Carbon Dioxide Sensitivity and Personality

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Although respiratory physiologists have long noted marked interindividual differences in ventilatory response to CO_2, these differences have not been related previously to personality. In this study, 33 volunteer test subjects underwent 3 or 4 trials of a rebreathing test for CO_2 sensitivity. During each trial the increase in the subject's ventilation was related to increase in alveolar CO_2. The subjects were also administered the Minnesota Multiphasic Personality Inventory (MMPI). Elevations were noted on nearly all standard scales of the MMPI for low responders to carbon dioxide, with the differences between high and low responders reaching statistical significance on several scales. Differences in personality traits between high and low responders to CO_2 suggests that this test may be useful for psychosomatic investigations. The interpretation of CO_2 sensitivity as an index of the excitatory level of the respiratory center in the medulla is discussed.

Despite many apparent relationships between respiration and psychological phenomena, the complexities of respiratory physiology—with its many interrelated regulatory influences, both voluntary and autonomic—have limited numerous attempts at establishing reproducible correlations. Earlier investigations, using spirographic tracings (1–5), as well as more recent work utilizing a greater array of physiologic measurements (O_2 uptake, end tidal CO_2 concentration, minute ventilation (6–8)), have attempted to assess respiratory function during various emotional states. These studies have suggested only very general correlations between personality variables and respiratory functioning. Considering the multiple control mechanisms involved in respiration, it is indeed unlikely that specific affective or cognitive styles would demonstrate any marked respiratory specificity.

We have recently become interested in a more specific, and possibly more heuristically promising respiratory parameter: the ventilatory response to CO_2, as an index of respiratory "sensitivity" to CO_2. Although physiologists have measured respiratory response to CO_2 for many years (9–13), it has not been used previously, to our knowledge, in psychophysiological studies. A steady state method measures respiratory response to CO_2 by allowing subjects to inhale several different concentrations of CO_2; each time respiration is monitored for 10–20 minutes to allow ventilatory increase to stabilize. Recently, Read (14, 15) has described a less time consuming and simpler rebreathing method, in which only 2–4 minutes of rebreathing into a closed system produces equally reliable results.

As part of a larger study of respiratory function in hot environments, we had noticed, consistent with past reports (12), marked interindividual differences in such CO_2 "sensitivity." In the group of subjects reported here, we investigated

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Received for publication February 8, 1972; final version received July 24, 1972.

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the possibility that differing ventilatory response to CO_2 might be associated with differing personality characteristics. We speculated that CO_2 response might be a much more sensitive method of studying relationships between respiration and personality than previous, more global measurements of respiratory function.

SUBJECTS AND METHODS

Thirty-three young U.S. Army enlisted men served as subjects. Their mean age was 20.6 years. They were recruited from a pool of military subjects, all of whom had volunteered variable periods of time during their military service to serve as test subjects for various research projects. We obtained their consent to be used as subjects by us for a study of physical performance in a hot climate. The CO_2 sensitivity data was obtained for each subject 1–4 weeks prior to his scheduled participation in the heat phase of the study—during several days of "preliminary testing," as we explained to the subjects. This period also included a physical examination, psychological testing, and orientation.

The rebreathing method of Read was conducted in the following manner: After sitting quietly for 15 minutes, the subject breathes out "as hard as he can" into the room air and then quickly inserts a mouthpiece. For the next 2 1/2–3 minutes the subject rebreathes a 7-l volume of approximately 6% CO_2–94% O_2 contained in a system consisting of a 13.5-l spirometer, large bore respiratory tubing, and a two-way respiratory valve with mouthpiece. Subsequent respiratory excursions of the spirometer bell are continuously recorded on an ink kymograph attached to the spirometer. After 60 seconds, and each 30 seconds thereafter, a small air sample is withdrawn from the closed rebreathing system and analyzed for CO_2 concentration (LB-1 Beckman CO_2 analyzer). Since the entire system is in equilibrium (alveoli to spirometer), P_{CO_2} of the system is also P_ACO_2 (14, 15). At the end of the 2 1/2 to 3 minutes the mouthpiece is removed. Most subjects report sensations of "being out of breath" during the experience, and some subjects report having felt dizzy during the trial. It is rare, however, for any significant discomfort to be reported, especially after the first trial.

Each subject was scheduled to have four trials on the CO_2 test; because of minor technical and administrative problems, 7 of the 33 subjects only underwent three trials. The data thus consists of some 125 measurements of CO_2 sensitivity on 33 subjects. All values were corrected to standard BTPS (body temperature, pressure ambient, saturated). Further, we became curious as the study progressed about resting P_ACO_2 (end-expiratory P_{CO_2}), and were able to obtain a P_ACO_2 on 18 of the subjects just prior to each of their trials on CO_2 sensitivity.

In addition, each subject was administered a complete Minnesota Multiphasic Personality Inventory (MMPI) (16). This was subsequently scored for all standard scales, as well as selected special scales.

RESULTS

For each trial a regression analysis was performed between P_ACO_2 and ventilation (respiratory rate times amplitude). As proposed by Read (15), we selected the ventilation value at a P_ACO_2 of 50 mm Hg (V_{E50}) as an index of CO_2 sensitivity. 50 mm Hg for P_ACO_2 was chosen as a convenient value, since most subjects' P_ACO_2 rises during each trial from approximately 45 mm Hg to approximately 60 mm Hg. Occasionally the first P_ACO_2 reading was already above 50 mm Hg and we then extrapolated the value. Read (15) has previously shown that V_{E50} is a more reproducible index than that drived from the alternative method of taking the slope of the regression line.

We found, as have previous investigators, quite consistent V_{E50} values for each subject across his trials, although occasional apparently aberrant values did occur. Kendall's Coefficient of Concordance (17), based upon the 26 subjects who had 4 trials, was 0.702 ($\chi^2 = 70.2$, $df = 25$, $p < 0.001$). Subjects' mean V_{E50} values ranged from 6.7 l/min to 37.1 l/min, with a mean V_{E50} for the entire group of 20.8 l/min. We call subjects whose mean V_{E50} was above this group mean "high responders" (N = 15), and those below it "low responders" (N = 18).

The subjects could have been placed in almost identical groups on the basis of their initial $V_{E_{50}}$ determination; values for the initial $V_{E_{50}}$ determination correlated 0.89 with mean values across all 3 or 4 trials.

Figure 1 plots the mean profiles on the standard MMPI scales between the two groups. Table 1 lists the mean differences between these scales, as well as several additional MMPI scales. All scales have K added, when appropriate, and are reported as T (standard) scores except on those scales in which T scores are not available (16). The group of low responders had elevations on nearly all standard and special scales, and lower scores on Barron's Ego Strength scale. Statistically significant elevations for the low group occurred on the Depression, Psychopathic, Psychasthenic, Social Introversion, and Welsh Factor A scales. The elevations on the Hypomanic scale for all subjects is consistent with a general trend which we have noticed for most of our volunteer test subjects.

On the 18 subjects in which we obtained resting P_ACO_2 measurements prior to each trial, mean resting P_ACO_2 values ranged from 33.9 mm Hg to 45.7 mm Hg. When each of these mean resting values was compared to the mean $V_{E_{50}}$ value for each subject, no correlation could be demonstrated ($r = 0.03$). These resting P_ACO_2 values were also compared to each MMPI scale; no significant differences were found on any MMPI scale based upon these resting P_ACO_2 values.

DISCUSSION

The general elevation of the MMPI in the group of low responders to CO_2 suggests a relationship between personality characteristics and differing respirato-

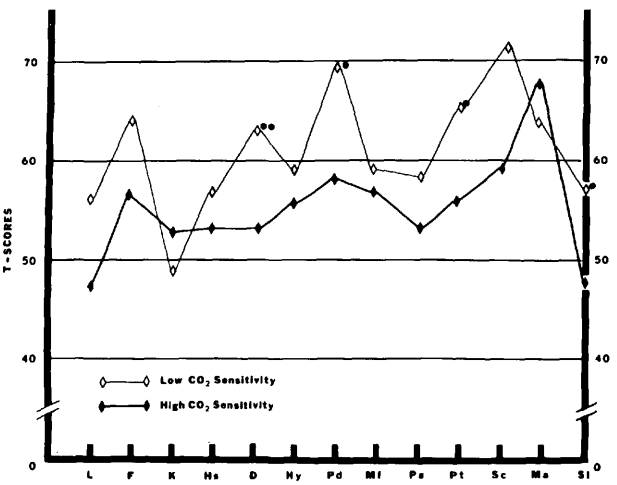

Fig. 1. MMPI profiles for both high and low CO_2 sensitive groups; ●$P < 0.05$, ●●$P < 0.01$.

Table 1. MMPI Scales for High and Low Sensitive Subjects

Scale	High CO_2 Sensitive group (N=15)		Low CO_2 Sensitive group (N=18)	
	Mean	SD	Mean	SD
Lie (L)	47.5	7.8	50.6	8.5
Correction (K)	52.5	10.9	49.4	13.4
Validity (F)	55.9	9.5	63.8	13.1
Hypochondriasis (Hs)	52.8	13.3	57.5	13.5
Depression (D)[b]	52.8	9.6	64.4	11.6
Hysteria (Hy)	55.2	8.5	59.0	10.4
Psychopathic (Pd)[a]	58.6	9.6	69.1	14.6
Mas-Fem (Mt-M)	56.7	7.9	59.5	8.45
Paranoia (Pa)	52.1	11.6	58.9	15.3
Psychasthenia (Pt)[a]	55.7	10.3	65.1	14.3
Schizophrenia (Sc)	59.7	12.3	71.1	19.63
Hypomania (Ma)	67.0	10.2	63.9	10.9
Social introversion (Si)[a]	48.1	9.7	55.4	10.4
Welsh A*	49.7	12.5	58.9	11.5
Welsh R	45.1	8.0	47.8	12.7
Barron ego strength	53.8	11.9	47.0	11.6

Difference between means (Student T):

[a] $P < 0.05$
[b] $P < 0.01$

ry response to inspired CO_2. The variation in respiratory response to CO_2 between subjects reflects differences in central nervous system control of respiration. Normally the level of CO_2 in the body is held rigidly stable by a rather fine balance between the rate and depth of breathing and CO_2 production from metabolism (13, 18). A rising CO_2 concentration, as produced in the rebreathing test, is perceived at two areas, the carotid and aortic bodies, located in the respective arteries, and the area about the lateral recesses of the fourth ventricle in the medulla (13, 18, 19). These areas, in turn, transmit stimulatory signals to the respiratory center in the medulla where they are integrated with other central and peripheral stimuli and translated into an increase in ventilation (13, 20). By using a high concentration of O_2 in the rebreathing system, as done in our test, the contribution of the peripheral chemoreceptors is probably insignificant (13). Thus, the response to CO_2 is determined by the sensitivity of the medullary receptors.

Previous investigators have primarily monitored ventilatory patterns during various emotional states. Alexander and Saul (1) and Finesinger and Mazick (2–4) noted respiratory hypofunction during states of depression (though sometimes also during anxiety or anger) in both asthmatics and anxiety neurotics. The predominant pattern in anxiety or anger in their study was hyperfunction. Using more modern respiratory measurements, including end tidal CO_2, Dudley et al. (6–8) have shown respiratory hypofunction during both naturally occurring and

hypnotically induced states of depression; hyperfunction occurred in states of anger and anxiety. McCollom et al. (21) have reported a decreased respiratory response to sound in subjects with lower scores on Barron's Ego Strength scale.

The difference between such past studies and ours is that we did not attempt to elicit respiratory changes in our subjects by taking measurements during naturally occurring or artificially created emotional stress. Although resting P_ACO_2 values were obtained in only 18 of our 33 subjects, it was notable that there was no relation between these values and CO_2 sensitivity. Our data would suggest that challenging the medullary center with an elevated level of CO_2 may allow us to detect intersubject differences which are not readily apparent when respiratory functioning is simply monitored.

In this group of presumably normal young adult male subjects, CO_2 sensitivity appeared to differentiate subjects along several MMPI measured psychological dimensions. Particularly notable is the striking difference in the MMPI Depression scale between high and low responders to CO_2. Further investigations, for example in a clinical psychiatric population, may be helpful in further clarifying the meaning of psychological differences on the basis of CO_2 sensitivity.

SUMMARY

Ventilatory response to CO_2 has long interested respiratory physiologists. This study describes the use of a rapid and simple rebreathing method for measuring CO_2 responsiveness which differentiated subjects on the basis of their MMPI profiles. Thirty-three volunteer test subjects, all young, male, Army enlisted men, were measured for CO_2 responsiveness during 21/2–3 minute trials, on 3–4 occasions during a two-day period. On the basis of the mean values for the group, each subject was classified as a "high" or "low" responder. MMPI data on the subjects indicated a consistent trend toward elevations of the standard scales among the group of low responders to CO_2 in relation to the group of high responders. There were statistically significant elevations for the low group on the Depression, Psychopathic, Psychasthenic, Social Introversion, and Welsh Factor A scales.

CO_2 sensitivity is thought to be primarily a reflection of the excitatory level of the respiratory center of the medulla. The data presented here suggest that CO_2 sensitivity may be a valuable tool for investigations into relationships between central nervous system state and personality.

ADDENDUM

Since the submission of this paper, we have become aware of a report[1] relating CO_2 sensitivity and the Extroversion scale of the Eysenck Personality Inventory. Despite several methodological differences from our study, the finding reported here of an inverse relation between MMPI Social Introversion and CO_2 sensitivity probably indicates a similar personality difference between high and low subjects.

We are grateful for the technical assistance of Allen Wicken, Charles Lower, Barry Witman, and Dennis Donovan, and to Miss Ella Munro for carrying out the statistical procedures.

[1]Sanders NA, Heilpern S, Roebuck AS: Relation between personality and ventilatory response to carbon dioxide in normal subjects: A role in asthma? Brit Med J 1: 719–721, 1972

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