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Alterations of auditory middle latency evoked potentials during yogic consciously regulated breathing and attentive state of mind

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Middle latency auditory-evoked potentials (AEP-MLRs) of 10 healthy male subjects in the age range of 21–33 years, were assessed to determine whether yogic pranayamic practice would cause changes in them. The pranayama type assessed here is an exercise of consciously-controlled rhythmic breathing involving timed breath-holding in each cycle of breathing, while the subject holds utmost attention and experiences the touch of inhaled air in the nasal passage. The results revealed that the Na-wave amplitude increased and latency decreased during the period of pranayamic practice, whereas the Pa-wave was not significantly altered. The change is interpreted as an indication of a generalized alteration caused in information processing at the primary thalamo-cortical level during the concentrated mental exercise of inducing modifications in neural mechanisms regulating a different functional system (respiratory). Further researches are required to understand the operational significances of such changes.

INTRODUCTION

Yogic practices were devised in ancient times to perhaps aid in realising the capability of highest possible functional harmony in body and mind. Pranayamic exercises are among the important yogic practices (Vivekananda, 1973). There are several varieties of pranayamas, some of them (ujjayi, bhastrika variants) require a conscious regulation of the breathing rhythm, maintaining specified ratios of time durations of inspiratory and expiratory phases, as well as timed breath-holding in the post-inspiration or post-expiration period, and also holding attention in either imagining the flow of energy along spinal column collaterally with breathing rhythm (Vivekananda, 1973), or in experiencing the sensation of inhaled air touching and passing through the nasal passage (Behanan, 1937), or on concentrating on certain other parts of the body. Since these types of pranayamic practices involve considerable exercising of conscious control processes with precision, a study of evoked potentials in them may reveal some clues of the brain mechanisms underlying such a conscious exercise. Furthermore, since the respiratory rhythm provides an observable indication of the subject being engrossed in the conscious control process, the experimenter can be sure of the subject engaged in the yogic practice during the data acquisition, unlike in subjects doing meditation when no such external indicator will be available to know whether the subject is smoothly continuing in the meditative exercise. For these reasons, we proposed to examine the ujjayi and bhastrika types of pranayama

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subjects to assess alterations in middle latency auditory-evoked potentials (AEP-MLRs). The AEP-MLRs were chosen to begin with, instead somatosensory MLRs to avoid compounding with any sensory-motor potentials produced during the controlled respiratory movements, and to reveal changes of a generalised nature that might be induced by the consciously attentive yogic exercise in the processing of information in a modality other than the somatosensory. The MLRs have been chosen for the study with the premise that conscious processes actively involve several cortical mechanisms and also that corticofugal control processes may exert significant alterations in the processing of information at the brainstem and thalamic levels (Desiraju, 1979, 1984; Steriade and Llinas, 1988; Pribram and McGuiness, 1993, in press).

METHODS

Subjects

10 male subjects with normal hearing and ages ranging from 21 to 33 years (average ± S.D. 25.2 ± 3.2 years) formed the group of pranayama. 10 more male subjects (age 22 to 42 years, mean ± S.D. 31.7 ± 6.8), who had no training in pranayama or in concentration exercise, were also assessed for detecting effects of attention maintained on the nasal air flow and on ongoing tidal respiration that was not controlled consciously. The study was explained to the subjects and their signed informed consent taken.

Before commencement of training in pranayama, each subject of the pranayama group was tested in three sessions conducted usually at several days apart, to assess baseline variations and changes in middle latency auditory-evoked potentials (AEP-MLRs) occurring in successive periods of the 20-min session. In each session of 20 min, a total of four recordings were made during the following time periods while the subject sat awake and relaxed with eyes closed: (i), one recording in the first 5-min period, i.e., in pre-test eyes closed baseline condition (PEC); (ii), two successive recordings in the next 10-min period, i.e., in eyes closed 'control' sitting without pranayama (ECC) and (iii), one recording in the last 5-min period, i.e., in eyes closed post-test condition (ECP). After acquiring data as described above, the subjects were introduced to the training in pranayama practice: 6 of them in the ujjayi type of pranayama, and 4 in the bhastrika type. After practising the pranayama for an average of 21.8 months (range 18–26 months), the subjects were reassessed in test sessions conducted to record the AEP-MLRs in the same temporal sequence of test periods mentioned above, except that the subjects practiced pranayama during the time-period PR, that corresponded in time to the ECC cited above.

Stimulation and recording settings

The AEP-MLRs were recorded from C_Z–A_1. In each time-period cited above, 1500 responses in the post-stimulus 70 ms time-period were averaged on a Nicolet (USA) Model Med-80-4 computer system. The preamplifier band width was set at 1–1500 Hz. Click stimuli of 40 μs duration, with alternating polarity, were delivered at 5 Hz binaurally through acoustically-shielded earphones. The intensity was set at 40 dB above the threshold of hearing which was about 24 dB under the abovementioned stimulus parameters. It was kept moderate enough so as not to disturb the concentration of subject, and yet be adequate to evoke the potentials with consistency. Subjects were confortably seated during recording sessions in a dimly lighted (twilight), air-conditioned and sound-attenuated cabin, and were watched throughout via a closed circuit low-light-sensitive television.

Measurements and statistical assessment

Peaking latencies of the waves were measured from the moment of stimulus delivery. Peaking amplitudes of the waves were measured taking the level existing at the time of stimulus delivery as the baseline. Averages of the peaking amplitudes and latencies of Na, Pa and Nb waves of the three repeat sessions of a subject were calculated for each time period. Since recordings were made twice in the time period ECC or PR of each of the three sessions, the average of the time period ECC or PR was based on six values. Such averaged values obtained under the conditions of ECC or PR, for the 10 subjects were subjected to the analysis of variance (Snedecor and Cochran, 1967; Zar, 1984) and to the matched pairs *t*-test, to infer whether significant changes occurred in the peaking of waves during pranayama. Also, the baseline data (of PEC time period) obtained before and after undergoing pranayama training were compared.

Since significant changes are observed for only Na wave, data of Pa wave are presented to only a limited extent, and of Nb wave not detailed in this paper for saving space.

Pranayamic methods

Utmost concentration has to be maintained during the following pranayamas. The subject is asked to concentrate on that point in the nasal passage where the inhaled air is first felt. This training in concentration is claimed to create, in the long run, a steadying effect on the mind (Behanan, 1937). During the pranayama, the subject sits with spine erect. In the ujjayi type of pranayama after a slow but complete exhalation through the left nostril, the next breath in inhaled through both nostrils at a uniform pace, with a partially closed glottis, and the abdominal muscles kept in a state or partial contraction. Inhalation is followed by timed breath-holding (the kumbhak phase), during which both nostrils are closed with the right hand, the glottis is also tightly closed, and the chin is lowered to touch the jugular notch (jalandhar bandha or chin lock). At the end of the kumbhak phase, the head is raised back to the normal level, the glottis is opened partially and the subject exhales through the left nostril, while the abdominal muscles go on contracting. This is followed by a phase of external breath-holding during which the abdomi-

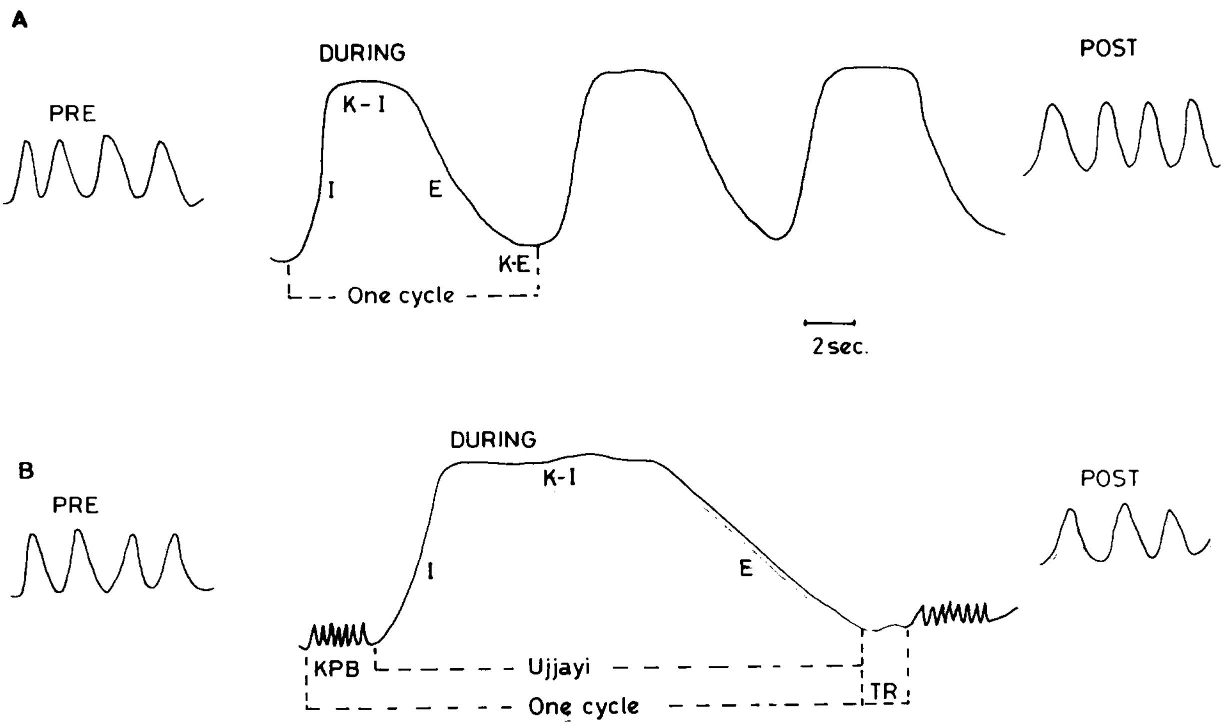

Fig. 1. Illustration of typical breathing cycles in 2 types of pranayamas. (A), ujjayi type, during which the duration of expiration (E) is typically twice that of inspiration (I), and there is a timed breath-holding at end-inspiration (K-I), and also at end-expiration (K-E). Such cycles of breathing are repeated at about 2/min. (B), bhastrika pranayama, in each cycle of which a cycle of ujjayi type of breathing is preceded by a set of rapid breathing cycles of shallow breaths (KPB). The figure also illustrates for comparison the tidal level of breathing of pre- and post-pranayamic periods. TR, transition phase between two bhastrika cycles.

nal muscles are specially held contracted (uddiyan bandha or abdominal lock). This comprises one cycle of ujjayi which is followed by the next (Fig. 1A). Proficiency is acquired through stages of practice; the first stage involves only inhalation and exhalation in the time (duration) ratio of 1:2, later on inhalation, timed internal breath-holding, and exhalation are practiced in the ratio of 1:1:2 and still later on with the ratio of 1:2:2. In the last stage, 'external' breath-holding is introduced, so that the ratio becomes 1:2:2:1. Six of the subjects of this study (RMC, RNG, SNT, SK, SKT and VD) had attained this level of accomplishment in the ujjayi pranayama practice. The average durations ± S.D. (in seconds) of the 3 phases, viz., inspitation, 'internal' breath-holding, exhalation, and 'external' breath-holding were 3.9 ± 1.0, 10.0 ± 3.0, 10.4 ± 1.5 and 5.0 ± 1.0, respectively. The average respiratory rate of these six subjects during pranayama was 2.4 ± 0.8 cycles/min. The four remaining subjects (PRJ, SJR, STP and NVR) practiced a modified version of the pranayama (Fig. 1B). In this, each breathing cycle began with exhalation (at the end of tidal breathing), followed by very shallow, rapid breathing at the rate of approximately 2 breaths/s for a total of 5 s, on average. During this part of rapid breathing (which is known as kapalabhati), the amplitude of respiration was usually only 1/5th of the tidal breathing. This is followed by a cycle of ujjayi pranayama, with inhalation, 'internal' breath-holding, and exhalation in the duration ratio of 1:4:2. There was no phase of 'external' breath-holding. The average durations ± S.D. (in seconds) of these three phases were 5.5 ± 0.7, 22.0 ± 2.5, and 8.0 ± 1.5, respectively. During the ujjayi part of the pranayama, the average respiratory rate was 1.6 ± 0.5 cycles/min. This combination of a brief kapalabhati part and a cycle of ujjayi constitutes one unit which is repeated as long as the session lasts. The glottis is kept open during the kapalabhati part, and partially or fully closed during the ujjayi part as cited above. Such a combination pranayama is called the bhastrika type.

The subjects were expected to keep up their proficiency by practising the pranayama daily for about 20 min, except for any occassional lapses. Their proficiency was checked periodically by a pranayama expert (teacher) to confirm that the subjects were maintaining their practice.

RESULTS

Evoked potentials recorded in different periods of the test sessions conducted on subjects before they were initiated into pranayama training

Peaking latencies and amplitudes of the Na and Pa waves recorded in the subjects before they were trained in pranayama, were not observed to be significantly changing (matched pairs t-test) in the three successive time periods (PEC, ECC, ECP) of a test session (Fig. 2). This check was done to know whether there could be any time effect, or sitting effect, on the evoked potentials recorded in successive time periods of a session. The amplitude of Na wave (mean ± S.D., 10 subjects) was 0.86 ± 0.3 μV in the PEC condition, 0.90 ± 0.44 μV in the ECC condition and 0.81 ± 0.65 μV in the ECP condition; of the Pa wave was 0.66 ± 0.30 μV in the PEC condition, 0.81 ± 0.35 μV in the ECC condition and 0.85 ± 0.45 μV in the ECP condition.

The latencies (mean ± S.D., 10 subjects) of the 3 waves were as follows: Na wave had 17.2 ± 1.54 ms in PEC state, 16.9 ± 1.63 ms in ECC state and 17.0 ± 0.96 ms in ECP state; Pa wave had 26.9 ± 2.12 ms in PEC state, 27.2 ± 2.21 ms in ECC state and 27.2 ± 2.02 ms in ECP state.

Evoked potentials recorded in different periods of pranayama sessions conducted after about 21 months of training and experience in pranayama

The Na wave-peaking amplitude (average of 10 subjects) recorded during pranayama state (PR) was significantly higher (by 108%) than that of the corresponding pretaining period (ECC, Table I, Fig. 2). The value of post pranayama period (ECP) was not significantly different from that of the pre pranayama period (PEC).

The peaking latency of the Na wave of PR was not different from that of PEC, but was significantly less (by 9%) than that of ECC (Table II, Fig. 2).

Analysis of variance test showed significant alteration of Na-wave amplitude in pranayama (Table III), but not so for latency ($F(2,27)$ 2.51, P 0.09). Analysis of Na wave peaking amplitudes done separately for ujjayi and bhastrika subjects showed a more significant alteration during ujjayi than during bhastrika compared to pre-pranayama periods with paired t-test (Table III), but ANOVA could not show adequate significance of the alterations probably due to small sample sizes.

The peaking amplitude and latency of the Pa wave were not significantly altered in pranayama compared to the immediately preceding baseline values of PEC state (Tables I and II). Their values of the period PR were also not significantly different from those of corresponding periods (ECC) of control sessions conducted before pranayama training. Also there were no significant differences in group averages of the 10 subjects for the 3 waves of PEC periods recorded before the subjects were trained in pranayama and after about 21 months of practice.

No differences in wave changes between the two types of pranayamas

There were no significant differences in the peaking amplitudes and latencies of the waves recorded during the two types of pranayamas, viz., in the ujjayi and bhastrika groups (Student's t-test). Further, the trend of increase of Na wave amplitude, and a reduction in its latency was generally observed during both types of

TABLE I

Mean and S.D. of peaking amplitudes (μV) of waves of middle latency auditory-evoked potentials recorded during periods of pranayama (PR), and in preceding eyes closed baseline periods (PEC)

ECP, post-pranayama eyes closed period; ECC, potentials recorded in control sitting sessions conducted on the subjects before they learned the pranayama. n = number of replications on each subject; ns, number of subjects for the group mean, PR, pranayama; B, bhastrika pranayama; U, ujjayi pranayama. n.s. not significant (level of significance $P > 0.050$).

Subject	*PR*	*Na wave (mean (S.D.))*				*Pa wave (mean (S.D.))*		
		Pre initiation ECC (n = 6)	*PEC (n = 3)*	*PR (n = 6)*	*ECP (n = 3)*	*Pre initiation ECC (n = 6)*	*PEC (n = 3)*	*PR (n = 6)*
PRJ	B	1.01(0.33)	1.72(0.38)	6.83(2.11)	3.33(1.78)	1.18(0.78)	0.60(0.35)	2.85(2.27)
STP	B	0.24(0.27)	0.71(0.05)	3.78(1.78)	0.45(0.58)	0.38(0.32)	0.83(0.23)	2.33(1.61)
SJR	B	0.70(0.26)	1.09(0.33)	1.84(0.83)	0.63(0.54)	0.53(0.19)	0.84(0.41)	0.53(0.17)
NVR	B	0.80(0.27)	0.40(0.28)	1.90(1.03)	0.58(0.15)	0.36(0.20)	0.44(0.32)	0.53(0.38)
(A) Sub-group mean (S.D.) ns = 4		0.68(0.32)	0.98(0.56)	3.58(2.34)	1.24(1.39)	0.61(0.38)	0.67(0.19)	1.56(1.20)
RMC	U	0.92(0.74)	2.89(2.05)	3.53(1.33)	2.24(1.29)	0.77(0.40)	2.13(1.40)	2.06(0.63)
RNG	U	0.48(0.18)	0.74(0.22)	1.69(0.46)	0.77(0.34)	0.93(0.54)	0.55(0.55)	2.01(2.39)
SNT	U	1.02(0.92)	1.22(0.22)	1.29(0.47)	1.44(1.04)	1.35(0.78)	0.62(0.38)	0.50(0.47)
SK	U	1.95(0.58)	2.70(1.35)	2.95(0.71)	2.33(0.49)	1.22(0.39)	0.14(0.88)	1.73(0.35)
SKT	U	0.87(0.23)	1.09(0.27)	2.05(0.67)	1.68(0.81)	0.83(0.38)	1.75(0.62)	3.02(0.78)
VD	U	1.03(0.39)	0.26(0.24)	0.88(0.76)	0.24(0.01)	0.60(0.45)	0.82(0.90)	0.93(0.89)
(B) Sub-group mean (S.D.) *ns* = 6		1.04(0.48)	1.48(1.07)	2.06(1.00)	1.45(0.82)	0.95(0.28)	1.16(0.64)	1.70(0.89)
Group mean (S.D.) *ns* = 10		0.90(0.44)	1.28(0.90)	2.67(1.73)	1.36(1.01)	0.81(0.35)	0.97(0.55)	1.64(0.96)
Paired t-tests significances				$P < 0.025$ [a] $P < 0.025$ [b]	n.s.			n.s. [b]

[a] Comparison of PR against ECC.
[b] Comparison of PR or ECP against PEC.

pranayama practices. Hence the results of the 10 subjects were averaged together.

No alterations of the Na waves during period of attention to respiration in untrained subjects.

AEP-MLRs of a group of ten subjects untrained either in pranayama or in concentration, recorded during attention focussed on their unregulated tidal breathing and sensing the accompanying air flow through the nose, revealed no statistically significant (paired t-test) differences in the Na and Pa waves compared to those of the pre-attention baseline periods of the test sessions, repeated thrice in each subject. The Na-wave peaking latencies (ms mean ± S.D. for 10 subjects) for the pre, during and post periods respectively were: 16.58 ± 1.57, 16.80 ± 1.25, 16.56 ± 1.52. The Na-wave peaking amplitudes (μV mean ± S.D.) for the pre, during, and post periods, respectively were: 1.08 ± 1.08, 0.83 ± 0.73, 0.80 ± 0.56. The usual trend of amplitude change in the subjects was towards reduction during the period of attention, contrary to the trend of increase occurring during pranayama.

DISCUSSION

The present results revealed that practices of the ujjayi of bhastrika types of pranayama resulted in a significant increase in peaking amplitudes of Na wave (by 108% over PEC value), and a significant decrease (by 9% of ECC value) in its latency. No such alterations of Na wave were produced in untrained subjects during concentrated attention held on the involuntarily on-going tidal breathing.

There were no alterations in the peaking amplitudes or latencies of the Pa wave. However, since it is well-known that the peaking of MLRs

TABLE II

Mean and S.D. of peaking latencies (ms) of waves of middle latency auditory-evoked potentials

The remaining details are the same as in Table I.

Subject	*PR*	*Na wave (mean (S.D.))*				*Pa wave (S.D.))*		
		Pre initiation ECC (n = 6)	*PEC (n = 3)*	*PR (n = 6)*	*ECP (n = 3)*	*Pre initiation ECC (n = 6)*	*PEC (n = 3)*	*PR (n = 6)*
PRJ	B	16.4(0.49)	15.3(0.78)	14.9(0.36)	16.17(0.17)	25.3(1.25)	23.3(1.66)	22.8(2.28)
STP	B	19.1(3.26)	14.5(1.18)	13.4(0.92)	12.97(0.58)	27.6(3.38)	28.1(1.59)	24.1(4.35)
SJR	B	17.2(0.83)	16.2(0.48)	16.1(0.87)	16.39(0.92)	25.9(3.44)	24.7(3.34)	23.2(1.51)
NVR	B	16.3(2.92)	17.8(0.32)	17.0(1.12)	17.63(0.52)	26.3(3.35)	24.3(0.80)	24.0(3.05)
(A) Sub-group mean (S.D.) *ns* = 4		17.3(1.29)	15.9(1.41)	15.4(1.55)	15.79(1.98)	26.27(0.97)	25.1(2.08)	23.5(0.62)
RMC	U	14.4(0.97)	14.2(0.82)	13.9(0.32)	13.63(0.26)	24.4(3.03)	20.5(0.69)	22.3(1.88)
RNG	U	17.6(1.74)	19.5(2.43)	16.6(2.48)	16.92(0.31)	29.5(3.40)	31.9(1.91)	23.6(5.04)
SNT	U	19.4(1.72)	16.5(1.19)	16.8(1.20)	17.78(1.72)	30.4(1.39)	26.9(1.18)	27.7(1.30)
SK	U	14.9(0.39)	14.5(1.28)	14.9(0.88)	15.03(0.37)	29.7(1.56)	26.3(3.35)	28.7(1.96)
SKT	U	15.8(0.90)	15.6(0.82)	14.7(0.94)	15.14(1.03)	25.1(0.62)	25.9(1.53)	21.4(1.01)
VD	U	17.6(1.29)	17.2(0.04)	15.5(0.42)	16.14(1.29)	27.5(2.45)	28.2(1.44)	24.9(1.16)
(B) Sub-group mean (S.D.) *ns* = 6		16.6(1.90)	16.3(1.96)	15.4(1.13)	15.77(1.48)	27.76(2.53)	26.6(3.70)	23.5(0.63)
Group mean (S.D.) *ns* = 10		16.9(1.63)	16.1(1.69)	15.4(1.23)	15.78(1.59)	27.17(2.11)	26.0(3.11)	24.3(2.31)
Paired t-tests significances				$P < 0.05$ [a] n.s. [b]	n.s. [b]			n.s.

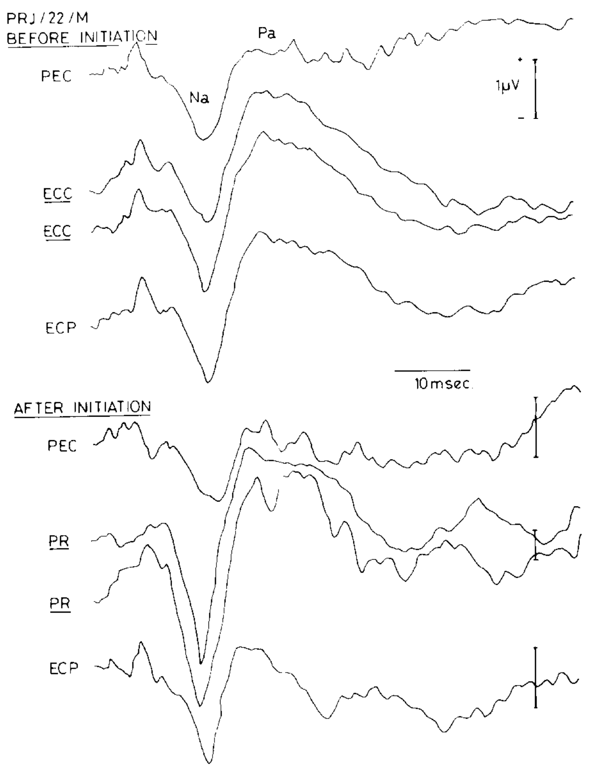

Fig. 2. Typical examples of AEP-MLRs recorded in a subject in a test session conducted before he was initiated into yogic practice, and again after having been initiated and practiced for 23 months. In each test session, AEP-MLRs were recorded four times, i.e., before (PEC), after (ECP) and during the pranayamic practice period (PR). In the sessions conducted before initiation into yogic training also, AEP-MLRs were recorded in the same sequence of time periods, the ECC corresponding to that of PR.

varies considerably (the later the wave type, the more of its variation, in general), it can not be ruled out that the Pa wave alterations may also attain statistical significance when a much larger number of subjects is examined.

The results support the view that the conscious pranayamic practice could lead to a generalized modulation of processing of signals, i.e., even in neural systems not involved in breathing regulation, and also that such a modulation could operate at the primary thalamo-cortical state. It has been postulated that the Na wave may be due to activity at the mesencephalic or diencephalic level and Pa wave to auditory cortex (Deiber et al., 1988). Also, experiencing pranayama exercise over the period of about 21 months did not seem to change the processing of signals at other times (non-pranayama periods) in the subjects, since there was no significant difference in the baseline values (PEC) of the Na wave, obtained before and after about the 21 months of pranayama practice. Hence, no permanent functional changes seem to have occurred in the auditory pathway at the level of generators of the Na wave, but the change occurred only during the periods of pranayama practice. Enhancement of Na wave under ordinary circumstances is interpretted to indicate a facilitation occurring in the processes of sensory signal transmission.

Since pranayama is entirely a voluntarily-controlled exercise, and since the comparison has been made between the AEP-MLRs of unattended involuntary (tidal) breathing period and of the consciously generated pranayamic breathing in the same subjects, the difference in the waves has been considered to be due to the conscious mental exercise and attention underlying the controlled pranayamic breathing, which may be exerted through corticofugal influences. Also, during the period of normal type of attention held on on-going breathing by an untrained group of subjects, no indication of such a change in the auditory signal processing (Na wave) was observed. Hence, the changes in the Na wave could possibly be related to the process of acquisition of specialised skills through training in pranayama to be able to hold the attention and generate consciously the sensorimotor signals that produce the specific breathing rhythm and associated thoughts of sensation proficiently without letting in distractions or breaks. It should be recalled here that the original goal of yoga is not merely an attention-holding process, but is to ultimately acquire ability to control 'mindstuff from taking various forms' (Vivekananda, 1973). It has been also stated that through pranayama "we begin by controlling the breath, as the easiest way of getting control of the prana" ..... "Thence arises supreme control of the organs" (Vivekananda, 1973).

It should also be mentioned here that in a separate study (unpublished) we have noted that

TABLE III

Statistical analysis of peakings of Na and Pa waves of MLRs

These were recorded during the condition of eyes closed control sitting periods with random thoughts (ECC) in test sessions conducted before the subjects were initiated and trained in pranayama, and recorded again after practising pranayama for about 21 months, in test sessions containing pre-pranayama baseline periods of eyes closed state with random thoughts (PEC), and during periods of the pranayama (Ujjayi or Bhastrika) exercise with attention kept on the voluntarily regulated breathing and experiencing in eyes closed state the flow of breath (PR). Comparison is also made (in ANOVA-IV) with data of MLRs of an additional group of subjects uninitiated in pranayama, recorded in test periods of sitting in eyes closed state with random thoughts (PEC^1), and during attention concentrated on the on-going tidal involuntary respiration and flow of breath through the nose in eyes closed state (ECC-concn.). For the ANOVA-I and II: *df* for *F* is 1,16; and *P*(1). n.s., not significant ($P > 0.10$). Other abbreviations are as in Table I.

	Na wave peaking F and P values		*Pa wave peaking F and P values*	
	Amplitude	*Latency*	*Amplitude*	*Latency*
ANOVA I				
a) Factor 1				
Sessions of				
Ujjayi X	1.13	0.17	0.61	1.80
Bhastrika	n.s.	n.s	n.s	n.s.
b) Factor 2				
Conditions of				
ECC × PR	10.91	5.41	7.51	8.44
	< 0.005	< 0.05	< 0.025	~ 0.01
c) a × b	2.95	0.29	2.25	0.01
interaction	n.s.	n.s.	n.s.	n.s.
ANOVA II				
a) Factor − 1				
Sessions of				
Ujjayi X	0.70	0.06	0.73	0.15
Bhastrika	n.s.	n.s.	n.s.	n.s.
b) Factor − 2				
Conditions of				
Pre-pranayama (PEC)	5.39	1.16	3.43	0.25
PR	< 0.05	n.s.	< 0.09	n.s.
c) a × b	2.73	0.03	0.02	0.01
interaction	n.s.	n.s.	n.s.	n.s.
ANOVA III				
Repeated measures			Tukey test (*q* (*df*, *k*):	
(conditions):			PEC vs. ECC = 1.035 (27,3) n.s.	
ECC, PEC, PR	6.42		PEC vs. PR = 3.787 (27,3) < 0.05	
F df 2,27	approx. 0.005		ECC vs. PR = 4.822 (27,3) < 0.01	
ANOVA IV				
Repeated measures			PEC^1 vs. PEC = 0.53 (36,4) n.s.	
(conditions) in			PEC^1 vs. ECC-concn. = 0.67 (36,4) n.s.	
two groups:			PEC vs. PR = 3.74 (36,4) < 0.06	
PEC^1, ECC-concn.,	4.88		ECC-concn. vs. PR = 4.94 (36,4) < 0.01	
PEC, PR	< 0.01			
F df 3,36				

Paired t-tests	*Ujjayi (U)*	*Bhastrika (B)*	*All (U and B)*
For Na amplitude	$t(5) = 4.287$	$t(3) = 2.178$	$t(9) = 2.594$
PEC vs. PR	$P(1) < 0.005$	$P(1) = 0.07$	$P(1) < 0.025$

the Na-wave changes were absent during pranayama in subjects of long-standing practice (more than 60 months experience of pranayama). The absence of the Na-wave change may be due to their practising pranayama for so long, by which time the practice would have become so automatic, like a reflexive automation, without needing much of a close attention and mental activity. In one subject (SKT), of the present group as well, a follow-up repeat study done after 30 months of pranayamic experience revealed that the Na-wave changes were no longer occurring during the pranayama session. This is consistent with what has been reported (Seitz et al., 1990) in voluntary motor learning, that alterations in activity (as seen through blood flow changes) or certain areas of the cerebral cortex 'vanished' after accomplishing the learning to perform a task automatically. When the discrete 'forms' of thoughts of sensation of the pranayamic exercise give place in automatic performance to a relatively uniform state of mind with some stilling of thoughts perhaps through other neural mechanisms, the general control over the primary thalamo-cortical processes of information transmission may no longer be required. At the present time, little is known about neural structures and processes that generate transcendental and abstract states of conscious experiencing, in contrast to some knowledge available on the ordinary perceptions of self-conscious states. The types of association cortical neural mechanisms, in particular of the prefrontal system with its limbic interactions (Desiraju, 1979; 1981) that are usually supposed to play roles in determining the nature of contents and states of human mind have yet to be identified. Moreover, advancement in understanding the fundamental source of consciousness and its relation to brain will ultimately determine the extent to which the above can be understood (Desiraju, 1984). The Na-wave changes observed in auditory pathway during attention and conscious regulation of respiratory cycles in pranayama may reflect some generalized process of a dynamic change induced in neural activity at the mesencephalic or diencephalic level.

Oxygen consumption values (Telles and Desiraju, 1991) determined during the period of practice of ujjayi of the type comparable to the variety used in the present study indicated a reduction in metabolism by 19%, and no signs of hypo- or hyperventilation effects. Further, transient changes in systemic circulation do not effect cerebral metabolism due to auto-regulation of blood flow in brain. Hence, the increase in Na-wave amplitude (while the Pa wave remains unchanged) as observed in the present study can not be supposed to be due to any changes in levels of cerebral O_2 or CO_2 as they are most unlikely to be caused.

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