



Original Contribution

POSSIBLE CONNECTION BETWEEN THE NASAL CYCLE AND CONSCIOUSNESS

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ABSTRACT

It is shown that there is a connection between the dynamics of the nasal cycle and the consciousness states of the brain. Accordingly to hypothesis, the switch of dominated airflow between left and right nostrils in time becomes only in consciousness states of the brain (in awake state, in REM dream and in dream of stages 1-2 of the non-REM sleep). This finding gives possibility to use nasal cycle as 'marker' for consciousness.

Key words: nasal cycle, sleep cycle, consciousness, brain

INTRODUCTION

The nasal cycle defined as switch of dominate nostril airflow from left to right side and reverse is good studied during diurnal period of day over healthy and sick persons in wake consciousness state [1, 2]. During diurnal period of day the periods of the nasal cycle may have duration between 1.0 and 5.0 hours with random pattern under the influence of various factors [3, 4, 5]. During night sleep the switch of the nostrils occurred nearly in same interval with periodicity multiplied by duration of the sleep cycle [3]. The investigations of Atanasov et al. [6, 7] and Kimura et al. [8] have shown the nasal cycle during night sleep is mutually connected to REM stage of the sleep. The experimental results of investigators have shown the change of dominate nostril airflow occurs during one of the stages of REM sleep and never occurred during slow-wave sleep stages. Recently, the awaking (waking) consciousness regard as 'primary consciousness state', wireless the REM stage of the sleep regard as form of 'secondary consciousness state' or 'proto-consciousness' [9, 10]. The consciousness is ambiguous concept, which is focused on multi-disciplinant debates. However, up to now, there is no universal definition for consciousness covering all its essential characters. A clinically defined

consciousness has two main components- awareness and arousal [11]. The presence of one or both of the components of the consciousness gives reason to believe that the given person is in a state of consciousness or is near a consciousness state. During diurnal phase of the day the healthy person normally is in awaking consciousness. In this state of consciousness the sensation and perception are vivid and externally generated. The thought is logical and progressive. The movement is continuous and voluntary. The characteristics of consciousness during night sleep are poorly studied. The sleep is divided to non-REM and REM stages, which alternate in a certain sequence forming about 1.5 hours periods [12]. It is established that in REM stage of the sleep there is reason to consider that there is 'minimum threshold' of consciousness [9, 10]. In 'REM proto-consciousness' the sensation and perceptions are vivid and internally generated, and the thought is illogical and bizarre. The movement is command but inhibited. However, just in some of REM stages of the sleep become about 70% nasal cycle reversal between two nostrils [6, 7, 8]. During the non-REM stage of the sleep the sensation and perception are absent. If the sleeper is awakened from REM sleep, dream recall rates are very high, about 80 to 90 percent of the awakenings yield some kind of dream report [13]. Even after non-rapid eye movement (NREM) awakenings (in stage 2), some mental content has been reported quite often [14]. Some researchers advocate the

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hypothesis that the mind never sleeps, that is, dreaming of some kind is present during the entire sleep process. Accordingly to other authors [15] sleep that contains dream is considered as conscious state while dreamless sleep is unconscious. Lucid dreams are reported far more often in REM sleep too [16, 17]. In fact the lucid dreams could be considered a hybrid state combining essential elements of REM sleep and waking consciousness. Therefore, dreams are the event that defines consciousness. The studies of Foulkes [14] and others researches [18, 19, 20] showed that dream-like mentation may occur during non-REM stage of sleep (stages 1 and 2) [21]. "Light sleepers" can experience dreaming during stage 2 non-REM sleep, whereas "deep sleepers", upon awakening in the same stage, are more likely to report "thinking" but not "dreaming". Despite this wealth of descriptive information about the stages of sleep, the functional purposes of the various sleep states are not known. Whereas most sleep researchers accept the idea that the purpose of non-REM sleep is at least in part restorative, the function of REM sleep remains

a matter of considerable controversy. The main difference between REM and non-REM dream is the mental content of activity. However, the dreams in REM and non-REM sleep differ by many characteristics, and mean only 40% of volunteers-sleepers associated dreaming with non-REM sleep [10] in comparison to mean 80% of sleepers associated dreaming with REM sleep [13, 22]. Thus, the non-REM sleep can present some consciousness state [23].

It is well known, that EEG brainwave frequencies correspond to brain states during wakefulness and sleep [10, 24]. The experimentally measured brainwaves diapason falls between 0.1 and 100Hz. The basic EEG diapasons are signed as: beta (14-40Hz), alpha (8-14Hz), theta (4-15Hz), delta (0.5-4Hz) and gamma (40-100Hz). The exemplary correspondence between EEG frequencies and mental states of the brain in wakefulness and sleep is given on **Table 1**. This connection gives possibility to make association between the brain waves frequencies and percent of nasal cycle reversals during wake and sleep.

Table 1. Brainwave frequency range and mental states

Brain state	Frequency range, f (Hz)	Mental state
Awake	12Hz to 100Hz	Conscious state
Stage 1	4Hz to 8Hz	Non-REM dream (Conscious state)
Stage 2	4Hz to 15Hz	Non-REM dream (Conscious state)
Stage 3	2Hz to 4Hz	Non-REM (Nonconscious state)
Stage 4	0.5Hz to 2Hz	Non-REM (Nonconscious state)
REM	15Hz to 30Hz	REM (Conscious state)

HYPOTHESIS

The dynamic of the nasal cycle (the switch of greater airflow between the left and the right nostrils in time) becomes only in consciousness states of the brain (in awake, in REM dream and in non-REM dream of stage 1 and 2). This finding gives possibility the nasal cycle to be used as 'marker' for consciousness i.e. as a peculiar 'marker' for consciousness. Exactly, around the moment of nasal cycle reversal the brain is in a conscious state or as close as possible to the conscious state.

DATA AND METHODS

Data were taken from study of Kimura et al. [8] on pattern of nasal cycle during 24hours continuous registration. The original data include 20 subjects, but we use data only for 16 subjects, which presented a change of nasal cycle during night sleep. The summarized data are presented on **Table 2**.

We examined: 1) the percent of nasal cycle reversals during stage 1 and 2, during REM

stages of sleep and during awake state of brain; 2) the statistic connection between percent of nasal cycle reversals and brainwaves frequencies during wake state and sleep stages.

The brainwaves frequencies used in calculations are given on **Table 3**. The used in calculations frequencies are about mean value for given frequency diapason.

A statistical program was used in calculations.

RESULTS AND DISCUSSION

The all nasal cycle reversals in all 16 subjects occur 169 times for 24 hours (of which 20 during night sleep- 13 times during REM and 7 times during 1 and 2 stage). In 149 times the nasal cycle reversals occur in diurnal period. The corresponding to stages percentages are given in **Table 4**. The brainwave frequencies in diurnal period (in awake consciousness), in REM stage (in REM consciousness) and in 1-2 stages (in non-REM consciousness) are compared with the percentages of nasal cycle

reversals in awake, REM and non-REM consciousness. Accordingly to the introduction all stages of sleep with dream can regard as 'conscious' states of the brain. This gives

possibility to find connection between percent of the nasal cycle reversals and brainwave frequencies, considered as electrophysiological characteristics of consciousness.

Table 2. Summary for the Nasal Cycle (data by Kimura et al., 2013)

No	Age (yr)	Number of Nasal Cycles	Body Position	Sleep Stage of Nasal Cycle Reversal	Number of REM Stages in Sleep
1.	31	11	Right	Stage 2	4
2.	20	17	Supine	Stage 2; REM	5
3.	22	10	Supine	REM	4
4.	24	14	Supine	REM; REM	4
5.	23	12	Supine	REM	2
6.	35	10	Right	REM	4
7.	24	8	Supine	REM	3
8.	42	8	Supine	Stage 2	4
9.	27	7	Supine	REM	5
10.	46	14	Right	Stage 1	3
11.	34	10	Supine	REM	2
12.	30	9	Left/Supine	REM; REM	4
13.	26	7	Right	Stage 1, 2	4
14.	56	16	Supine	Stage 1, 2; 1, W	6
15.	28	6	Supine	REM	4
16.	34	10	Supine	REM	3

Table 3. Brain states and frequencies

Brain state	Frequency, f (Hz)
Awake	50 Hz
Stage 1, 2	10 Hz
Stage 3,4	2 Hz
REM	22 Hz

Table 4. Percent (%) of the nasal cycle reversals during diurnal and night (sleep) period and corresponding brainwave frequencies (in Hz).

Diurnal period	REM	Stage 1 and 2	Stage 3 and 4
88.16%	7.69%	4.14%	0%
50 Hz	22 Hz	10 Hz	2 Hz

The relationship schematically is presented on **Figure 1.**

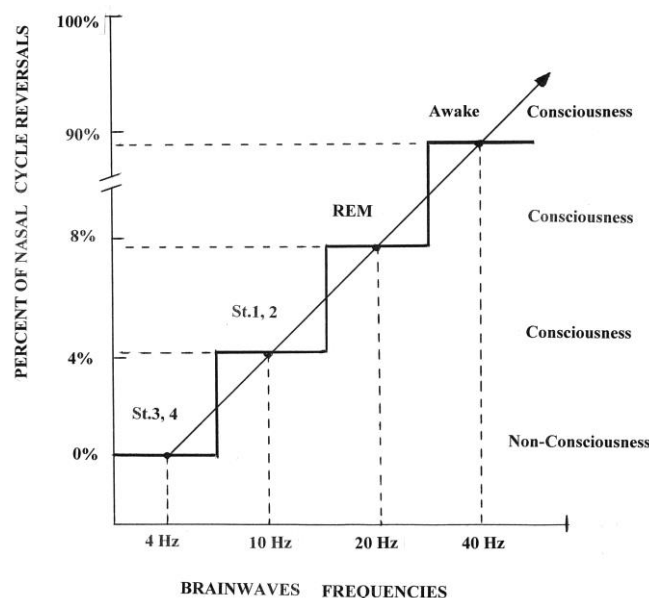


Figure 1. Nasal cycle reversals - brainwaves frequencies relationship.

From **Figure 1** is observed that in stages 1-2, in REM stage and awake state, which are conscious states there is a change of the nasal cycle status. In non-conscious state of the brain with minimum brainwave frequencies (0.5-4 Hz) no nasal cycle switching was observed. The percent of the nasal cycle reversal increase with growth of brainwaves frequencies. At the

same time the level of consciousness from stage 1-2 to REM stage and awake consciousness increases too.

On **Figure 2** is presented the exact mathematical relationship between percent of nasal cycle reversals and brainwaves frequencies.

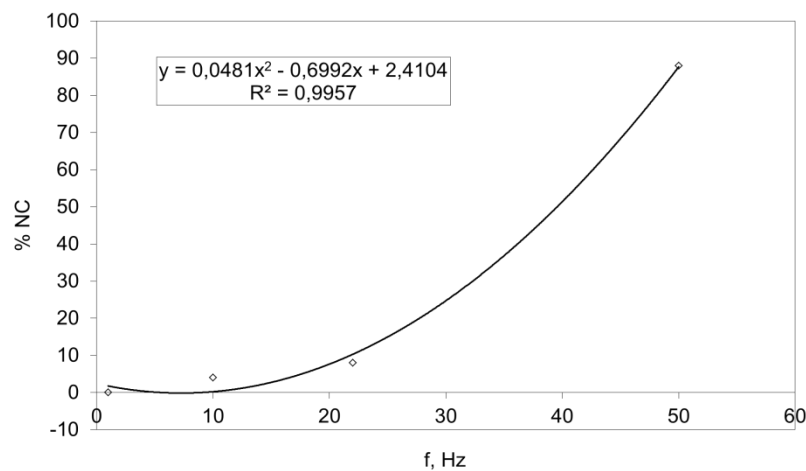


Figure 2. Mathematical connection between percents of Nasal Cycle Reversals (% NC) and Brainwaves Frequency (f, Hz).

The percent of nasal cycle reversals on **Figure 2** should not be regarded as function of brainwaves frequency, but only as a link

between them. The connection between variables can be approximated by a quadratic function of the type:

$$y = 0.0481x^2 - 0.6992x + 2.4104 \quad (R^2=0.9957) \quad (1)$$

where ‘y’ is % of the nasal cycle reversals and ‘x’ is the brainwaves frequency (f, Hz). The high corresponding coefficient $R^2 = 0.9957$

shows that the relationship between the two dimensions is not random. The Eq.1 can be presented also like:

$$\% \text{ NC} = 0.0481 f^2 - 0.6992 f + 2.4104 \quad \text{with } R^2=0.9957 \quad (2)$$

Kimura et al. [8] found that the reversal of cyclic phase during sleep tended to be associated with REM sleep in 68.8%, and associated with postural changes in 18.8% (which correspond to mean postural changes 3.75 times among 16 subjects). From Table 2 it can be seen that the nasal cycle reversals can be associated not only with postural changes of nasal cycle but also with stages 1-2 of night sleep. Indeed, 50% of the nasal cycle reversals (switches) in stages 1- 2 (in subjects No 2, No 8 and No 14) become in position ‘supine’, which does not itself cause nasal cycle reversal, unlike ‘left’ or ‘right’ body positions. In 7 cases (total) the nasal cycle reversal becomes in 1 and 2 sleep stages that correspond to ~ 4% of all nasal cycle reversals during night sleep. The nasal cycle reversals in REM stages becomes in 13 cases, that correspond to ~ 8% of nasal cycle reversal during sleep. Thus, the ratio between the non-

REM to REM dreams is 1 part dreams in non-REM sleep to 2 parts dreams in REM sleep. Interesting is the fact, that the same is the mean ratio between dreaming sleepers upon awakening in non-REM stage (mean~40%) and REM stage (mean~80%) of sleep [13, 22]. The ~88% of all nasal cycle reversals (149 cases) occur in diurnal period of the day, which is from 11 to 22 folds more than nasal cycle reversals in non-REM, and respectively in REM stages of sleep. The ratio between the nasal cycle reversal during diurnal period (149) and during night sleep (20 times) is 7.45 ‘diurnal’ nasal cycle reversals per 1 ‘sleep’ nasal cycle reversal.

A scientific interest is the question: whether switching the nasal cycle into stages 1,2 and REM stages are equivalent, and how they affect the quality of sleep? This important psychophysiological problem is not discussed

and is under consideration [25, 26]. The reverse question of how the quality of sleep affects the number of nasal cycles can also be put? Assuming that the number of nasal cycles during the day is constant (149 times), and during night sleep varies at least 1 to 3 times per subject, then for 16 subjects with 1 nasal cycle reversal this ratio will be 9.3 'diurnal' nasal cycle reversals per 1 'sleep' nasal cycle reversal. In the case of 3 times nasal cycle reversals per subject (with total 48 nasal cycle reversals in 16 subjects) the ratio between 'diurnal' nasal cycle reversals and 'sleep' nasal cycle reversals will be 3.1 'diurnal' per 1 'sleep' nasal cycle reversal. By this way we get the possible proportions between the nasal cycle reversals during the day and during sleep in healthy people. In our case this ratio is between 9.3 and 3.1. The assumption of a 3-times nasal cycle reversals comes from the author's own measurements (unpublished data) for cases of night-time sleep with a duration greater than 8.0 -9.0 hours and more.

MEDICAL APPLICATIONS OF THE HYPOTHESIS

From the above presentation it can assume that the pattern of nasal cycle can present a new method for detection of consciousness i.e. as a peculiar 'marker' for consciousness. Until 2003 year when the connection between the sleep and the nasal cycle was registered by Atanasov et al. [6, 7] the dynamics of the nasal cycle during sleep was not studied [5, 27]. So far, the similar is situation in relation to dynamics of the nasal cycle during brain diseases, including disorders of consciousness, coma and related states [28]. The recent methods for detection of consciousness consist mainly of three groups: neuro-imaging technics, electroencephalography technics and behavior assessment [29, 30]. In addition to these well-established techniques the presence or absence of nasal cycle reversals in patients with brain diseases can be new method for detection of consciousness. One issue of fundamental importance is whether there is a nasal cycle in the absence of consciousness, what we have in the states of coma. Another fundamental issue is the relationship between the parameters of the nasal cycle and the tendency of recovering the patients from coma and related states. These and many other issues are subject to experimental development and measurements in the future. As well as, the future studies in such scientific fields will reveal the limits of relevance and importance of the nasal cycle not only as a respiratory but also as a psychophysiological and psycho-neurological phenomenon.

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