Respiration Physiology (1988) **72**, 123–130
Elsevier

RSP 01392

Effects of focusing attention on breathing with and without apparatus on the face

P.J. Western and J.M. Patrick

Department of Physiology and Pharmacology, University of Nottingham Medical School, Clifton Boulevard, Nottingham NG7 2UH, U.K.

(Accepted for publication 21 November 1987)

Abstract. In an attempt to identify a cause for the alteration in breathing pattern seen when conventional respiratory apparatus is applied to the face, we have studied the effects of causing the subject to focus attention on breathing by counting breaths in threes for 5 min. We used the respiratory inductance plethysmograph in 18 naive subjects who were unaware that their breathing was being measured. In the control periods, distraction was provided by a recorded story played through head-phones. The experiment was repeated with the rim of a facemask applied to the face. Focusing attention on breathing caused a prolongation of inspiration at a constant mean inspiratory flow, and a lengthening of expiration. Tidal volume but not ventilation was increased. The facemask rim caused no significant change. It is concluded that conscious awareness of breathing could account for a major part of the effect of conventional respiratory apparatus.

Conscious control; Effects of apparatus; Respiratory inductance plethysmograph; Ventilation monitoring

The conventional methods used for ventilatory measurements in human subjects require the connection of apparatus, either an airtight facemask or a mouthpiece and noseclip, to the upper airway. These alter ventilation and its patterns at rest (Milner, 1970; Gilbert *et al.*, 1972), in exercise (Sackner *et al.*, 1980) and during CO_2 breathing (Weissman *et al.*, 1984). Therefore their use in the laboratory or in ambulatory monitoring (Patrick *et al.*, 1980; Vibert *et al.*, 1987) may provide a distorted view of normal control mechanisms or obscure the subtle effects of factors such as drugs or face immersion.

Among possible explanations for the effects of respiratory apparatus are (a) the introduction of additional dead space or resistance to airflow, (b) the stimulation of facial trigeminal receptors around the nose and mouth, (c) the altered relative contributions of the nasal and oral routes of breathing, and (d) influences on brain-stem nuclei or spinal motor-neurones from higher centres when the act of breathing is brought to the subject's consciousness. The first three have been extensively studied, but rather

Correspondence address: Dr. J.M. Patrick, Department of Physiology and Pharmacology, University of Nottingham Medical School, Clifton Boulevard, Nottingham NG7 2UH, U.K.

little direct attention has been given to the last despite the long recognition of the importance of conscious control of breathing.

The objective of the present study was to determine the effects of focusing the subject's attention on breathing, with and without the presence of additional sensory input similar to that normally associated with direct respiratory measurements, but without added dead space and without necessitating any change in the route of breathing. A preliminary report of this work has been given (Patrick and Western, 1987).

Methods

Subjects. Eighteen healthy male subjects (age 17–59 years, weight 59–96 kg, height 1.67–1.92 m, $FEV_1 \times 100/FVC$ 77–93%) were studied. None had taken part previously in respiratory experiments of any kind. They were deliberately misled into believing that the procedures related to ECG monitoring and no mention was made of the real purpose of the experiment. The protocol met the requirements of the Medical School Ethical Committee and the subjects gave consent in writing.

Apparatus. ECG chest electrodes were fitted and connected to a monitor but no detailed analysis was carried out on the heart rate recordings. A respiratory inductance plethysmograph ('Respitrace'; Cohn *et al.*, 1982) was fitted in the standard way and used in the AC mode. The oscillator was taped to the clothing beneath an elasticated retainer. The subject, wearing a headphone set, was seated in a comfortable chair which fully supported the trunk and arms, and was asked to adopt a relaxed posture and to move as little as possible during the experiment.

Protocol. For half of each experiment a soft lightweight plastic facemask was fitted, supported by a single elastic strap around the head. The mask had been cut away so that no dead-space was added. All that remained was a 1–2 cm wide rim in apposition to the chin, the cheeks and the bridge of the nose.

The primary intervention was to direct the subject's attention to his breathing ('focusing'): it was the intention not to introduce any deliberate voluntary respiratory control. He was merely told 'count your breaths in groups of three and on the third breath press the button in your hand'. The button activated an event-marker on the chart-record, and confirmed that the subjects complied with these instructions. Reminders were given on only three occasions. The focusing period was preceded by a distraction period in which the subject listened to a tape-recorded story relayed through the headphones. After the period of focusing the subject was told to forget the counting and the story was resumed. In this way one period of focusing and two periods of distraction were achieved both with and without the facemask rim in place, giving a total of six periods each lasting 5 min. For half the subjects the periods with the mask preceded those without, but every experiment began with a single distraction period without the facemask after a steady ventilatory pattern had been established. The analogue signals from the inductance plethysmograph were displayed on a Grass Polygraph and simultaneously recorded onto a Racal Instrument Tape-recorder (Store 4) for computer analysis of the final 2 min period later.

Calibration of the respiratory inductance plethysmograph. The calibration procedures were always delayed until the end of the completed experiment: no identifiable respiratory equipment, apart from the face-mask rim, was introduced before this time. The subject, who remained in the same seated position, wore a noseclip and took about 25 breaths from an air-filled bag-in-a-box system connected to a dry spirometer (Ohio), voluntarily providing a range of tidal volumes. Simultaneous recordings of the spirometer volume and of the signals from the two plethysmograph coils were made and these were analysed as described below. A pilot experiment showed that a calibration performed after 30 min sitting in the chair did not differ from that at the outset.

Analysis of tape-recorded waveforms. The tape-recordings were played back at the original recording speed into a BBC Microcomputer Model B with the ADC sampling each channel at 20 Hz. The waveforms were inspected on the screen together with the peaks and troughs that had been identified by the BASIC program. Volume calibration was performed using a multiple regression analysis of the inspired tidal volumes (V_T) derived from the spirometer record on the one hand and the two RIP coils on the other (*cf.* Bolton *et al.*, 1981). This provided an equation of the form

$$V_{T,\ \mathrm{spirometer}} = a + b_1 \cdot V_{T,\ \mathrm{rib\ cage}} + b_2 \cdot V_{T,\ \mathrm{abdomen}} \tag{1}$$

R^2 values were between 0.822 and 0.987 (mean 0.956), giving standard errors of the estimate of 40 $\pm$ 13 ml (SD). The regression coefficients (a, b_1 and b_2 in eq. (1)) were then used to calculate the actual tidal volume of each breath in the experimental record. This method of calibration assumes that the two coils always moved in the same direction, *i.e.* there was no paradoxical breathing. This was established from an inspection of the shapes obtained when the rib-cage and abdominal signals were displayed in the X-Y mode, and confirms the findings of Sackner *et al.* (1984) in their normal subjects.

The inspiratory and expiratory durations (T_I, T_E) were also calculated. Mean steady-state values for these and other derived respiratory variables (duty cycle, T_I/T_{TOT}; inspired ventilation, $\dot{V}_I$; and mean inspiratory flow, V_I/T_I), were calculated for each period for each subject. Two-and three-way analysis of variance (ANOVA) providing within-subject comparisons (SPSS-X) was used to identify significant effects of the interventions.

sults

r each measured and derived variable, values in the two distraction periods before d after each focusing period were first compared. There were no significant differ- :es (paired *t*-test), so for each variable the average of the pre- and post-focusing values .s taken for comparison with the single value obtained during focusing.

Table 1 summarises the results for the 18 subjects. The *F*-values in a 3-way ANOVA shown in table 2. The effect of applying the facemask rim was not significant for y variable: nor were the interactions between facemask and focusing.

The significant effect on the ventilatory pattern of focusing attention on breathing bles 1 and 2) is illustrated in fig. 1 for the periods with and without the facemask)arately. In both situations, focusing had the effect of prolonging inspiration by about ?% without affecting mean inspiratory flow (VT/TI). Tidal volume and total breath

TABLE 1

an ± SE (n = 18 subjects) for respiratory variables with and without focusing attention on breathing, with and without a facemask.

	VT (ml)	TTOT (sec)	TI (sec)	TE (sec)	TI/TTOT (%)	$\dot{V}$I (L·min^{-1})	VT/TI (ml·sec^{-1})
face mask; unfocused	372	3.89	1.54	2.32	39.7	5.79	248
	23	0.11	0.05	0.09	0.7	0.33	16
face mask; focused	447	4.58	1.90	2.68	42.0	5.92	239
	51	0.39	0.15	0.25	0.8	0.46	17
:e mask; unfocused	383	4.09	1.65	2.44	40.6	5.72	232
	25	0.15	0.06	0.11	0.7	0.33	14
:e mask; focused	484	5.12	2.13	2.99	42.3	5.98	232
	53	0.50	0.18	0.33	0.8	0.39	16

TABLE 2

nmary of the 3-way analysis of variance for respiratory variables. For each factor listed, the *F*-ratio and its significance (**P* < 0.1; ***P* < 0.01) are given. d.f. = degrees of freedom.

	d.f.	VT	TTOT	TI	TE	TI/TTOT	$\dot{V}$I	VT/TI
ojects	17	10.93 **	4.89 **	3.60 **	6.27 **	6.86 **	15.25 **	15.61 **
:using	1	16.86 **	12.98 **	18.90 **	9.97 *	18.54 **	1.16	0.47
:emask	1	1.05	1.36	1.96	1.14	1.58	0.01	0.45
:using × facemask	1	0.35	0.23	0.19	0.23	0.09	0.09	0.21
sidual	50	–	–	–	–	–	–	–

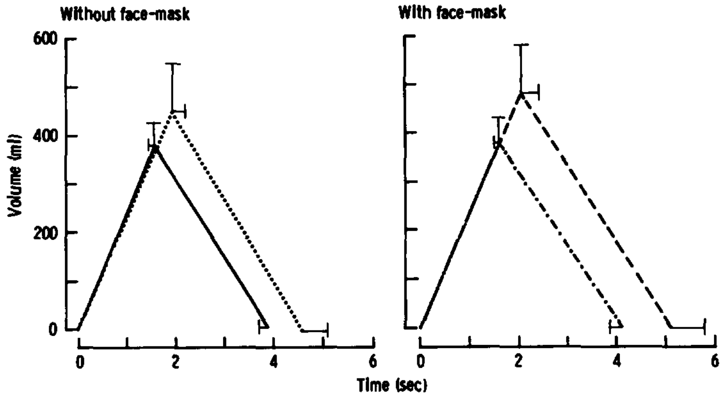

Fig. 1. Representation of the mean breath in 18 subjects with (......, ---) and without (—, -.-) their attention focused on their breathing (a) without facemask and (b) with a facemask rim applied to the face. The bars for tidal volume, inspiratory duration and total breath duration show the 95% confidence limits for the mean of 18 values.

duration were increased by 23% and 21% respectively. Inspired ventilation was slightly but not significantly increased.

Discussion

These data show that when a subject's attention is focused on breathing by the requirement to count breaths, a deeper and slower pattern of respiration results, with no change in overall ventilatory drive. The changes are small and were only revealed by studying a relatively large number of subjects whose individual responses varied widely. Careful attention was paid to the avoidance of any clue which might have allowed the subjects' deliberate conscious control to influence the outcome. Neither the purpose nor even the context of the experiment was revealed before the final calibration of the unobtrusive respiratory monitoring device. Counting breaths in groups of three was not intended to be stressful, and it proved to be a good method of focusing the subjects' attention on their breathing. We wished to avoid any stress of mental arithmetic which both Gautier (1969) and Bechbache *et al.* (1979) found to cause a shortening of Ti and Te: they interpreted this as a response to anxiety. The recorded story, which had no emotive or rhythmic content, provided adequate distraction during the remaining periods.

Respiratory physiologists wishing to exclude cortical influences commonly 'distract' their subjects by getting them to read a book, listen to recorded words or music, or watch a video screen. However, it has recently been pointed out that these distracting activities may themselves affect ventilation. Shea *et al.* (1987) have described the respiratory

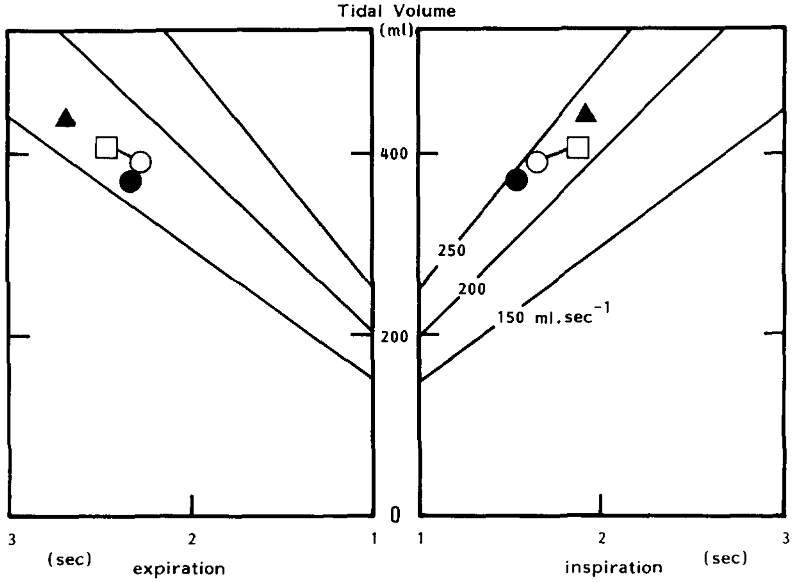

Fig. 2. Comparison of results of Shea *et al.* (1987) (□, ○) with those of present study (▲, ●), showing mean tidal volume and inspiratory and expiratory duration in subjects sitting at rest with no respiratory apparatus applied to the face (18 subjects in each study). (○, ●) Listening to a story; (□) relaxed wakefulness, no auditory input; (▲) counting breaths in threes. Isopleths for mean inspiratory and mean expiratory flows at 150, 200 and 250 ml · sec^{-1} are given.

effects of listening to a story in subjects lying at rest with their eyes closed. The changes found in their 18 subjects are illustrated in fig. 2, alongside the data from the present experiments. The similarity between the absolute values in the two groups of subjects listening to a story is striking. When our subjects stopped listening to the story and counted their breaths instead, they changed their breathing pattern in much the same way as Shea's subjects did when their auditory input was switched off and they were not focusing attention on their breathing, but by twice as much. This suggests that no more than half the difference between the two conditions in our experiment can be attributed to the effect of listening to the story *per se*. The rest is attributed to a separate effect on the rhythm generator of neuronal traffic consequent upon the subjects' conscious perception of their breathing. It is noteworthy that it is the pattern and not the overall ventilatory drive that is changed by focusing attention on breathing: neither mean inspiratory flow nor minute ventilation are altered. This adds further weight to previous suggestions (Cunningham, 1974; Vibert *et al.*, 1987) that overall ventilation and its detailed pattern are controlled independently.

This new observation provides a possible mechanism for at least part of the widely-described effect on ventilatory patterns of using conventional equipment. Gilbert *et al.* (1972) described the slowing and deepening of breathing that accompanied the insertion of the mouthpiece of a respirometer. This is generally credited as the earliest report of this phenomenon, but Milner in 1970 had made a similar observation while developing an inflated jacket for making respiratory measurements. He pointed out that 'the use of a spirometer focuses the subject's attention on his breathing, leading to increased tidal volumes and often hyperventilation'. In fact, breath durations in his study were increased by 11% with the use of the spirometer in his 6 adult subjects, tending to offset the 23% rise in tidal volume.

The effects seen by Milner (1970), Gilbert *et al.* (1972) and many others is not due to gentle stimulation of the skin around the mouth and nose because the facemask rim has no effect in adults, as shown here and previously by Maxwell *et al.* (1985). Application of a noseclip alone does not alter ventilatory drive, expressed as minute ventilation or VI/TI (Weissman *et al.*, 1984; Maxwell *et al.*, 1985; Perez and Tobin, 1985), and it has inconsistent effects on respiratory timing. Perez and Tobin (1985) found that the insertion of an occluded mouthpiece without a noseclip had no respiratory effect, although Gilbert *et al.* (1972) had found a rise in tidal volume and a fall in frequency when an open mouthpiece was applied. In none of these studies was ventilation increased by the addition of either a noseclip or a mouthpiece alone.

When the two are used together, however, there are consistent findings of a raised tidal volume with a constant duty cycle (TI/TTOT). Either ventilation or mean inspiratory flow, or both, are raised. Three groups (Sackner *et al.*, 1980; Maxwell *et al.*, 1985; Perez and Tobin, 1985) found prolongations of both inspiratory and expiratory durations and therefore a fall in respiratory frequency, but Askanazi *et al.* (1980) reported a rather stable timing pattern that was not affected by applying apparatus to the face. Some of the minor discrepancies between these reports may relate to the wide variability in response between subjects and the degree to which they directed attention to their breathing.

A further source of variation would have been any failure to ensure that the route of breathing (oral and nasal) was not altered by the intervention. Weissman *et al.* (1984) found no change in VT and VI when naive subjects changed from nose to mouth breathing, and Hirsch and Bishop (1982) found that the addition of a noseclip made no difference to the breathing pattern recorded using a facemask. These data suggest that the enforced change in the route of breathing to the mouth from the natural route through the nose does not of itself alter the breathing pattern.

Gilbert *et al.* (1972) suggested that there were four possible ways in which the application of conventional respiratory apparatus could change the natural resting ventilation. They were by (a) adding dead space, (b) changing the route of breathing, (c) stimulating the face, and (d) bringing about a conscious awareness of breathing. Weissman *et al.* (1984) suggest that the route of breathing is only important if a change in airway resistance occurs, and this might be detected by upper airway receptors (Douglas *et al.*, 1983). The reflex response to facial stimulation seems to be of little importance in adults (Maxwell *et al.*, 1985; and the present study). The change in ventilatory pattern produced here simply by making the subjects focus attention on their breathing suggests that conscious awareness of breathing is an important factor in respiratory control in man at rest. Conventional apparatus may draw a subject's attention to his breathing by altering airway resistance or by causing discomfort around the nose or mouth.

Acknowledgements. P.J.W. is supported by an MRC Research Studentship. The BBC Computer and the Respiratory Inductance Plethysmograph were purchased with a grant from the British Heart Foundation. Mr. John Hillier provided valuable assistance with the computer programming. We are grateful for the willing cooperation of our subjects, and regret that we had to mislead them in order not to prejudice the outcome of the study.

References

Askanazi, P., P.A. Silverberg, R.J. Foster, A.T. Hyman, J. Milic-Emili and J.M. Kinney (1980). Effects of respiratory apparatus on breathing pattern. *J. Appl. Physiol.* 48: 577–580.

Bechbache, R.R., H.H.K. Chow, J. Duffin and E.C. Orsini (1979). The effects of hypercapnia, exercise and anxiety on the pattern of breathing in man. *J. Physiol. (London)* 293: 285–300.

Bolton, D.P.G., P.A. Johnson and J. Marsh (1981). The accuracy of a measurement of tidal volume from rib cage and abdominal movements. *J. Physiol. (London)* 322: 39–40P.

Cohn, M.A., A.S.V. Rao, H. Broudy, S. Birch, H.L. Watson, N. Atkins, B. Davis, F.D. Stott and M.A. Sackner (1982). The respiratory inductance plethysmograph: a new non-invasive monitor of respiration. *Clin. Respir. Physiol.* 18: 643–658.

Cunningham, D.J.C. (1974). Integrative aspects of the regulation of breathing. In: Respiratory Physiology, edited by J.G. Widdicombe. MTP International Review of Science. London, Butterworth, pp. 303–370.

Douglas, N.J., D.P. White, J.V. Weil and C.W. Zwillich (1983). Effect of breathing route on ventilation and ventilatory drive. *Respir. Physiol.* 51: 209–218.

Gautier, H. (1969). Effets comparés de stimulations respiratoires spécifiques et de l'activité mentale sur la forme du spirogramme de l'homme. *J. Physiol. (Paris)* 61: 31–44.

Gilbert, R., J.H. Auchinloss, J. Brodsky and W. Boden (1972). Changes in tidal volume, frequency and ventilation induced by their measurement. *J. Appl. Physiol.* 33: 252–254.

Hirsch, J.A. and B. Bishop (1982). Human breathing patterns on mouthpiece or facemask during air, CO_2, or low O_2. *J. Appl. Physiol.* 53: 1281–1290.

Maxwell, D.L., D. Cover and J.M.B. Hughes (1985). Effect of respiratory apparatus on timing and depth of breathing in man. *Respir. Physiol.* 61: 255–264.

Milner, A.D. (1970). The respiratory jacket: a new method for measuring respiration. *Lancet* ii: 80–81.

Patrick, J.M., A.M. Ross, and S.P. Hanley (1980). Unobtrusive respiratory monitoring. Proceedings of the 3rd International Symposium on Ambulatory Monitoring 1979, Northwick Park, London, Academic Press, pp. 321–328.

Patrick, J.M. and P.J. Western (1987). Ventilatory consequences in man of focusing on breathing and of using a facemask. *J. Physiol. (London)* 382: 52P.

Perez, W. and M.J. Tobin (1985). Separation of factors responsible for change in breathing pattern induced by instrumentation. *J. Appl. Physiol.* 59: 1515–1520.

Sackner, J.D., A.J. Nixon, B. Davis, N. Atkins and M.A. Sackner (1980). Effects of breathing through external dead space on ventilation at rest and during exercise II. *Am. Rev. Respir. Dis.* 122: 933–940.

Sackner, J.D., H. Gonzalez, M. Rodriguez, A. Belsito, D.R. Sackner and S. Grenvik (1984). Assessment of asynchronous and paradoxic motion between rib cage and abdomen in normal subjects and in patients with chronic obstructive pulmonary disease. *Am. Rev. Respir. Dis.* 130: 588–593.

Shea, S.A., J. Walter, C. Pelley, K. Murphy and A. Guz (1987). The effect of visual and auditory stimuli upon resting ventilation in man. *Respir. Physiol.* 68: 345–357.

Vibert, J-F., M-F. Villard, D. Caille, A.S. Foutz and A. Hugelin (1987). Does a multi-oscillator system control respiratory frequency independently of ventilation. In: Proceedings of the Symposium on 'Concepts and Formalizations in the Control of Breathing', Solignac, France (in press).

Weissman, C., J. Askanazi, J. Milic-Emili and J.M. Kinney (1984). Effect of respiratory apparatus on respiration. *J. Appl. Physiol.* 57: 475–480.