, with an average of 1.34 minutes. The total duration of alpha waves was also calculated and it had an average of 12.23 minutes.

The results obtained in monitoring meditation using a musical background are presented in Table 4.

Table 4

EEG in meditation with a musical background

Entry	Total duration of meditation (min)	Wave types (%)			Entering in α state (min)	Total duration of α waves (min)
		α	β	Δ		
1.	15	47	7	46	0.16	7.05
2.	30	43	1	56	0.1	12.9
3.	30	52	3	45	0.1	15.6
4.	30	65	12	23	0.25	19.5
5.	20	53	7	40	1	10.6
6.	20	56	2	42	0.5	11.2
7.	20	50	1	49	0.1	10
Average	23.57	52.28	4.71	43	0.31	12.4

The length of the meditation ranged between 15 and 30 minutes; the subjects maintained this state until they achieved a complete state of relaxation. In this EEG recordings beta, alpha and delta waves were present, with an average percentage of 4.71%, 52.28% and 43%. The period of time in which the subjects had entered the alpha state varied between 0.1 and 2 minutes, with an average of 0.31 minutes. The total duration of alpha waves had an average of 12.4 minutes.

Comparing EEG values obtained in sleep, with or without a musical background. To see whether the musical background had any influence on the sleep, a comparison was made between the results obtained in monitoring sleep with a musical background and those obtained in monitoring sleep without a musical background.

The comparison of values obtained in monitoring sleep, with or without a musical background is presented in Table 5, as well as in Figure 1.

Table 5

Comparison of values obtained in monitoring sleep, with or without a musical background

Group		Periods of REM	Average duration of a period of REM (min)	% REM from the total	Frequency of REM (min)
Sleep without musical background	x±ES(n)	5.01±0.23(7)	14.21±0.87(7)	21.85±1.86(7)	66.5±3.22(7)
Sleep with musical background	x±ES(n)	4.98±0.20(7)	14.00±0.81(7)	21.42±1.36(7)	66.9±2.88(7)
	±D%	-0.6	-1.48	-1.97	0.65
	p	0.91 NS	0.86 NS	0.85 NS	0.92 NS

NS – not significant; ES – standard error; D – difference.

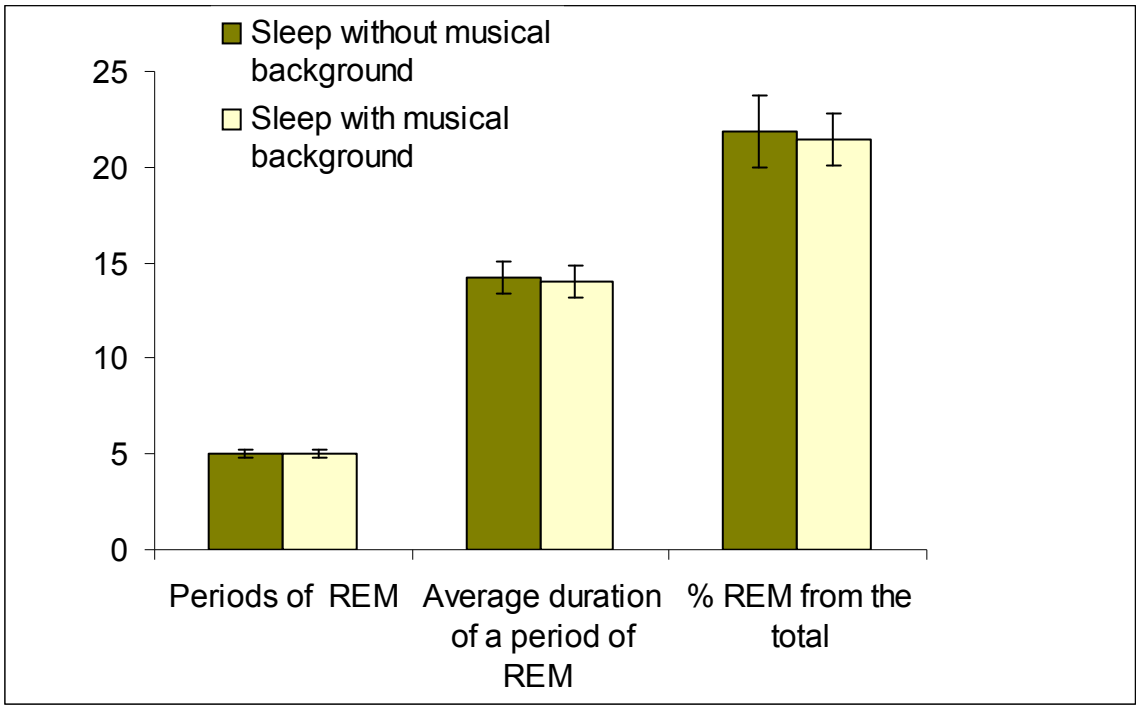

Figure 1. The influence of musical background on the EEG characteristics during sleep

As it can be seen in both Table 5 and Figure 1, the influence of the musical background on the REM sleep cannot be stated very clearly, even though a decrease in both the average duration of a period of REM sleep and the percentage of REM sleep was recorded when using the musical background. It was also recorded a slight increase in the frequency by which the periods of REM sleep occurred when having a musical background, but all these modifications were statistically not significant (NS).

Comparing EEG values obtained in meditation, with or without a musical background. Too see whether the musical background had any influence on the meditation (especially on the alpha waves), a comparison was made between the results obtained in monitoring meditation with a musical background and those obtained in monitoring meditation without a musical background. These data are presented in Table 6, as well as in Figure 2.

Table 6

Comparison of values obtained in monitoring meditation, with or without a musical background

Group		Wave types (%)			Entering in α state (min)
		α	β	Δ	
Meditation without musical background	x±ES(n)	54.57±2.99(7)	7.01±1.98(7)	38.4±4.43(7)	1.34±0.36(7)
Meditation with musical background	x±ES(n)	52.28±2.65(7)	4.71±1.55(7)	43±3.86(7)	0.31±0.12(7)
	±D%	-4.19	-32.81	11.98	-76.66
	p	0.57 NS	0.37 NS	0.44 NS	0.01 x

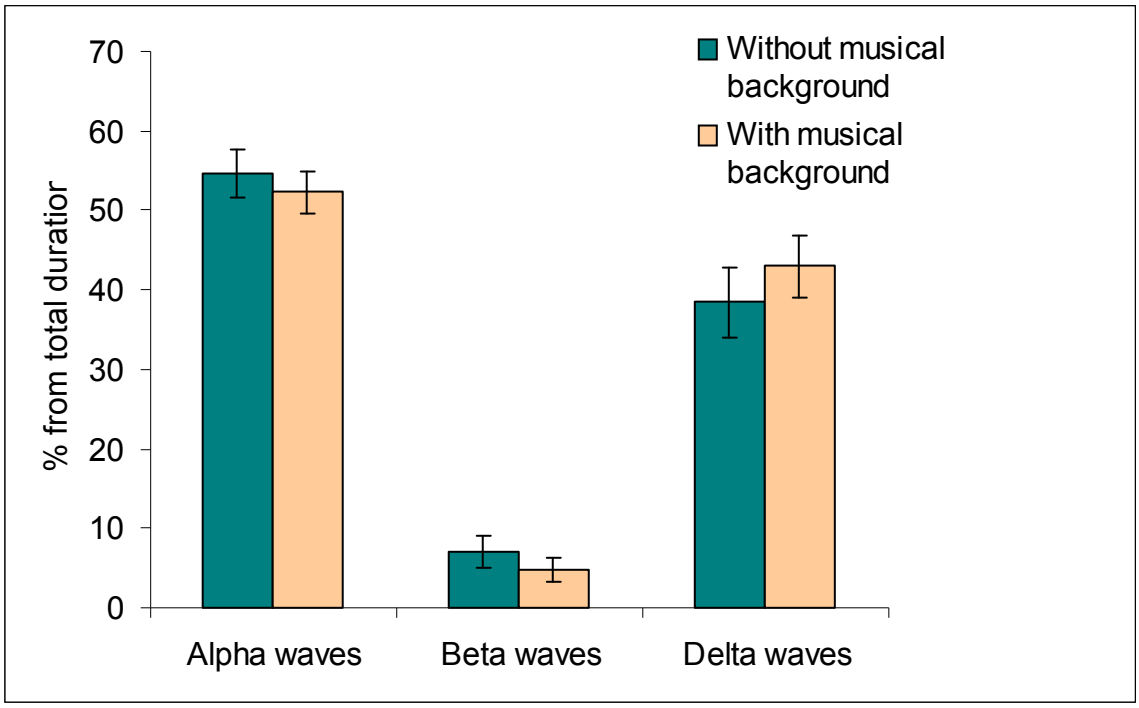

Figure 2. Percentages of alpha, beta, delta waves (% from the total amount of sleep).

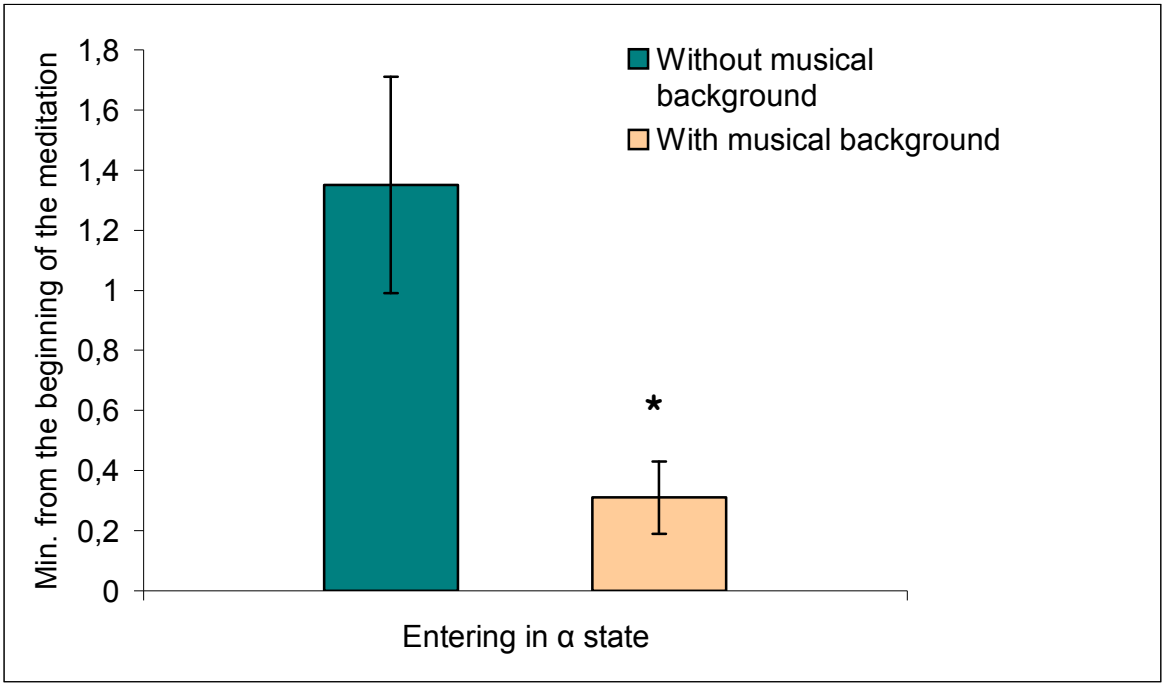

Figure 3. The moment when the alpha waves appeared (min. from the beginning of the meditation) depending on the presence of the musical background.

In meditation with musical background, the presence of delta waves increased and that of the beta waves decreased, but these changes are insignificant (NS). Instead, it was recorded a significant decrease of the period of time in which the subjects entered in alpha state. This leads us to the conclusion that the musical background has a major influence on the duration of entry in alpha state (and hence the relaxation), reducing it substantially.

Conclusion. When using the musical background, there were not any significant changes in the REM sleep; it was recorded a decrease in the percentage of REM from the total amount of sleep and a slight increase in the frequency by which the periods of REM sleep occurred.

Regarding the meditation, the musical background had an effect on the brain waves activity, namely, a tendency of increase in the percentage of delta waves and a slight decrease in the percentage of beta waves, but all of these were statistically insignificant.

What was really significant was the major decrease in the period of time in which the subjects entered alpha state, when using the musical background in meditation. This leads us to the conclusion that the musical background has a major influence on the duration of entry in alpha state (and hence the relaxation), reducing it substantially.

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