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RELATIONSHIPS BETWEEN INDIVIDUAL DIFFERENCES IN
PERSONALITY AND RESPIRATORY BEHAVIOR: AN EXPLORATORY
STUDY

City University of New York

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AN EXPLORATORY STUDY

by

SHEILA SPERBER HAAS

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Abstract

RELATIONSHIPS BETWEEN INDIVIDUAL DIFFERENCES
IN PERSONALITY AND RESPIRATORY BEHAVIOR:
AN EXPLORATORY STUDY

by

Sheila Sperber Haas

Adviser: Professor Howard Ehrlichman

Apart from the few studies involving individual variation in CO₂ sensitivity, relationships between psychological characteristics and respiratory behavior have rarely been investigated via individual differences. Moreover, provision for possible sex differences is almost universally absent.

80 men and 80 women were administered: the Personality Research Form (PRF), the Eysenck Personality Inventory (EPI), the Rod and Frame. Respiratory behavior was recorded during conditions characterized by consistent individual response differences not fully accounted for by anatomic and physiological variation: (1) at rest; (2) 5% CO₂ added to room air; (3) two mechanical loads (increased resistance, increased elastance, each augmenting an inherent characteristic of the respiratory system). Data was collected on background variables (e.g., smoking history, physical activity) that might influence respiratory behavior.

Male and female samples were equal on background variables, personality characteristics and respiratory parameters. Simple correlations between personality and respiratory variables yielded no strong

relationships or interpretable patterns. Additional analysis did not disclose any relationship between Rod and Frame and respiratory behavior, or between the EPI and female respiratory behavior. For males, consistent significant relationships emerged only between resting breathing and Neuroticism. A Multiple Regression of PRF traits on each of the respiratory parameters demonstrated that a configuration of personality traits substantially increased the amount of variance explained from an average of 5-6% to 23-26%. A Profile Analysis generated the following: (1) Examining respiratory behavior in terms of breathing pattern was considerably more productive than using respiratory rate or tidal volume alone; (2) In each respiratory condition a configuration of personality traits successfully distinguished between the extreme respiratory groups; (3) There was a striking congruence in the trait configurations for males and females, and for each of the respiratory conditions; (4) Within each respiratory condition there was also a marked male-female correspondence in the relationships expressed in the profiles between individual traits and respiratory behavior.

A pronounced similarity in content and relationship between the profiles characterizing resting slow/deep breathers and those minimally responsive to CO_2 did not extend to strength of response. There was tentative evidence that the personality profiles for the extreme CO_2 response groups may reflect a possible physiological interaction between resting respiratory pattern and CO_2 sensitivity. The reduced similarity in personality-respiratory relationships between resting and load-response personality profiles was consonant with the poor correlation between resting and loaded respiration. The seemingly contradictory relationships between respiratory change and elements of the two

load-response personality profiles appeared to reflect two dimensions of orientation along which respiratory responses to mechanical loads may vary, as well as possible load-specific personality concomitants.

Possible error sources affecting both personality and respiratory measurements were discussed. The strength and consistency of the observed relationships despite these countervailing factors are viewed as additional support for the validity of the results.

The various personality profiles were analyzed using factors previously extracted from the PRF. Certain elements, or basic life orientations, consistently opposed each other: positive (stable, capable, confident) vs. negative (cautious, passive, dependent). A positive orientation + a dislike of restrictions characterized slow/deep resting breathers and those minimally responsive to CO₂. For both mechanical loads a negative orientation + a dislike of restrictions characterized the inefficient response group.

The degree to which the recorded respiratory behavior represented real life vs. a reaction to the testing environment was discussed. Existing evidence favors its being a "real" phenomenon, although situational influences cannot be discounted.

The critical importance of respiratory pattern as a parameter and resting respiration as a behavioral area were discussed, and the immediate implications for research technique and data interpretation emphasized. They indicate a direction very different from that traditionally followed. Discussion also included the implications of the overall findings for Rehabilitation Medicine.

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INTRODUCTION

The complexity, flexibility and partly volitional nature of the respiratory system make it a logical biological area in which to seek a relationship with the complexities of human personality.

One would expect respiratory behavior to be highly sensitive to the expression of individual differences in part because of the neurological influences involved. The respiratory center, which is the primary regulatory site, is located in the brainstem reticular tissue. Differences in reticular function and/or organization are hypothesized to underlie both respiratory (Bulow, 1963; Schaefer, 1958) and personality (Eysenck, 1967) differences. Hypothalamic and cortical influences on respiratory regulation originate from non-autonomic areas of the brain involving emotional and learning behavior, obviously important influences on individual differences.

The respiratory system is capable of adapting to an impressively broad continuum of demands. Respiratory adjustments range from the continuous and imperceptible through those gross adjustments that utilize the full extent of one's pulmonary capacities. Although respiration is an involuntary behavior essential to life, it is also involved in such voluntary behaviors as speech, laughter, singing, playing wind instruments. We can temporarily suspend or otherwise alter our breathing pattern. Our respiratory system, particularly the trachea and bronchi, forms an interface with our physical environment much as our skin does. This interface is dynamic. We take in the air that surrounds us, and we give carbon dioxide in exchange.

Apart from the small number of studies involving stable individu-

al variation in respiratory responsiveness to carbon dioxide (CO₂), however, a perspective of individual differences has rarely guided those investigating relationships between respiratory behavior and psychological characteristics. Focus has generally been on a universal, transient respiratory response to an emotionally charged stimulus. Individual differences in response direction as well as in the range of normal values for a given response have traditionally been ignored. An overview of this work presents a fuzzy picture of equivocal results.

This body of work also tends to suffer from basic inadequacies in experimental design, e.g., poorly constructed experimental groups, a critical absence of control groups, inappropriate independent and dependent variables. There was little attempt to standardize independent variables. Most of these investigations also reflect the lack of awareness of sex differences that then characterized the social sciences.

In addition, a basic misconception in much laboratory study of respiratory behavior views respiration as regulated by the Autonomic Nervous System. Although neither the respiratory center nor the area of hypothalamic control are part of the ANS, respiration in the psychological literature has often been reduced to the stepchild status of a peripheral index of arousal (emotion, drive, ANS reactivity, etc.)

The present study, couched in terms of individual differences, is directed toward restoring the respiratory system to its proper place in psychological research via an investigation that is a substantial improvement over previous work and far more comprehensive in scope. An important goal is to generate a basic body of data that will signifi-

cantly increase our understanding of personality-respiratory relationships and provide a springboard for further work. The investigation has been designed to study the respiratory behavior of a large number of men and women while at rest and during moderate chemical and mechanical constraints. Individual differences in respiratory behavior are examined in relation to individual personality differences as defined primarily by the Personality Research Form, the best available objective personality measure.

REVIEW OF THE LITERATURESEARCH FOR GENERAL LAWS: TEMPORARY RESPIRATORY CHANGE AS A FUNCTION OF TRANSIENT EMOTIONAL CHANGE

This area of research evolved from attempts to use respiratory change as a lie detection test (Landis & Gullette, 1925; Larson & Haney, 1932). These efforts at identifying liars by changes in the inspiratory/expiratory duration ratio were not successful, but they initiated a series of studies over the decades that attempted to establish a relationship between emotional states and respiration. Both patient (psychiatric and respiratory) and normal populations were considered legitimate sources for subjects. The basic paradigm of such studies was to stimulate the subjects and record alteration in whatever respiratory parameter was of interest. Several investigators chose extremely painful stimulus situations, which adds ethical considerations to whatever other problems may be attendant upon their work.

An early study of normal subjects examined cardiac and respiratory activity during frustration (Lacey, 1941). To induce frustration, Lacey strapped each subject (male) into a chair immobilizing his arms, then rubbed his naked back with an irritant that caused the skin to burn and itch violently. Subjects were not matched for skin sensitivity or pain tolerance. Lacey looked at heart rate, inspiration/expiration duration ratio, and their variability. He found that measures of variability increased reliably with increasing frustration, while level of response showed no consistent relationship. The barbaric nature of the experimental condition outweighs whatever understanding might have

been gained of emotional-physiological relationships.

Finesinger studied "respiratory reactivity" in psychiatric patients (Finesinger & Mazick, 1940; Finesinger, 1943). He defined "respiratory reactivity" as change in ventilation^{*1}, ignoring the fact that marked changes in respiratory rate^{*} and tidal volume^{*}, if they are compensatory, would leave ventilation unchanged. (It would have been far more informative to examine changes in tidal volume and respiratory rate as well.) Finesinger initially examined respiration in relation to "pleasant" and "unpleasant" stimuli, using thoughts of pleasant and unpleasant activities and feelings. He concluded that: (1) respiratory reaction tended to be toward unpleasant thoughts, and (2) Group I patients (hysteria, phobia and anxiety neurosis) were the most reactive; Group II patients (hypochondriasis, reactive depression, compulsion neurosis, questionable schizophrenia) showed little change; Group III (normals) fell midway. He made no attempt to consider a common link among the pathologies that appeared similar in "respiratory reactivity".

Finesinger next exposed subjects from these same diagnostic categories to alternating periods of painful stimuli (injections, skin pricks, electric shocks), recall of these stimuli, and rest. Recall of pain, most likely an unpleasant thought for his subjects, did not produce any respiratory change this time, but the discrepancy with his initial results was ignored. As for ventilatory change in response to pain, Group I was again the most reactive, Group II the least, and

¹Readers unsophisticated in respiratory physiology will find a Glossary of Respiratory Terminology appended. Each term defined in the Glossary is asterisked (*) in the text the first time that it appears.

Group III midway. These three subject groups, however, were unequally represented and tested, which might distort results. Group I averaged 9 subjects for each diagnostic category; Group II averaged 3 subjects per category; Group III comprised 15 control subjects. Some subjects were tested only once and others twice or more, and few if any subjects were given all three painful stimuli. Interestingly, the most "reactive" group was the one with both the largest number of subjects and individual tests (and therefore the most data points), and the least "reactive" group had the smallest number of both subjects and individual tests.

Finesinger analyzed spirogram tracing patterns for respiratory irregularities associated with "pleasant" and "unpleasant" thoughts. He found the greatest number of irregularities for Group I, but no significant difference between Groups II and III. Finesinger again ignored a conflict with earlier results (he had originally found a difference between Groups II and III), and interpreted this as additional evidence that psychoneurotics can be separated into distinct groups on the basis of their respiratory reactions. The conclusion as expressed does not appear warranted since the four types of pathology in Group II are not different from the normal population. Again, there was no attempt to go beyond the surface by examining possible bases for the observed similarities and differences. Finesinger noted that the spirogram tracings during relaxed periods were not consistent across subjects, yet no mention was made of possible individual respiratory differences.

A much later investigation of psychologic and respiratory change used chronically hospitalized psychiatric patients selected specifi-

cally for marked mood fluctuations and severe interpersonal problems (Dudley, Martin & Holmes, 1964). They were considered to be more labile, and therefore more easily aroused, and more likely to experience stressful situations during the course of the experiment. Most of these subjects also suffered from some form of respiratory pathology, which received only incidental mention despite its potentially significant influence on respiratory behavior. No normal (both psychiatric and respiratory) subjects were included as controls. Respiration was recorded during ostensibly actual and hypnotically induced periods of calm, and during real-life stress situations and hypnotic suggestion of them. During temporary stress, increased respiratory rate and ventilation appeared to correlate with "action-oriented" responses (a desire, not an action, to alter the stressful situation), and reduced ventilation with "non-action-oriented" responses (the lack of such a desire). (The authors appear to have identified thought and deed.) During long-term stress situations subjects who were angry or anxious tended to increase their ventilation; those characterized by despair tended to reduce their ventilation. In the author's attempt to associate respiratory change with active vs. passive ideational responses to stress, they did not mention the institutional personality that characterizes most of the chronically hospitalized.

Dudley studied normal subjects to support this contention that aggressive and passive response styles to stress are reflected in respiratory behavior. In one study the stressor was the pain from a tightening steel headband (Dudley et al, 1964). If the subject cried out for the pain to stop, he was termed aggressive and the experiment was stopped. The subject who meekly submitted to the pain was con-

sidered passive and the experiment continued, presumably until that point at which risk of physical injury would have arisen. There was no consideration of ethical issues. In his other work (Dudley et al, 1965), 10 subjects were exposed to this head pain while one simply recalled his chronic migraine headaches, then they all underwent the hypnotic suggestion of head pain, exercise, relaxation, depression, anxiety (for some) and anger (for others). The dependent variable was ventilation, ignoring possible compensatory changes in tidal volume and respiratory rate. Dudley concluded that deep relaxation, depression states and a passive response to head pain appeared to correlate with diminished ventilation; action-oriented pain responses and exercise, anger and anxiety states tended to be characterized by increased ventilation.

Stevenson and Ripley (1952) were interested in possible associations between respiratory pathology and emotional state. They chose out-patients with bronchial asthma, one-third of whom also suffered from severe anxiety. (This inclusion of anxiety state patients was never explained. There was no treatment of them as a sub-group, nor any consideration -- statistical or otherwise -- of their possible influence on the results.) The investigators used respiratory responses to ideational stimuli, including discussion of disease-related topics, and relaxation periods. The use of pneumographic records provided ipsative data that prevented any comparison among subjects. The basic conclusion was that every subject at one time or another showed an increase in respiratory rate and/or tidal volume. "Anxiety" stimuli most frequently elicited change, with "resentment" topics second. The lack of a control group free of respiratory pathology and the lack of a

separate analysis for the anxiety state patients did not prevent the authors from discussing their results as applicable to all patients with bronchial asthma. The fact that during "unpleasant" states 14 subjects increased their respiratory rate while 8 others either decreased it or showed no change received no discussion.

A sizeable group of studies treats respiration as merely a "peripheral indicant of autonomic nervous system activity" (Malmo, 1962, p.392), a peephole providing evidence of autonomic arousal/reactivity/anxiety. Perhaps the distinction between "automatic" and "autonomic" has gradually blurred. A current physiology text finds it necessary to point out that although "most of the autonomic functions are involuntary,...this does not mean that all involuntary functions are autonomic" (Eyzaguirre & Fidone, 1975, p.315).

Respiration, primarily an involuntary behavior, belongs to the somatic nervous system. The somatic and autonomic systems are clearly anatomically differentiable. Reflex systems in which motor neural pathways activate skeletal muscle and the response is skeletal movement are termed *somatic reflexes*. When such neural pathways activate smooth muscle, glands and the conducting tissue of the heart, the responses are termed *autonomic reflexes* (Patton, 1966). Nunn states that "...respiratory muscles...(are) skeletal muscles...." (Nunn, 1977, p.32). His discussion of neurological control of respiration typically does not contain a single reference to the autonomic nervous system.

Perhaps the seeds of confusion were sown by the researchers who focused on anxiety and respiratory change, and fertilized by the knowledge that hypothalamic pathways regulate both respiration and the

autonomically-mediated aspects of anxiety. "...The same general regions (of the limbic area of the cortex)...appear to subserve the autonomic and respiratory correlates of certain types of behavior" (Young, 1966, p.791). Proximity, however, is not identity. "...The hypothalamus integrates both somatic and autonomic components of various behavioral patterns" (Smith, 1966, p.687). Whatever the initial cause, many psychologists today regard an increase in respiratory rate as incontrovertible evidence of increased autonomic activity. Some representative experiments follow.

Murray (1963) studied "autonomic" correlates of anger, including changes in heart rate and respiratory rate. Goldman-Eisler (Eysenck, 1967) used resting respiratory rate to classify subjects as high or low in autonomic arousal. In a study of verbal response stereotypy as a function of drive, "the autonomic responses (indicating drive level) were skin resistance and respiration rate" (Vellutino, 1971, p.852). Respiratory rate was an autonomic indicant of anxiety in a study utilizing claustrophobic subjects (Miller & Bernstein, 1972). A study of sex differences in autonomic response to shock relied solely upon respiratory rate as a dependent variable (Liberson & Liberson, 1975). Respiratory rate measured degree of ANS activity in response to medication in hyperkinetic boys (Barkley & Jackson, 1977). Both rate and tidal volume were regarded as indicators of ANS activity in studying the effects of long-term drug addiction (Prystav, 1975, 1976). Klorman et al (1975) included respiratory variables in an assessment of autonomic response styles to stressful visual stimuli, and were puzzled at the typical lack of congruence between respiratory and cardiac responses. Two studies of autonomic response stereotypy included res-

piratory parameters as indices of autonomic activity (Bundy, 1976; Sersen, Clausen & Lidsky, 1978).

Treating respiration as a peripheral autonomic response rather than a centrally organized system responsive to an integration of reticular, hypothalamic and cortical control severely limits its utilization as an avenue for exploring relationships between the physiological and psychological aspects of individual differences. The actual interpretation of experimental results, however, is unaffected if "arousal" and "autonomic activity" are free of theoretical implications. Such an example from the brief catalogue above is Murray's study of the physiological correlates of anger.

When experimental hypotheses, however, are generated by a theory of individual differences in autonomic function, it is a significant error to use respiratory rate for classifying subjects on autonomic reactivity. Such is the case with the Goldman-Eisler experiment. Eysenck conceives his dimension of Neuroticism as reflecting autonomic activity and lability. Goldman-Eisler, testing a hypothesis involving the differential responses of subjects high and low on Neuroticism (i.e., high vs. normal autonomic activity and lability), used resting respiratory rate to classify her subjects on autonomic activity and, therefore, on Neuroticism. Using respiratory parameters to study the autonomic effects of medication (Barkley & Jackson, 1977; Prystav, 1975, 1976), can also produce seriously distorted conclusions.

Overview: The body of work attempting to establish universal relationships between transient emotional and respiratory change has previously been criticized for focusing on deviant psychological states (Berg & Adams, 1962) and treating respiration as a simple peripheral

phenomenon (Brady, 1962). As already noted, experimental design has tended to be seriously inadequate. Rarely were findings explored beyond the immediate surface, or related to concepts and issues in personality theory. Data hinting at the existence of individual differences was never even discussed.

Too many investigators relied upon very painful stimulus situations for producing emotional arousal. In addition to ethical questions, intense reactions to pain may well obscure more subtle differences in emotional arousal.

These investigations taken in toto provide an undifferentiated picture. There is a tendency for some people to alter their respiratory pattern some of the time during some emotional circumstances. Despite this, psychological researchers continue to use increase in respiratory rate as a standard physiological index of state anxiety (e.g., Beiman, 1976; Breen, 1976; Girodo & Pellegrini, 1976; Salter et al, 1976).

INDIVIDUAL DIFFERENCES: STABLE RESPIRATORY BEHAVIOR AND PERSONALITY TRAITS

An early study was initially phrased as an investigation of general laws between type of mental activity and respiratory pattern, but the unexpected emergence of stable individual patterns across tasks compelled the investigators to alter their perspective and direction (Golla & Antonovich, 1929). The respiration of 70 subjects, primarily medical and science students (45 female, 25 male), was recorded at rest and during: (1) mental arithmetic; (2) poetry recall; (3) music recall; (4) mentally assembling an argument's pro's and con's; (5) mentally building a cube from small blocks, painting its sides, disas-

sembling it and counting the number of painted sides on each block. Consistent differences in basal respiratory pattern divided the subjects into two virtually equal groups, each with the same proportions of males and females. A "regular" pattern (relatively fast and shallow) characterized one, and an "irregular" pattern (variable tidal volume and respiratory rate, overall relatively slow and deep) characterized the other. Each subject maintained his basal pattern during the first four tasks. On the fifth task all of the regular breathers maintained their pattern; 80% of the irregular breathers -- those able to complete the task -- became much more regular, while the 20% who abandoned the task remained irregular.

Extensive testing identified subjects as predominantly visual or aural in handling information and problem-solving, a mode that each subject considered as stable from childhood. Thirty-three of the 34 regular breathers were visual; 28 of the 32 irregular breathers were aural. The fifth task had been unique in that it forced subjects to deal with it visually or not at all. Although the underlying nature of the relationship that emerged was then left open to question, concepts in laterality would be a likely approach.

A later study (Alexander & Saul, 1940) was intended to relate individual respiratory patterns with "eliminative" and "intaking" personality tendencies. The initial report assessed the reproducibility of the individual spirogram tracings (75% were reproducible over several recordings), but was never followed by the actual analysis.

McCollum, Burch and Roessler (1969) looked at the respiratory response of 32 male subjects (medical and dental students) to five stimulus intensities each of light and sound, one in a series of ex-

periments to locate physiological variables capable of discriminating between high and low ego strength (E_s) subjects on the Minnesota Multiphasic Personality Inventory (MMPI). High E_s subjects primarily increased their tidal volume, while low E_s subjects primarily increased their respiratory rate. The investigators felt that their results were inconclusive because their experimental design did not properly control for the E_s covariant of trait anxiety.

Four fairly recent experiments converge upon individual differences in CO_2 sensitivity*. Physiologists, unsuccessful in their attempts to account fully for the wide range of consistent individual differences in responsiveness to CO_2 in both normal (Bulow, 1963; Rebuck et al, 1974) and patient (Lourenco, 1969; Clark, 1974; Howell, 1974) populations, felt that personality differences might hold an answer (Rebuck et al, 1974; Clark, 1974; Howell, 1974).

Clark and Cochrane (1970) studied 44 patients suffering from emphysema and/or chronic bronchitis, the two common types of Chronic Obstructive Pulmonary Disease (COPD). The subjects' sex was not noted. (It is possible that they were primarily male, since the COPD population is two males for each female.) The investigators speculated that personality differences might help to explain the well-documented discrepancy in COPD patients between degree of pulmonary impairment and actual CO_2 retention. The difference between each subject's actual and predicted CO_2 retention (based on his degree of respiratory impairment) was plotted against his scores on the Eysenck Personality Inventory (EPI). These CO_2 differences showed no correlation with Neuroticism, but were correlated with Extraversion (E) ($P < .001$). E scores above the mean were associated with decreased CO_2 retention, and E

scores below the mean with increased CO₂ retention. The investigators read Eysenck's concept of Extraversion as reflecting the prevalent level of excitation in the entire central nervous system rather than specifically in the reticular system. They speculated that their subjects' E scores reflected a differential excitability of the respiratory motor neurones, with high E scorers capable of greater motor output at any given CO₂ concentration. They commented upon the multifactorial basis of CO₂ retention, including personality factors and central sensitivity to input stimuli.

Saunders, Heilpern and Rebeck (1972) administered the EPI to 25 male and 25 female subjects (hospital staff volunteers) with no history of respiratory or psychiatric problems. CO₂ sensitivity was measured with the Read rebreathing technique*. Their male subjects averaged significantly higher sensitivity to CO₂ than the women, although the broader male response range indicated that the least sensitive men were less sensitive than the least responsive women. No attempt was made to relate CO₂ sensitivity to respiration under resting conditions. CO₂ sensitivity was not related to Neuroticism in either sex. Extraversion correlated +.61 with CO₂ sensitivity in the women, but did not correlate with male CO₂ sensitivity. No reference was made to Clark and Cochrane's reported relationship between CO₂ sensitivity and Extraversion that was most probably not limited to women.

The authors concluded that their study indicated a relation between personality structure and central chemoreceptor sensitivity, speculating -- on the basis of their obtained sex differences -- that the relation between ventilatory response and cortical function is multifactorial. They also speculated that a woman's personality struc-

ture may play a role in determining the level of ventilation adopted if and when she develops respiratory disease.

Shershow, King and Robinson (1973) looked at MMPI responses and ventilation in 33 males. They employed the Read rebreathing technique and used the range of individual responses to a specific concentration of CO₂. The ventilatory range was broad (6.7 l./min. - 37.1 l./min.), with each subject's ventilation consistent across several trials. Those above the average (20.9 l./min.) were termed high responders to CO₂, and those below termed low responders. Low responders were significantly elevated on the scales for Depression (P < .01), Psychopathy (P < .05), Psychasthenia (P < .05) and Social Introversion (P < .05). Resting CO₂ concentration in expired air did not correlate either with ventilation during rebreathing or with MMPI responses. The differential ventilatory response to CO₂ was hypothesized to reflect differences in medullary center sensitivity. Further work was called for to clarify psychological differences related to CO₂ sensitivity.

A fourth study (Arkinstall et al, 1974) initially approached variation in CO₂ sensitivity via a consideration of genetic vs. environmental¹ contributions. The reports of Clark and Cochrane and of Saunders et al prompted the investigators to add several personality inventories to their protocol: the EPI, Jackson's Personality Research Form (PRF), and the Spielberger State-Trait Anxiety Inventory. CO₂ sensitivity was measured by the Read rebreathing technique in 30 pairs

¹"Environmental" refers primarily to such things as athletic activity and medical history.

of twins of both sexes (the number of males and females unstated). There were 17 pairs of monozygous (MZ) twins (who are genetically identical) and 13 dizygous (DZ) pairs (whose genetic similarity is only 50%). Comparing response similarity within MZ pairs to that within DZ pairs indicated that the tidal volume response to increased CO₂, showing far greater variability within the DZ pairs, is primarily genetically determined. The frequency response, which was equally variable in both MZ and DZ pairs at lower CO₂ levels (and more variable than the tidal volume response in the DZ pairs), would appear to be strongly influenced by environmental factors at these levels. The authors speculated that personality effects constitute an environmental factor. They found significant direct correlations between ventilation and Extraversion ($P < .03$), and between frequency and Neuroticism ($P = .01$). Each twin pair was examined to see if the twin with the higher physiological response to CO₂ was also higher on specific personality traits. The only consistent relationship was between the PRF Aggression scale and the frequency response. (No mention was made of looking for inverse relationships.) The investigators concluded that both "nature and nurture" affect the ventilatory response to increased CO₂.

The possibility of sex differences does not appear to have been thoroughly treated. Although intra-pair respiratory variability was found to be the same for male and female twins, this physiological similarity does not assure a similarity of relationships between respiratory response and personality characteristics. Males and females were distinguished on the graph relating frequency response to Aggression (which does not reveal sex differences), but there is no indication of separate analysis for the other two personality tests. Inspection

of the data for such sex differences is not mentioned in the text.

Overview: The studies of individual differences in respiration and personality are generally less vulnerable to methodological criticism, and they reflect an understanding of respiratory physiology lacking in the search for general laws. The fact that individual differences have not been cancelled out by group averages has generated somewhat more substantial results. This miniscule body of work, however, is not unflawed. For one, the possibility of sex differences is not consistently considered. Clark and Cochrane made no mention of their subjects' sex. McCollum et al and Shershow et al noted the use of male subjects but did not confine the applicability of their results to men. Although the remaining three investigations studied both men and women (only one, however, using equal numbers), only Saunders et al were thorough in their search for sex differences. They found a significant one. The other two reported the lack of sex differences in respiratory response, but either did not consider (Golla & Antonovich), or only partially considered (Arkinstall et al), the possibility of sex differences in the relationship between respiratory response and personality traits.

Other than the one work published in 1929, no researcher has looked at differences in normal resting breathing. One study examined resting breathing in patients with serious respiratory impairment; the remaining were concerned only with respiratory alteration resulting from stimulation (sound, light, increased CO_2). The most frequently used personality measures were the EPI and the MMPI, the first of which provides only a broad, two-dimensional view of personality and the second of which -- in addition to drawing a profile of psychiatric

abnormality -- is poorly regarded in terms of basic validity. Four of the six studies used subjects -- medical/dental/science students, hospital staff, COPD patients -- whose familiarity with the environment and equipment involved in respiratory testing is not representative of the general population. The possible consequences of their lack of naivete are ignored.

METHODS

This investigation was designed to identify relationships between individual differences in stable personality factors and respiratory behavior, and to identify possible sex differences in such relationships. Objective personality measures describing the normal rather than the abnormal personality were administered. They were chosen for both potential theoretical relevance and psychometric standards. Resting respiratory behavior was recorded as well as respiratory response to two stimulus conditions: (1) chemical loading^{*}, i.e., increased CO₂ concentration in the inspired air, and (2) mechanical loading^{*}, i.e., augmenting the inherent mechanical impediments that the respiratory muscles contract against.

The relevance of differences in CO₂ responsiveness was discussed in the review of the literature. External mechanical loads have come into use in respiratory physiology for studying ventilatory responses to disease processes that narrow the airways or limit lung expansion. Individual ventilatory differences characterize patients with the same degree of mechanical impairment. Normal subjects show similar individual differences in response to these artificial external mechanical loads in the degree to which they maintain their ventilation and the way in which they alter their resting respiratory pattern to achieve this ventilation. These latter differences, which have been ignored in the literature (e.g., Pope, Holloway & Campbell, 1968) are not explainable by physiological principles (Axen, 1974). The possibility of personality determinants has been raised (Milic-Emili, 1976) because of the cortical influences on conscious respiratory behavior.

Both of these areas, therefore, provide consistent individual respiratory response differences that cannot be satisfactorily accounted for by physiological principles. Both experimental conditions also offer the advantages of non-stressful and objectively standardized and graded stimuli. The equipment is non-invasive and does not cause physical discomfort.

SUBJECTS

One hundred and sixty adult volunteers -- 80 males and 80 females -- free of obvious respiratory and psychiatric pathology were recruited via advertisements at Columbia University, the CUNY Graduate Center, New York University at Washington Square, and the New York University Medical Center. Subjects were paid \$5.00 for their participation, which involved an average of one hour for the personality measures and one hour for respiratory behavior. Full effort was made to allay preliminary fears regarding respiratory testing, both by answering questions and acquainting each subject with the apparatus, without revealing the nature of the loaded conditions. At the conclusion each subject was given a full explanation of the entire procedure, and provision was made for interested subjects to obtain a summary of the eventual results of the study. Testing took place in the Cardiopulmonary Laboratories in the research wing of the Institute of Rehabilitation Medicine at the New York University Medical Center complex.

PERSONALITY MEASURES

Personality Research Form (PRF): The PRF, generating 21 scores based on Murray's system of needs, provides an informative assessment of personality traits in the normal population. Both the theoretical

and psychometric foundations of this inventory are excellent. The shorter version (Form E, 352 items) was used because the significant saving in testing time far outweighed the small degree of reliability possibly relinquished. The test manual contains a full description of the personality characteristics subsumed by each scale (Jackson, 1967).

Eysenck Personality Inventory (EPI): Eysenck's most recent theory of individual differences in personality structure (1967) is tied to functional differences in the cortico-reticular arousal system and the visceral brain-reticular activation system, the same CNS components that are the loci of respiratory control. His personality inventory measures the dimensions of Extraversion (E) and Neuroticism (N). N, representing Neuroticism at the high end and Stability at the low, is ostensibly an index of autonomic lability. E, representing Extraversion at the high end and Introversion at the low, is held to reflect the relative juxtaposition of hypothalamic vs. cortical excitement (which in turn is a function of the inherent degree of reticular arousal). The extreme Introvert embodies pronounced cortical arousal with consequent hypothalamic inhibition. The extreme Extravert reflects inhibited cortical activity with consequent release of hypothalamic responsiveness.

Eysenck would predict relationships between N and both resting respiration and response to mechanical loads. He contends (1967) that subjects with higher N scores have a higher resting respiratory rate. Because of their greater lability, his theory would also predict a greater rate increase in response to mechanical loads and a greater rate increase on the first unloaded breath.

Eysenck's theory would also anticipate a relationship between E and CO₂ sensitivity. Inhalation of a moderate CO₂ concentration depresses cortical and stimulates hypothalamic activity (Carey, Schaefer & Delgado, 1955; Eisele, Eger & Muallem, 1967; Gellhorn, 1953; Schaefer, Cornish & Stuntz, 1952; Tenney & Lamb, 1964), which would appear to relate CO₂ response to Eysenck's E dimension. Eysenck has postulated, and given evidence to support, that Extraverts -- who are cortically depressed relative to Introverts -- are consequently significantly more sensitive to depressant drugs because they are so much closer to threshold. Therefore one would expect Extraverts to be more sensitive to CO₂, and the results of Clark and Cochrane, Saunders et al and Arkinstall et al cited earlier suggest the existence of such a relationship.

Edwards Personality Inventory: Four scales were selected from the Edwards Personality Inventory for their apparent relevance. Two scales purportedly measure the degree to which an individual (1) Conceals Feelings, and (2) is Easily Influenced. It was felt that high scores on these two scales, reflecting those who appear to be less in touch with their own feelings and attitudes, might correlate with inappropriate responses to mechanical loads. The other two scales ostensibly measure Energy and Competitiveness. It was felt that high scores on these scales might correlate with high effort in response to mechanical loads.

Portable Rod and Frame Test: A measure of field dependence-independence was included because of the nature of the individual differences reported in CO₂ sensitivity and in response to mechanical loading. A possible, and logical, characterization of those with a high CO₂ sen-

sitivity and/or those who respond efficiently to mechanical loading vs. their counterparts is that the former are responding to appropriate internal physiological stimuli while the latter are responding to psychological stimulus components of the external environment. Because the equipment, which was on loan, had to be returned before the full number of subjects had been tested, data was accumulated for 79 of the 80 women and 62 of the 80 men.

RESPIRATORY PROCEDURES

Vital Capacity* (VC): VC was measured by spirometry with the subject in the supine position. VC was initially used to screen volunteers for abnormal pulmonary function¹, and was for eventual statistical use in data analysis if it were found that parameters of respiratory behavior were significantly influenced by individual differences in VC.

CO₂ Breathing: Inspired air was drawn, via a demand valve, from a tank containing 5% CO₂ mixed with room air.

Resistive Loading²: Three rubber stoppers, each fitted with a narrow-bore glass tube, were inserted in order of increasing narrowness into the inspiratory limb. The situation is comparable to breathing through increasingly narrow straws. The greater the subjects' airflow

¹Volunteers were rejected from the study if their VC was below 1 SD from predicted limits for their sex, age and height.

²Although three graded stimulus values were used, only the data from R3 were analyzed because individual response differences become more pronounced as load size increases.

the greater the pressure opposing inspiration. The added resistance* introduced by these loads, calibrated at the average airflow rate observed in normals during quiet breathing, was:

<u>Stimulus Value</u>	<u>Added Resistance</u> ¹
R1	6 cmH ₂ O/L/sec. (3x normal values)
R2	12 cmH ₂ O/L/sec. (6x normal values)
R3	37 cmH ₂ O/L/sec. (18x normal values)

Elastic Loading²: Six 5-gallon cylindrical cans were connected in parallel to a common length of pipe. Each can was fitted with a drum faucet permitting its individual addition to, or removal from, the circuit to alter load size. Inspiration from these cans develops a negative pressure at the mouth in direct proportion to the volume of air removed from the can (i.e., a back pressure, exactly like the vacuum created by inspiring the air from a glass held tightly over the mouth) which opposes further inspiration. The greater the number of cans in the system, the less the added elastance*. On a breath inspired from 6 cans, for example, only 1/6 of this breath comes out of each can; on an equally deep breath inspired from 2 cans, 1/2 of this breath comes from each can, and this greater volume of air removed from each causes a proportionally greater back pressure. The loads used in this study were:

¹The resistance inherent in the normal pulmonary system is approximately 2 cmH₂O/L/sec.

²Although four graded stimulus values were used, only the data from E4 were analyzed because individual response differences become more pronounced as load size increases.

<u>Stimulus Value</u>	<u>Added Elastance</u> ¹
E1 (6 cans)	10 cmH ₂ O/L (2x normal values)
E2 (3 cans)	17 cmH ₂ O/L (3½x normal values)
E3 (2 cans)	24 cmH ₂ O/L (5x normal values)
E4 (1 can)	40 cmH ₂ O/L (8x normal values)

APPARATUS

Vital capacity was measured by spirometry. The equipment set-up used for the recording of respiratory behavior and imposition of the chemical and mechanical loads is schematically diagrammed in Fig. 1. The subject, in a relaxed supine position, breathed through a rubber mouthpiece with a foam rubber clip over his nose. The mouthpiece was fitted to a J-valve, separating the inspiratory and expiratory limbs of the apparatus. The expiratory limb contained a catheter to transmit a continuous sample of expired air to a capnograph to monitor expired CO₂. The inspiratory limb was connected to a valve permitting inspiration from the atmosphere or from any of the three loads. The subject was unable to observe the Experimenter's manipulations of the equipment. The following parameters were continuously recorded on a Grass Model 7 polygraph: (1)Airflow: sensed by a pneumotachograph fitted in series to the inspiratory limb and converted to an electrical signal by a Statham differential pressure transducer; (2)Tidal Volume: integrated electronically from the airflow signal; (3)Instantaneous

¹The elastance inherent in the normal pulmonary system is approximately 5 cmH₂O/L.

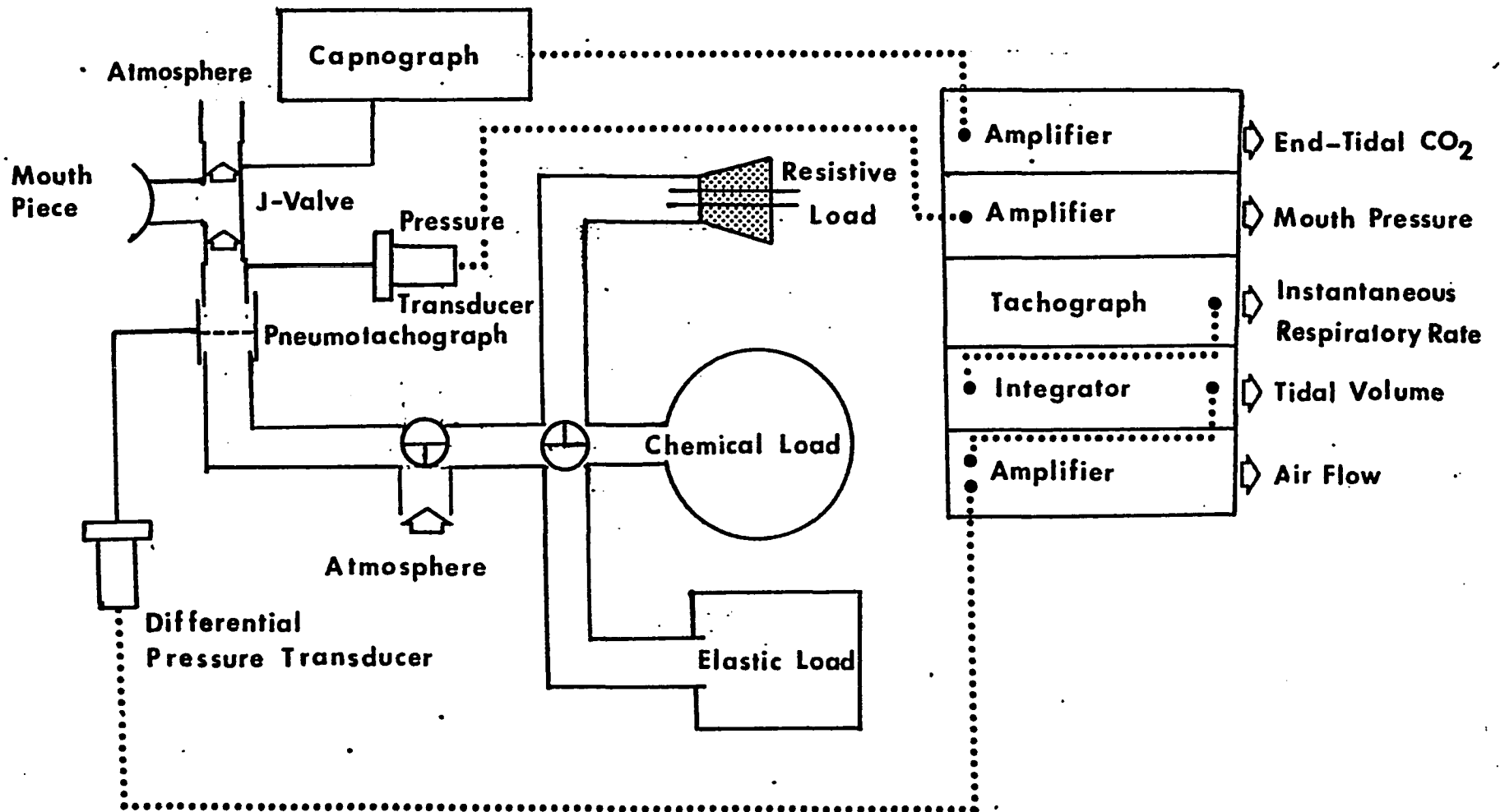


FIGURE 1: APPARATUS SCHEMATIC

Respiratory Rate: the tidal volume signal triggers the tachograph to give an instantaneous respiratory rate; (4)Mouth Pressure: sensed in the inspiratory limb near the mouth and converted to an electrical signal by a Statham pressure transducer; (5)End-Tidal CO₂^{*}: analyzed by an infrared light CO₂ analyzer (capnograph).

MEASUREMENTS AND CALCULATIONS

Resting Respiration:

1. Tidal Volume.
2. Respiratory Rate.
3. Ventilation.
4. End-tidal CO₂.

An average was calculated for each of the four "resting" minutes, and then these averages were averaged.

CO₂ Breathing:

1. Latency: time elapsed from start of stimulus to appearance of a respiratory response (defined as an increase in ventilation $\geq 20\%$).

2. Steady state latency: time elapsed from start of stimulus to appearance of a steady state (defined as a ventilation not less than 10% of that achieved by the conclusion of the test).

3. TV, RR, Ventilation and end-tidal CO₂ were recorded at 1 minute, 2 minutes, 3 minutes, and 4 minutes after start of stimulus, and at the steady state demarcation. The first three measures were expressed as a percentage of control.¹

¹Control consists of the values averaged from the 5 breaths just preceding presentation of the load.

4. The slope of the ventilatory response to 5% CO₂, indicating the increase in ventilation per unit of increase in end-tidal CO₂, was calculated at these same intervals. $(\text{CO}_2 \text{ ventilation minus Control ventilation}) \times 1000 / (\text{CO}_2 \text{ end-tidal CO}_2 \text{ minus Control end-tidal CO}_2)$.

Mechanical Loads:

1. The loaded response was analyzed in terms of the change from control of: TV, RR, Ventilation, Inspiratory Duration (Ti), Expiratory Duration (Te), and mean inspiratory airflow (TV/Ti). Mouth pressure (which is nearly atmospheric during unloaded breathing) was also recorded.¹ The three trials at each of the largest loads were averaged.

2. The first unloaded breath (i.e., the first "normal" breath following removal of the load) was analyzed in terms of the change from control of: TV, RR and Ventilation².

INTERVIEW DATA

An interview conducted at the conclusion of respiratory testing gathered information on background variables (1) that would require statistical control if they turned out to influence variation in respiratory behavior; (2) that would permit assessment of the degree of similarity between male and female samples. These variables were:

¹Mouth pressure was included as a continuing check against calibrations for airflow and tidal volume, since it is proportional to the former in resistive loads and proportional to the latter in elastic loads. It was not included in the actual data analysis.

²Change in the first unloaded breath was measured for an examination of Eysenck's predictions concerning the respiratory lability of high N subjects. Analysis of variation along this parameter, therefore, was restricted to the EPI.

1. Age
2. Height
3. Race
4. History of respiratory problems
5. Smoking history
6. Presence of fears of suffocating/drowning
7. History of strenuous physical activity
8. History of breath control activity (yoga, diving, wind instrument, etc.)
9. History of psychotherapy

TESTING SEQUENCE

When each subject arrived at the laboratory he/she was given a brief written introduction concerning the nature of the experiment (see Appendix). The personality tests were administered before the respiratory tests to give the individual time to feel more at ease in a laboratory setting that, for most, was new and strange. The subject answered the questionnaires in a small, quiet room. When these were completed, the Rod and Frame test was administered and VC measured.

Subjects were acquainted with the respiratory equipment prior to testing. The tubing and valves through which they would breathe, and the various pieces of sensing and recording equipment, were identified and their functions explained in simple terms. Subjects were assured that the mouthpiece could be removed immediately if they had to cough or sneeze, and informed that there would be periodic resting points, if desired, during the testing. Questions were answered unless they would have required information regarding the respiratory loads, in which case they were deferred to the post-test period.

Then the subject assumed the supine position and the mouthpiece and noseclip were adjusted. The Experimenter told the subject that this initial period was for him/her to relax and get used to the equipment, and that the Experimenter would let him/her know when the first test was to begin. Once a stable ventilation had been achieved, resting respiratory behavior was recorded for 4 consecutive minutes. Then the subject was told that a four-minute test would begin very shortly, but no clue was given as to the nature of the test or to when he was actually switched to the 5% CO₂ air mixture. At the conclusion of CO₂ breathing subjects were given an opportunity to rest. For those who chose to continue without a break, no further testing was begun until ventilation had returned to normal.

The two mechanical loads formed the final segment of testing. Order of presentation was randomly varied. Within each load stimulus values were presented in order from lightest to heaviest to avoid anxiety. Each stimulus value was presented on three successive trials, for one inspiration only, with each presentation delayed until the subject had resumed a stable breathing pattern for 10 breaths.

Once respiratory testing was over, the Experimenter interviewed the subject to collect background information. The nature of each of these tests, and the rationale for their inclusion, were then explained.

LAW OF INITIAL VALUE

The Law of Initial Value (LIV) refers to a potential relationship between resting and change measurements such that the higher the initial (resting) value, the smaller the post-stimulus increase from this

value and the greater the possibility of a paradoxical reaction, i.e., a decrease in activity (Claridge, 1967; Eysenck, 1967; Wilder, 1962). A function normally operating at its ceiling would either not show any post-stimulus change, termed a "ceiling effect" (Averill & Opton, 1968), or would show this paradoxical decrease in activity. Analyzing data generated by a function or system affected by the LIV requires statistical elimination of its influence on change measures to permit accurate assessment of the relationship between stimulus and response.

The literature regarding the influence of the LIV on respiratory responses is equivocal. Eysenck notes the possibility in a very cautiously worded statement: "The evidence to date *seems to suggest* that this law operates for some types of autonomic (sic!) activities such as heart rate and respiration rate responses...." (1967, p.57; emphasis is added). Bram (1970) discusses the general inconsistency of the LIV data presented in the literature as well as the methodological shortcomings of this work. Utilizing an approach relatively free from these flaws, he found respiratory rate change completely unaffected by the LIV while tidal volume gave "some weak evidence" for an increasing response magnitude as a function of increasing initial value.

The design of this investigation should preclude the potential involvement of the LIV. The maximum limits of the respiratory capabilities of the normal system are far beyond not only the range of resting levels found in normal subjects, but the maximum challenges posed by the respiratory loads used in this investigation. CO₂ breathing involves a moderate concentration of CO₂, and the highest mechanical

load in each category is well below reported tolerance limits (Pope, Holloway & Campbell, 1968)¹. Because the literature is equivocal, however, the data were inspected for ceiling effects and/or paradoxical reactions by plotting each subject's TV and RR change at R3 and E4 against his control values.

STATISTICS

The exploratory nature of the study precluded any a priori decisions regarding the statistical approach to data analysis. The only decision taken at this point was to maintain the males and females as separate samples whether or not they were substantially different in terms of background, personality characteristics or respiratory behavior. Such similarity would not preclude the possibility of different relationships emerging in the data. If the Law of Initial Value appeared relevant to any of the measures of respiratory change, appropriate statistical correction would be taken.

¹Range of tolerance levels for resistive loading is 140-380 cmH₂O/L/sec. for 2 minutes duration. Range of tolerance levels for elastic loading is 60-200 cmH₂O/L for 2 minutes duration.

RESULTS

LAW OF INITIAL VALUE

Change in each subject's tidal volume and respiratory rate during the highest resistive and elastic load were plotted against his/her control values (Figs. 1-4, Appendix). The lack of correlation between these resting values and degree of change confirmed the absence of an LIV effect.

COMPARISON OF MALE AND FEMALE SAMPLES

Very few differences emerged between the male and female samples. They all worked and/or went to school in the metropolitan New York area. Just over 50% of each sample studied full-time, and approximately 25% of each were part-time students with a full-time job. Of the remaining 25%, all of whom had completed an undergraduate or graduate degree, most worked full-time and the others were unemployed.

The similarity of the male and female samples in regard to background factors, personality variables and respiratory parameters is portrayed in Tables 1, 2 and 3, respectively. There were no differences along any of the background variables. Significant differences appeared on only four of the PRF scales, on one of the four Edwards Personality Inventory scales, and on the Rod and Frame. Although the women's average sum of errors over the 8 trials was typically substantially higher than the men's, outside of a small number of extreme female scorers the men and women were no different.

There were few differences in respiratory behavior. The significant difference in VC simply reflects the fact that men are physically larger than women, and the differences in average resting TV and venti-

TABLE 1: COMPARISON OF MALE AND FEMALE
 SAMPLES--BACKGROUND VARIABLES*

<u>BACKGROUND VARIABLES</u>	<u>MALE</u>		<u>FEMALE</u>	
	<u>N</u>	<u>%</u>	<u>N</u>	<u>%</u>
	Avg. = 25.5 (SD=5.4)		Avg. = 23.8 (SD=5.0)	
	Age		Age	
RACE				
Caucasian	73	91.2	69	86.2
Black	5	6.3	9	11.2
Hispanic	2	2.5	2	2.5
SMOKING HISTORY				
None	52	65.0	43	53.8
Stopped	10	12.5	15	18.7
Smoker	18	22.5	22	27.5
RESPIRATORY PROBLEMS				
None	55	68.8	65	81.3
Past and/or Current	25	31.3	15	18.8
RESPIRATORY-RELATED FEARS				
No	61	76.3	59	73.7
Yes	19	23.7	21	26.2
STRENUOUS PHYSICAL ACTIVITY				
No	42	52.5	51	63.7
Yes	38	47.5	29	36.3
BREATH CONTROL ACTIVITY				
No	47	58.7	51	63.7
Yes	33	41.3	29	36.3
EDUCATIONAL/PROFESSIONAL				
Student	43	53.8	44	55.0
Student + FT Job	18	22.5	20	25.0
Graduate, FT Job	13	16.3	12	15.0
Graduate, Not Working	6	7.5	4	5.0

*2-tailed t-tests did not reveal any statistically significant differences between males and females.

TABLE 2: COMPARISON OF MALE AND FEMALE
 SAMPLES--PERSONALITY VARIABLES

<u>PERSONALITY VARIABLES</u>	<u>MALE</u>		<u>FEMALE</u>		<u>P < *</u>
	<u>AVERAGE</u> <u>SCORE</u>	<u>SD</u>	<u>AVERAGE</u> <u>SCORE</u>	<u>SD</u>	
PRF:					
Abasement	44.6	9.7	46.7	9.4	NS
Achievement	49.0	10.5	51.4	9.1	NS
Affiliation	50.5	9.3	49.8	10.2	NS
Aggression	54.9	9.9	51.2	9.4	NS
Autonomy	50.1	7.9	53.5	11.1	.05
Change	50.6	9.7	51.2	8.1	NS
Cognitive Structure	50.4	9.0	50.2	8.3	NS
Defendence	50.6	8.5	52.4	8.0	NS
Dominance	50.1	10.2	50.9	9.4	NS
Endurance	44.8	10.9	48.1	10.7	NS
Exhibition	53.5	10.0	50.4	9.3	NS
Harmavoidance	53.7	10.1	50.9	9.1	NS
Impulsivity	54.4	10.5	50.7	7.8	.01
Nurturance	51.5	8.6	51.2	9.7	NS
Order	50.2	10.3	48.9	10.5	NS
Play	51.3	8.2	47.6	10.5	.01
Sentience	53.6	9.1	52.1	10.4	NS
Social Recognition	49.8	8.8	47.9	8.5	NS
Succorance	51.4	9.0	48.2	9.7	.05
Understanding	54.4	9.0	53.1	10.3	NS
Desirability	49.2	10.6	48.0	12.4	NS
EPI:					
Neuroticism	59.5	27.4	66.4	29.6	NS
Extraversion	49.9	29.9	51.5	26.5	NS
EDWARDS:					
Conceals Feelings	11.0	4.3	9.0	4.8	.01
Easily Influenced	6.0	3.8	7.0	4.6	NS
Competitiveness	12.0	4.4	11.0	4.3	NS
Energy	10.0	3.7	10.0	3.1	NS
ROD AND FRAME:					
Avg. Sum of Errors	33.3	28.9	59.1	57.7	.001

*2-tailed t-tests were performed.

TABLE 3: COMPARISON OF MALE AND FEMALE
 SAMPLES--RESPIRATORY PARAMETERS

RESPIRATORY PARAMETERS	MALE		FEMALE		P < *
	AVERAGE	SD	AVERAGE	SD	
VITAL CAPACITY (L)	4.5	0.7	3.2	0.5	.001
RESTING:					
TV (L)	0.9	0.3	0.7	0.2	.001
RR (breaths/min)	13.1	5.1	14.3	5.4	NS
Ventilation (L/min)	10.0	2.7	9.0	2.2	.01
End-Tidal CO ₂ (%)	5.5	0.4	5.2	0.5	.001
CO ₂ SENSITIVITY:					
Response Latency (sec)	48.3	30.2	50.8	30.5	.01
Steady State Latency (sec)	145.3	46.0	158.5	37.1	NS
Steady State Ventilation ¹	194.1	47.0	213.7	64.7	NS
Slope at Steady State	1.4	0.9	1.5	1.4	NS
RESISTIVE LOAD: ¹					
TV	67.4	63.6	66.8	69.5	NS
RR	102.4	53.2	104.2	47.6	NS
Ventilation	43.1	24.2	47.0	23.7	NS
Ti	227.8	176.5	191.2	140.5	NS
Te	92.9	110.0	85.2	58.6	NS
TV/Ti	27.1	11.5	32.4	13.4	.01
TV 1st Unloaded Breath	125.9	41.5	128.0	52.5	NS
RR 1st Unloaded Breath	108.5	32.6	103.8	24.8	NS
Vent'n 1st Unloaded Breath	131.8	52.2	125.2	37.4	NS
ELASTIC LOAD: ¹					
TV	34.0	28.4	36.0	20.9	NS
RR	204.7	146.4	191.5	100.4	NS
Ventilation	54.3	34.3	57.5	32.8	NS
Ti	77.7	54.1	72.8	38.0	NS
Te	66.0	38.2	64.5	31.9	NS
TV/Ti	42.1	14.3	49.1	15.4	.005
TV 1st Unloaded Breath	116.6	41.6	119.0	42.7	NS
RR 1st Unloaded Breath	108.6	30.6	110.2	30.7	NS
Vent'n 1st Unloaded Breath	117.7	42.6	126.5	51.6	NS

* 2-tailed t-tests were performed.

¹ Values express % change from control.

lation also reflects this anatomical difference. The women's average end-tidal CO_2 was lower than the men's. Although the women took longer to begin responding to 5% CO_2 in their inspired air (and longer to approach a steady state, although this did not achieve significance), their ventilatory increase at the steady state was significantly greater. Slope at the steady state (Slope SS) was also higher for women, but did not reach significance. In response to mechanical loads, the only substantial difference arose on TV/Ti , the mean inspiratory airflow. This difference in effort, however, is explainable physiologically, i.e., women have stiffer respiratory systems than men do because their lungs are smaller.

This similarity between the male and female samples permits the assumption that potential sex-related differences concerning personality and respiratory relationships will not be attributable to differences in sample characteristics in the above areas.

INFLUENCE OF BACKGROUND VARIABLES

The few small correlations between background variables and parameters of respiratory behavior (Table 4) indicate the lack of any need to remove their influence statistically. The average correlation of .25 has an R^2 of .06, indicating that either variable in the pair can explain only 6% of the variance in the other. There is no overlap in correlations between male and female samples.

PERSONALITY-RESPIRATORY CORRELATIONS

The four scales from the Edwards Personality Inventory proved to correlate too highly with the PRF scales (Table 5) for them to be of any use in the analysis. They were, accordingly, dropped.

TABLE 4: SIGNIFICANT CORRELATIONS* BETWEEN
BACKGROUND AND RESPIRATORY VARIABLES¹

	A G E	H G T.	V C	R A C E	R P E R S O P. B.	F R E A S R P. S	A P C H T Y I S. V.	C B N R T R H. L.	P S T Y H C E H'. R.	O L R O D A E D R
<u>RESTING:</u>										
TV	+36	+24	+32							
RR	-30		-30		-25					
Ventilation						-25				
CO ₂	-33						-23			
<u>CO₂ SENSITIVITY:</u>										
Steady State Latency	-42	+23	+30							
Steady State Vent'n				+27			+24			
Slope at Steady State				+29						
<u>RESISTIVE LOAD:</u>										
TV		+27	+27							
Ventilation					+22					
Ti		+30								
TV/Ti					+27					
TV 1st Unloaded Br.		+25			+26					
Vent'n 1st Unloaded Br.		+27		+24	+30					
<u>ELASTIC LOAD:</u>										
TV	-25									
RR	+25				+23					
Te	-26			+23	-29				-26	
TV/Ti	-24	-26						-24		+26
TV 1st Unloaded Br.					+26					
RR 1st Unloaded Br.	+25			+38						
Vent'n 1st Unloaded Br.				+31						

*Correlations in male sample are in standard typeface; those in female sample are in italics.

¹Because of the total absence of significant correlations, the following variables were omitted from the table: Smoking History; Response Latency (CO₂ Sensitivity); RR, Te and RR 1st Unloaded Br. (Resistive Load); Ventilation and Ti (Elastic Load). For significant correlations "P" ranged from <.05 to <.001, with 73% of these correlations at P<.05.

TABLE 5: SIGNIFICANT CORRELATIONS
BETWEEN EDWARDS AND PRF SCALES*

<u>EDWARDS P.I. SCALE</u>	<u>MALE</u>		<u>FEMALE</u>	
	<u>CORRELATES WITH PRF SCALES</u>		<u>CORRELATES WITH PRF SCALES</u>	
CONCEALS FEELINGS	Affiliation	-27	Abasement	+30
	Aggression	-23	Aggression	-52
	Exhibition	-25	Dominance	-23
	Impulsivity	-33		
	Nurturance	-32		
	Sentience	-34		
	Succorance	-24		
EASILY INFLUENCED	Autonomy	-27	Abasement	+53
	Dominance	-47	Aggression	-33
	Endurance	-33	Autonomy	-35
	Exhibition	-43	Dominance	-54
	Social Recog.	+30	Exhibition	-28
	Succorance	+33	Impulsivity	+31
	Desirability	-26	Sentience	-34
			Social Recog.	+23
			Succorance	+32
			Understanding	-31
		Desirability	-32	
COMPETITIVE	Achievement	+22	Achievement	+31
	Defendence	+27	Affiliation	+26
	Dominance	+38	Cognitive St.	+28
	Social Recog.	+25	Dominance	+39
			Endurance	+22
			Exhibition	+33
			Order	+22
			Desirability	+26
ENERGY	Autonomy	+22	Achievement	+32
	Impulsivity	+32	Change	+24
	Social Recog.	+24	Defendence	+28
			Endurance	+28
			Harmavoidance	-24
			Nurturance	+23
			Sentience	+32

*"P" ranged from $<.05$ to $<.001$, with the average $P <.02$.

The zero-order correlations between the respiratory variables and the PRF and Eysenck personality variables (Table 6) demonstrate that no single personality factor accounts for much, if any, of the variance in respiratory behavior. The few significant correlations explain, on the average, only 5-6% of the variance. In addition, there is virtually no overlap in the correlations for men and for women. The nature of these correlations and the lack of any pattern make them very difficult to interpret.

In contrast to several earlier reports on CO₂ sensitivity, no correlation appeared between ventilatory increase and Eysenck's Extraversion scale. There is no confirmation of Arkinstall et al's findings of a relationship between (1) CO₂ sensitivity and the PRF Aggression scale, and (2) frequency response and Eysenck's Neuroticism scale.

The intercorrelation matrix of measures of respiratory response (Table 7) reveals highly correlated parameters within each respiratory condition but little relationship of parameters across respiratory conditions. Outside of a very modest correlation indicating that male and female deeper breathers tend to be less sensitive to CO₂, neither CO₂ responsiveness nor the response to mechanical loads can be predicted from resting respiratory behavior. There is no relationship between responses to chemical and mechanical loading, and the response to one type of mechanical load is a poor predictor of response to the other. The correlations are sparse, and the resultant R²'s indicate that they account for a very small part of the variance. No correlation was found between mechanical loads for the parameters of respiratory behavior on the first unloaded breath.

REDUCTION OF VARIABLES

Applying a factor analysis to the respiratory variables to reduce the data for further analysis was decided against for two reasons, the inherent relatively reciprocal relationship between TV and RR and the lack of strong correlation between respiratory conditions. Applying a factor analysis to the field of personality variables would have diluted the data in exchange for the convenience of a smaller number of variables to handle, a loss of information not worth this gain. Although a Discriminant Analysis would have permitted the derivation of functions utilizing personality variables to predict respiratory behavior, the nature of the discriminant function would not provide any basis for understanding the relationships between the personality and respiratory variables, and would also be somewhat dependent upon the particular points chosen for dividing subjects into categories on the basis of respiratory behavior. It would also leave unsolved the question of reducing the number of respiratory variables.

A multiple regression analysis of personality variables against each of the respiratory parameters would indicate whether or not personality variables in combination, rather than singly, would have greater explanatory power for variation in respiratory behavior.

First the index of CO₂ responsiveness was reduced to one parameter, slope at the steady state (Slope SS), chosen because it was the most consistently and highly correlated to the other CO₂ response measures. Further elimination of respiratory variables awaited the results of the multiple regression to avoid any unnecessary loss of information.

Multiple Regression Analysis

A stepwise forward selection procedure was used¹, with a .50 entry criterion. For each respiratory parameter, the initial step located the personality variable that produced the largest R^2 . Then, for each of the remaining personality variables, individual F-statistics were calculated that reflected each variable's contribution to the model, were it to be included. Of those personality variables with a partial F-statistic that reached the criterion specified for entry, the variable with the largest F-statistic would be added to the model. This procedure was repeated until no personality variable produced a partial F-statistic meeting the criterion. At each repetition, partial F-statistics were recomputed for variables already in the model. Variables were not dropped from the model if they fell below the significance criterion when further variables were added, however, to avoid losing information at this early stage.

The multiple regression results are in Tables 1 and 2 of the Appendix. The final significant R^2 's ranged from .16 to .28 for the men, and from .12 to .40 for the women. This is a substantial increase over the R^2 's from the simple correlations, which ranged from .05 to .18 for the men and .05 to .13 for the women. Personality variables in combination account for a significantly greater portion of the variance in respiratory behavior. Certain personality scales appeared much more consistently than others in the configurations associated with respira-

¹Before the analysis was run, individual scatterplots drawn for RR and TV parameters of resting and loaded respiratory behavior against PRF scales indicated some curvilinear relationships. A log transformation was performed on all of the respiratory variables before any further analysis.

tory variation, although the relationships were often in opposite directions in the two samples.

The substantial R^2 's and the hints of consistency in the association of personality traits that emerged in the multiple regression results demonstrated the value of approaching the data via configurations of personality variables. A profile analysis was used for a more direct grasp of the ways in which these personality traits were capable of discriminating between subjects who differed in their respiratory behavior.

PROFILE ANALYSIS

The respiratory variables were pared down to the essential components of ventilation: resting TV and RR, change in TV and RR during resistive and elastic loads. The CO_2 sensitivity parameter had previously been reduced to Slope SS. The subjects in each sample were categorized as low, moderate and high along each of these respiratory variables to isolate those at the extremes. In order of magnitude within each parameter the first 16 subjects (20%) were low, the next 48 subjects (60%) were moderate, and the remaining 16 subjects (20%) fell into the high category. The specific values identifying these categories for each respiratory variable were established separately for each sample (Table 8). Within each respiratory variable, personality scale average scores were calculated for the subjects in each of the three categories.

The personality variables in the initial profiles were derived from the multiple regression configurations. Criteria for inclusion were (1) those scales with a partial F-statistic with a $P \leq .15$ that (2)

TABLE 8: VALUES* DEFINING SUBJECT CATEGORIES
IN THE RESPIRATORY VARIABLES USED IN PROFILE ANALYSIS

RESPIRATORY CONDITION	LOWER 20% (n=16)	MIDDLE 60% (n=48)	UPPER 20% (n=16)
<u>RESTING</u>			
TV (ml)	<u>Shallow</u> 387-598 <i>273-404</i>	<u>Moder. Depth</u> 625-977 <i>497-873</i>	<u>Deep</u> 989-2086 <i>875-1497</i>
RR (Breaths/min)	<u>Slow</u> 4-9 <i>7-10</i>	<u>Moder. Rate</u> 10-16 <i>11-17</i>	<u>Rapid</u> 17-34 <i>18-35</i>
<u>CO₂ SENSITIVITY</u>			
Slope SS	<u>Least Responsive</u> +0.23 - +0.85 <i>-0.10 - +0.78</i>	<u>Moder. Responsive</u> +0.88 - +1.69 <i>+0.79 - +1.88</i>	<u>Most Responsive</u> +1.72 - +4.83 <i>+2.02 - +8.28</i>
<u>RESISTIVE LOAD</u>			
TV (% control)	<u>Shallowest</u> 5-20% <i>7-23%</i>	<u>Moder. Change</u> 21-110% <i>24-87%</i>	<u>Deepest</u> 114-303% <i>93-471%</i>
RR (% control)	<u>Slowest</u> 11-57% <i>16-62%</i>	<u>Moder. Change</u> 59-143% <i>64-126%</i>	<u>Fastest</u> 145-320% <i>129-278%</i>
<u>ELASTIC LOAD</u>			
TV (% control)	<u>Shallowest</u> 7-16% <i>7-18%</i>	<u>Moder. Change</u> 18-41% <i>19-49%</i>	<u>Deepest</u> 42-180% <i>50-102%</i>
RR (% control)	<u>Slowest</u> 46-111% <i>82-113%</i>	<u>Moder. Change</u> 112-265% <i>114-260%</i>	<u>Fastest</u> 267-778% <i>276-537%</i>

* Values for male subjects are in standard typeface; those for female subjects are in italics.

were associated with more than one parameter within the respiratory condition. For each respiratory condition this produced a nucleus of scales common to both sexes as well as scales unique to each sex (Table 9). Univariate two-way analyses of variance performed for each respiratory situation, using TV and RR as the independent variables and the remaining PRF scales, indicated several interaction effects between rate and volume. This added five additional personality scales to the initial profiles: Sentience to the male profile for resting respiration, Play to the male profile for resistive load response, Endurance and Play to the male personality trait profile for elastic load respiratory response, and Achievement to both the male and female profiles for elastic load respiratory response.

The resulting personality profiles were only moderately encouraging. Some personality scales produced good separation between the extreme categories, some items showed an equality between the extreme groups (although they differed significantly from the moderate group), and some differences disappeared when standard errors were considered.

Respiratory Pattern vs. Single Parameters

Redrawing the personality profiles for respiratory behavior in the resting and the two loaded conditions with the extremes defined by both rate and volume¹ noticeably improved the separation achieved by rate

¹The extremes defined by a combination of rate and volume represent the two ends of the continuum of respiratory patterns, ranging from the extremely slow/deep breather to the extremely rapid/shallow breather. For resting respiratory behavior, for example, subjects who fell in both the "deep" TV category and the "slow" RR category were designated the "slow/deep breathers". For the pattern response to each of the mechanical loads, for example, the "slow/deep responders" are those who appeared in the categories representing the greatest increase in TV and the greatest decrease in RR.

**TABLE 9: PRELIMINARY PERSONALITY PROFILE TRAITS
SELECTED FROM MULTIPLE REGRESSION CONFIGURATIONS**

<u>RESPIRATORY CONDITION</u>	<u>TRAITS COMMON TO BOTH SEXES</u>	<u>UNIQUE TO MALES</u>	<u>UNIQUE TO FEMALES</u>
RESTING	Achievement Aggression Defendence Dominance Sentience Succorance Understanding Desirability	Change Nurturance Social Recog.	Abasement Affiliation Autonomy Exhibition Play
CO ₂ SENSITIVITY	Achievement Dominance Nurturance Social Recog.	Abasement Affiliation Defendence	Harmavoidance Play Understanding
RESISTIVE LOAD	Affiliation Defendence Harmavoidance Order Play	Abasement Achievement Cognitive St. Exhibition Nurturance Social Recog. Desirability	Sentience
ELASTIC LOAD	Achievement Aggression Change Defendence Endurance Impulsivity Nurturance Order Play Sentience Desirability	Abasement Autonomy Exhibition Social Recog.	Affiliation Harmavoidance Succorance

or volume in artificial isolation. Figure 2 illustrates this improvement. The number of subjects in the extreme breathing pattern categories for resting and mechanical load conditions are indicated in Table 10.

Inspection of the extreme category means for those personality scales excluded from the initial profiles identified additional scales for each sample that significantly separated these behavioral groups. The final personality profiles for the extreme behavior groups in each respiratory condition, then, included all of the personality scales that achieved a significant separation between them.

Personality Profiles for Slow/Deep vs.
Rapid/Shallow Resting Respiratory Patterns

The male and female personality profiles for the extreme groups in resting respiratory pattern were merged. The overall profile was divided into segments by grouping those traits appearing in both male and female profiles, those traits appearing only in the male profile, and those appearing only in the female profile.

The nucleus of common traits was larger than initially apparent because of the small numbers of subjects in the pattern extremes and the consequent fairly large standard errors. A number of traits provided significant separation between slow/deep and rapid/shallow breathers in one sample and showed an identical relationship in the other despite the large overlapping standard errors. Although the scores are sometimes at different levels, all but one of the relationships are in the same direction in this common nucleus. Aggression is the one exception. The male and female personality profiles for slow/deep vs. rapid/shallow resting breathers are presented in both Figure 3 and

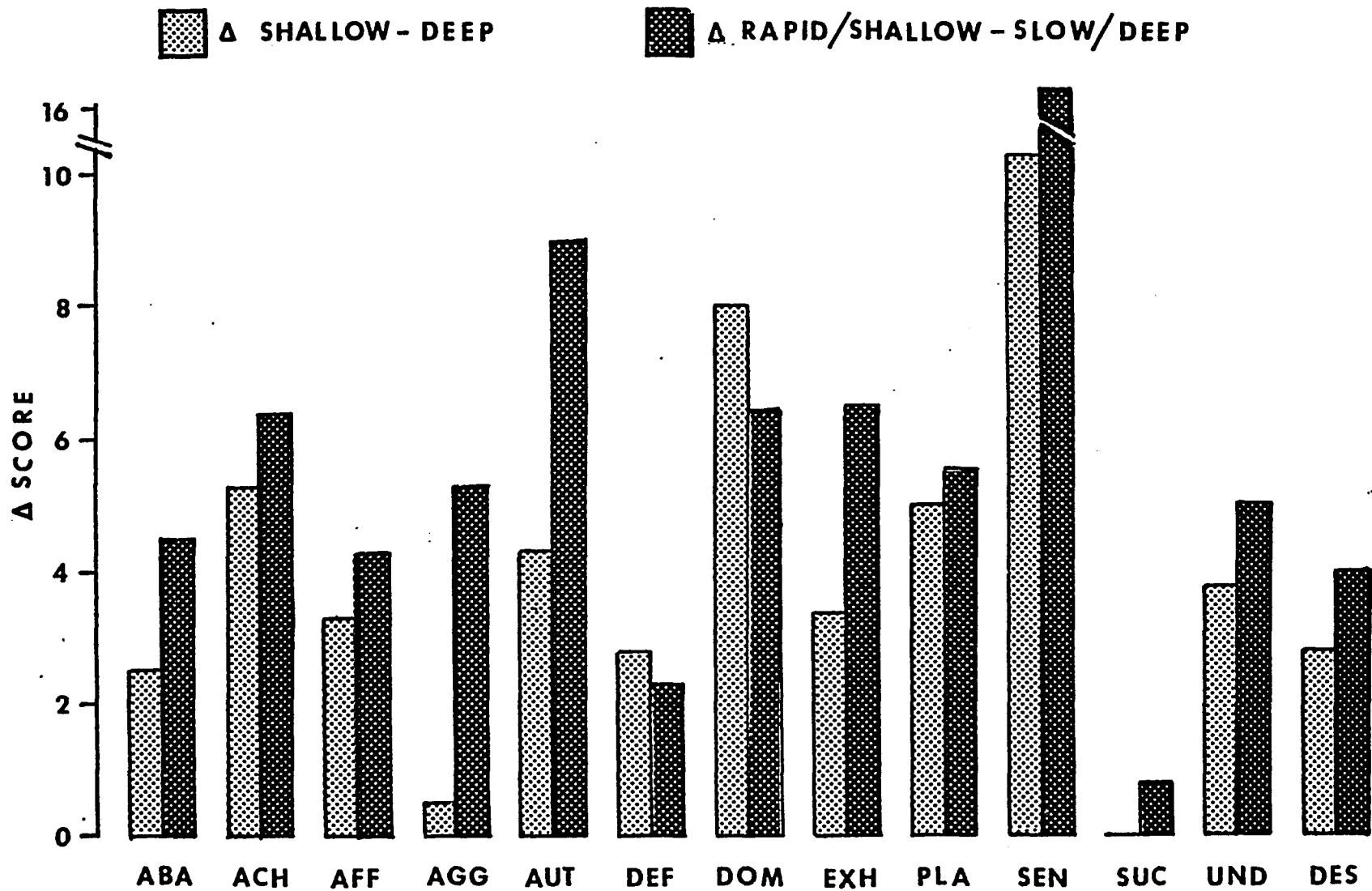


FIGURE 2: SEPARATION OF EXTREME GROUPS ACHIEVED BY BREATHING PATTERN VS. SINGLE PARAMETER IN GENERATING PRELIMINARY PERSONALITY PROFILES FOR FEMALE RESTING RESPIRATORY BEHAVIOR

**TABLE 10: EXTREME RESPIRATORY BEHAVIOR GROUPS
DEFINED BY BREATHING PATTERN**

<u>RESPIRATORY CONDITION</u>	<u>MALE</u>	<u>FEMALE</u>
<u>RESTING</u>		
Slow/Deep	n=12	n=10
Rapid/Shallow	n= 8	n= 8
<u>RESISTIVE LOAD</u>		
Slow/Deep	n=12	n=13
Rapid/Shallow	n=10	n=10
<u>ELASTIC LOAD</u>		
Slow/Deep	n=10	n= 7
Rapid/Shallow	n= 8	n= 8

Table 11.

Looking at the overall PRF scale means in Table 2, it becomes clear that both extreme groups stand out clearly from the mean on some traits (e.g., need for Dominance), while on others only one of the extreme groups is defined as different (e.g., need for Exhibition). This observation underlines the importance of looking at traits in a configuration rather than separately.

The significance of the difference between the profiles for slow/deep and rapid/shallow resting breathers was tested within each sample using an application of analysis of variance (Morrison, 1967). The slow/deep and rapid/shallow categories are regarded as treatment factors. The dependent variables (or response factors) are the differences between adjacent personality scales. The basic questions are: (1) whether or not the two profiles are parallel (i.e., have the same shape) and, if they are, (2) whether the levels are significantly different. A one-way multivariate analysis of variance is used to determine whether or not the profiles are significantly different in shape. The existence of a treatment x response interaction would be reflected in non-parallel profiles. If, however, the profile shapes are shown to be parallel, a one-way univariate analysis of variance on the sums of the dependent variables across each of the respiratory groups will indicate whether or not they are of identical height.

Inspection of the personality profiles for resting respiratory behavior revealed an obvious combination of both non-parallel and parallel (but non-level) components. So as not to blur the results, they were separated into their non-parallel and parallel components and the two sub-profiles analyzed separately. Table 12 displays the results of

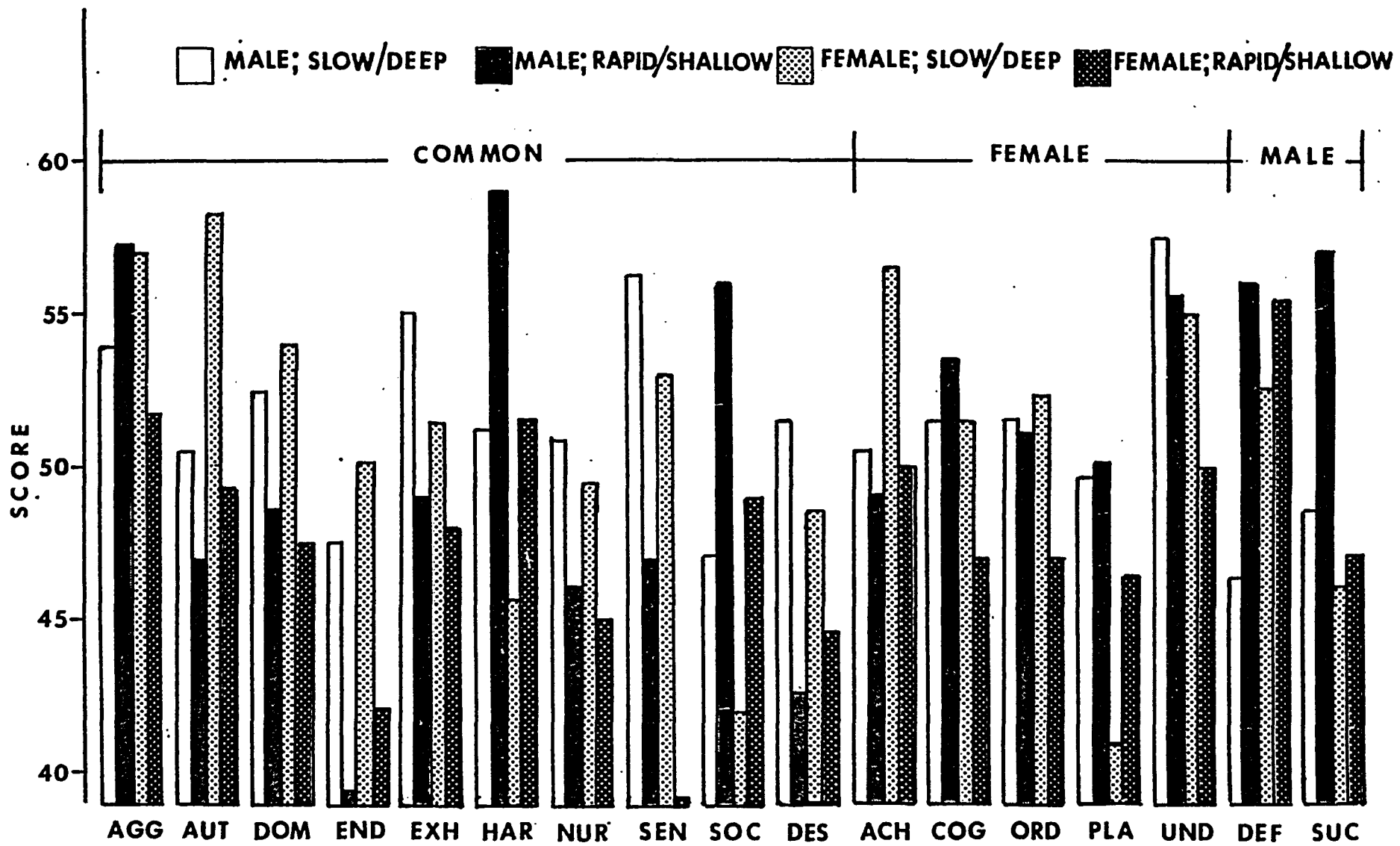


FIGURE 3: PERSONALITY PROFILES FOR EXTREME RESTING RESPIRATORY PATTERN GROUPS

TABLE 11: PERSONALITY PROFILES ASSOCIATED WITH
EXTREMES IN RESTING RESPIRATORY PATTERN*

<u>MALE</u>	<u>FEMALE</u>
aggression	AGGRESSION
AUTONOMY	AUTONOMY
DOMINANCE	DOMINANCE
ENDURANCE	ENDURANCE
EXHIBITION	EXHIBITION
harmavoidance	harmavoidance
NURTURANCE	NURTURANCE
SENTIENCE	SENTIENCE
social recognition	social recognition
DESIRABILITY	DESIRABILITY
defendence	---
succorance	---
---	ACHIEVEMENT
---	COGNITIVE STRUCTURE
---	ORDER
---	play
---	UNDERSTANDING

*UPPERCASE indicates that the group of slow/deep breathers scored higher on the PRF scale relative to the group of rapid/shallow breathers. Lowercase indicates that they scored below the rapid/shallow breathers.

TABLE 12: STATISTICAL ANALYSIS OF PERSONALITY PROFILES FOR EXTREME RESTING RESPIRATORY PATTERNS

	NON-PARALLEL COMPONENT	P <	PARALLEL COMPONENT
<u>MALE</u> (n=20)	D1=Desirability - Aggression	*	D1=Endurance - Exhibition
	D2=Aggression - Defence	*	D2=Exhibition - Nurturance
	D3=Defence - Autonomy	*	D3=Nurturance - Desirability
	D4=Autonomy - Harmavoidance	*	
	D5=Harmavoidance - Sentience	.05	
	D6=Sentience - Social Recog.	.005	
	D7=Social Recog. - Dominance	*	
	D8=Dominance - Succorance	*	
	D9=Succorance - Endurance	.05	
Wilks' criterion yields an F of 0.90 (df=9,10), P .56. The null hypothesis of no difference in shape must be accepted.			Univariate Anova on the sums of the variables yields an F of 4.30, P .05. The null hypothesis of no difference in levels can be rejected.
<u>FEMALE</u> (n=18)	D1=Autonomy - Harmavoidance	*	D1=Aggression - Dominance
	D2=Harmavoidance - Sentience	.01	D2=Dominance - Endurance
	D3=Sentience - Social Recog.	.001	D3=Endurance - Exhibition
	D4=Social Recog. - Order	*	D4=Exhibition - Nurturance
	D5=Order - Play	.05	D5=Nurturance - Desirability
	D6=Play - Aggression	*	D6=Desirability - Achievement
Wilks' criterion yields an F of 3.97 (df=6,11), P .02. The null hypothesis of no difference in shape can be rejected.			D7=Achievement - Cognitive St. D8=Cognitive St. - Understanding
			Univariate Anova on the sums of the variables yields an F of 6.01, P .03. The null hypothesis of no difference in level can be rejected.

* Approached significance.

the statistical profile analysis.

For the female profile, the non-parallel component is significantly different in shape ($P < .02$) and the parallel component significantly different in level ($P < .03$). For the male profile the parallel component is significantly different in level ($P < .05$), but the non-parallel segment does not achieve overall statistical significance although several of the individual variables do.

Personality Profiles for Low
vs. High CO₂ Sensitivity

Profiles of those personality scales separating subjects at the upper and lower extremes of responsiveness to CO₂ (Table 13) were developed in the same manner as those for resting respiratory pattern. The nucleus of traits common to men and women consisted of five scales: Autonomy, Order, Social Recognition, Succorance and Desirability. Order is the one common scale in this profile that reflects opposite relationships for men and women. The highly responsive women and low responsive men fell below the mean, with their respective counterparts above the mean.

Of these five common traits, all except Order and Succorance appeared in the common nucleus for resting respiratory pattern. Succorance was unique to males, and Order to females.

Of the four scales unique to women in the context of CO₂ sensitivity, Affiliation appears for the first time. Endurance and Harm-avoidance were part of the common nucleus for resting respiration, and Play is unique to women in both respiratory situations. Of the five scales unique to the men in the context of CO₂ sensitivity, Abasement appears for the first time. Exhibition and Sentience were part of

TABLE 13: PERSONALITY PROFILES ASSOCIATED WITH
EXTREMES IN CO₂ SENSITIVITY*

MALE	FEMALE
AUTONOMY	AUTONOMY
order	ORDER
social recognition	social recognition
succorance	succorance
DESIRABILITY	DESIRABILITY
abasement	---
cognitive structure	---
defendence	---
EXHIBITION	---
SENTIENCE	---
---	affiliation
---	ENDURANCE
---	harmavoidance
---	play

*UPPERCASE indicates that the low CO₂ sensitivity group scored higher on the PRF scale relative to the high sensitivity group. Lowercase indicates that they scored below the high sensitivity group.

the common nucleus in the resting respiratory profile. Defence is again unique to men in both respiratory situations. Cognitive Structure was previously unique to the women.

A comparison of the personality profiles for resting respiratory pattern and CO₂ sensitivity (Table 14) reveals a powerful congruence between the profiles characterizing (1) slow/deep breathers and subjects low on CO₂ sensitivity, and (2) rapid/shallow breathers and subjects high on CO₂ sensitivity. Of the nine personality scales in the women's CO₂ sensitivity profiles, seven applied to women in the resting respiratory profiles, one applied only to men (Desirability), and one is new (Affiliation). The seven scales characterizing the women in both respiratory conditions describe the slow/deep breather and the women low on CO₂ sensitivity in the same terms relative to their counterparts. Desirability, for example, describes the female slow/deep breathers and the low CO₂ sensitive women in the same way.

Of the ten personality scales in the men's CO₂ sensitivity profiles, seven applied to men in the resting respiratory profiles, two were relevant only to women (Cognitive Structure and Order), and one is new (Abasement). The seven scales characterizing the men in both respiratory conditions describe the slow/deep breather and the low CO₂ sensitive male in the same terms relative to their counterparts. Cognitive Structure and Order, however, reflect the opposite relationship.

These results raise the question of the nature of the relationship between the personality profiles for the extreme groups in resting breathing pattern and CO₂ sensitivity. Are the profiles similar because the two groups comprise the same subjects, i.e., are the slow/deep breathers the same individuals who are minimally responsive to

TABLE 14: PERSONALITY PROFILE ELEMENTS
COMMON TO EXTREME GROUPS IN RESTING
RESPIRATORY PATTERN AND CO₂ SENSITIVITY*

MALE	FEMALE
AUTONOMY	AUTONOMY
defendence	ENDURANCE
EXHIBITION	harmavoidance
SENTIENCE	ORDER
social recognition	play
succorance ¹	social recognition
DESIRABILITY	succorance ¹
	DESIRABILITY

*UPPERCASE indicates that both the group of slow/deep resting breathers and the group minimally sensitive to CO₂ scored higher on the PRF scale relative to their respective counterparts. Lowercase indicates that these two groups scored below their respective counterparts.

¹Unique to males in the resting respiratory pattern profiles, but a common characteristic in the personality profiles for the extreme groups in CO₂ sensitivity.

CO₂ and the rapid/shallow breathers those who are the most responsive to CO₂? Alternatively, are the profiles similar in content and shape but not in level, i.e., are the same relative positions of each respiratory condition's extreme groups on the common personality scales characterized by different absolute values on these scales?

Schaefer (1954, 1958), investigating CO₂ sensitivity with male subjects, found that his minimally CO₂ responsive individuals tended to be slower/deeper resting breathers, and his highly responsive ones tended to be faster/shallower breathers. He cited several earlier works that he felt pointed in this direction. Further substantiation is lacking, though, because subsequent studies of CO₂ sensitivity have not examined the relationship to resting breathing pattern.

Of the 10 female slow/deep breathers in the present female sample, 3 were also minimally responsive to CO₂, 2 were highly responsive and the remaining 5 were in the moderate group. Of the 8 rapid/shallow breathers, only 1 was highly sensitive to CO₂. One was minimally sensitive, and the other 6 were moderate. The lack of correlation between either resting TV or RR and CO₂ sensitivity, as indexed by Slope SS (Table 7), is paralleled by the negative results of separate chi-square analyses of resting TV, RR and pattern in relation to Slope SS (Table 15).

Of the 12 slow/deep breathers in the present male sample, 3 were also minimally responsive to CO₂, 2 were highly responsive and the remaining 7 were in the moderate group. Of the 8 rapid/shallow breathers, 4 were highly responsive to CO₂ and 4 were in the moderate group. There is a modest inverse correlation between Slope SS and resting TV ($r = -.32, P < .004$) (Table 7). Deeper breathers are over-

TABLE 15: OVERLAP OF SUBJECTS IN EXTREME GROUPS OF
RESTING RESPIRATORY PATTERN AND CO₂ SENSITIVITY

	<u>MALE</u>	<u>FEMALE</u>
RESTING RESPIRATORY PATTERN x CO ₂ SENSITIVITY (df = 2)	$\chi^2 = 3.84$ NS	$\chi^2 = 1.22$ NS
RESTING TIDAL VOLUME x CO ₂ SENSITIVITY ¹ (df = 4)	$\chi^2 = 10.56$ P .03	$\chi^2 = 8.69$ NS
RESTING RESPIRATORY RATE x CO ₂ SENSITIVITY (df = 4)	$\chi^2 = 2.46$ NS	$\chi^2 = 5.35$ NS

¹There is a higher than expected percentage of deep breathers among those minimally sensitive to CO₂ (38% instead of 20%), and of shallow breathers in the maximally sensitive group (44% instead of 20%).

represented in the low CO₂ sensitivity group (38% instead of the expected 20%) and shallower breathers over-represented in the high sensitivity group (44% instead of the expected 20%). A chi-square analysis was significant at $P < .03$ (Table 15). There was no significant association, however, with resting respiratory pattern.

The only significant overlap, therefore, is between male deep breathers -- not slow/deep breathers -- and males low on CO₂ sensitivity. Although statistically significant, the actual number of subjects involved is very small.

The alternative explanation, that the common aspects of the resting and CO₂ sensitivity profiles represent different points on the same personality scales, is more productive (Tables 16A, 16B). Comparing the seven personality scales common to resting respiratory pattern and CO₂ sensitivity reveals, for each sample, that the counterpart profiles for resting respiratory pattern oppose each other across a broader range of scores (on five of the seven scales for men, and six of the seven scales for women). The CO₂ sensitivity profiles are, in addition, characterized by higher scores than the resting profiles on several scales (Exhibition and Sentience for men; Endurance, Harm-avoidance, Play and Social Recognition for the women).

For the males, looking at each respiratory condition's counterpart profiles in relation to the sample mean provides further differences. For resting respiratory pattern the sample mean falls somewhere between the counterpart profiles on all seven scales. For the CO₂ profiles, however, both profiles fall below the sample mean on one scale, the low sensitivity profile approaches the sample mean on four scales, and the high sensitivity profile approaches it on one scale.

TABLE 16A: COMPARISON OF SCORES ON
PRF SCALES COMMON TO MALE PROFILES FOR RESTING
RESPIRATORY PATTERN AND CO₂ SENSITIVITY GROUPS

<u>PRF SCALES</u>	<u>SAMPLE MEAN</u>	<u>RESTING PATTERN</u>		<u>CO₂ SENSITIVITY</u>	
		<u>SLOW/DEEP</u>	<u>--RAPID/SHALLOW</u>	<u>LOW</u>	<u>-----HIGH</u>
Autonomy	50.1	50.4	47.1	49.8	46.5
Defendence	50.6	46.3	55.9	49.2	54.5
Exhibition	53.5	54.9	49.0	56.1	50.6
Sentience	53.6	56.2	47.1	57.7	54.2
Social Recog.	49.8	47.3	56.0	48.9	54.2
Succorance	51.4	48.4	57.1	51.4	54.4
Desirability	49.2	51.5	42.2	49.4	46.3

TABLE 16B: COMPARISON OF SCORES ON
PRF SCALES COMMON TO FEMALE PROFILES FOR RESTING
RESPIRATORY PATTERN AND CO₂ SENSITIVITY GROUPS

<u>PRF SCALES</u>	<u>SAMPLE MEAN</u>	<u>RESTING PATTERN</u>		<u>CO₂ SENSITIVITY</u>	
		<u>SLOW/DEEP</u>	<u>--RAPID/SHALLOW</u>	<u>LOW</u>	<u>-----HIGH</u>
Autonomy	53.5	58.3	49.2	57.1	50.1
Endurance	48.1	50.2	41.8	51.2	44.8
Harmavoidance	50.9	45.4	51.2	48.4	53.0
Order	48.9	52.6	47.0	51.0	47.6
Play	47.6	40.7	46.5	45.5	52.5
Social Recog.	47.9	42.0	48.8	47.0	51.7
Desirability	48.0	48.6	44.3	48.7	45.0

The lack of significantly overlapping populations beneath the profile similarities does not preclude the possibility of interaction between resting respiratory pattern and CO₂ sensitivity. An examination of the data provides some support for the existence of such an interaction on the physiological level. For both the males and females minimally responsive to CO₂, 2 of the 3 slow/deep breathers are the 2 least sensitive subjects in the category. For the males highly responsive to CO₂, 3 of the 4 rapid/shallow breathers are among the most sensitive in this group (including the most sensitive). The one woman who is both highly CO₂ sensitive and a rapid/shallow breather, however, is not near the upper boundary of sensitivity.

Is there evidence of an interaction on the personality level as well, e.g., do those subjects just noted, who show some indication of an interaction on the physiological level, give the most extreme personality scores in their category? The data do appear to indicate a possible interaction (Tables 17A, 17B) although, as above, the small number of subjects prohibit definitive conclusions.

The 3 low CO₂ sensitive men who are slow/deep breathers show the extreme average score in the appropriate direction on all seven of the scales shared by both respiratory conditions. This group includes the most extreme individual score on six of the scales and the second most extreme score on the remaining scale. The 4 highly CO₂ sensitive men who are also rapid/shallow breathers show the extreme average score in the appropriate direction on four of the seven shared scales. This group includes the most extreme individual score on four scales and the second most extreme individual score on the other three scales.

For the women, the pattern is less consistent. The 3 low CO₂ sen-

TABLE 17A: AVERAGE SCORES ON PRF SCALES COMMON TO MALE
 PROFILES FOR RESTING RESPIRATION AND CO₂ SENSITIVITY
 IN REGARD TO PATTERN x CO₂ SENSITIVITY INTERACTION

<u>MINIMAL CO₂</u> <u>SENSITIVITY</u>	<u>AUT</u>	<u>def</u>	<u>EXH</u>	<u>SEN</u>	<u>soc</u>	<u>suc</u>	<u>DES</u>
Slow/Deep Breathers (n=3)	55	39	61	62	43	49	58
Others (n=13)	50	51	56	57	50	53	47
<hr/>							
<u>MAXIMAL CO₂</u> <u>SENSITIVITY</u>	<u>aut</u>	<u>DEF</u>	<u>exh</u>	<u>sen</u>	<u>SOC</u>	<u>SUC</u>	<u>des</u>
Rapid/Shallow Breathers (n=4)	41	55	51	47	55	58	50
Others (n=12)	49	55	51	57	53	54	45

UPPERCASE indicates that the respective CO₂ sensitivity group scored higher on the particular PRF scale compared to its counterpart. Lower-case indicates that the respective CO₂ sensitivity group scored lower on the particular PRF scale compared to its counterpart.

TABLE 17B: AVERAGE SCORES ON PRF SCALES COMMON TO FEMALE
 PROFILES FOR RESTING RESPIRATION AND CO₂ SENSITIVITY
 IN REGARD TO PATTERN x CO₂ SENSITIVITY INTERACTION

<u>MINIMAL CO₂</u> <u>SENSITIVITY</u>	<u>AUT</u>	<u>END</u>	<u>har</u>	<u>ORD</u>	<u>pla</u>	<u>soc</u>	<u>DES</u>
Slow/Deep Breathers (n=3)	62	51	41	45	34	45	41
Others (n=13)	57	52	51	52	49	47	51
<hr/>							
<u>MAXIMAL CO₂</u> <u>SENSITIVITY</u>	<u>aut</u>	<u>end</u>	<u>HAR</u>	<u>ord</u>	<u>PLA</u>	<u>SOC</u>	<u>des</u>
Rapid/Shallow Breathers (n=1)	31	54	39	43	64	61	51
Others (n=14)	51	44	54	48	52	50	44
<hr/>							

UPPERCASE indicates that the respective CO₂ sensitivity group scored higher on the particular PRF scale compared to its counterpart. Lower-case indicates that the respective CO₂ sensitivity group scored lower on the particular PRF scale compared to its counterpart.

sitive slow/deep breathers and the 1 high CO₂ sensitive rapid/shallow breather show appropriately extreme average scores for only four of the seven PRF scales common to the two respiratory conditions. The low CO₂ sensitive sub-group includes the most extreme individual score on two scales, and the second most extreme score on three scales. The one highly sensitive rapid/shallow breather produced the most extreme score on one scale and the second most extreme score on another.

Profiles for Respiratory Response
Patterns to Mechanical Loads

The procedure already described was used to construct personality profiles associated with the extreme male and female respiratory response patterns to resistive and elastic loads (Table 18). With few exceptions, the same personality scales appear in both the male and female profiles. Several of these common scales, however, express a different relationship with loaded respiratory behavior for each sex (Achievement and Harmavoidance for both loads; Aggression, Nurturance and Order for elastic loading).

The personality profiles developed for loaded respiratory behavior correspond substantially with the profiles associated with resting respiratory patterns (Table 11). In the male load-response profiles, eight of the thirteen personality scales appeared in the men's resting pattern personality profile and four in the women's unique resting profile component. In the female load-response profiles, nine of the twelve personality scales appeared in the women's resting pattern personality profile and one in the men's unique component.

This consistency, however, does not extend to the relationships between personality scale and respiratory pattern, in contrast to the

TABLE 18: PERSONALITY PROFILES ASSOCIATED WITH THE
EXTREME LOADED RESPIRATORY RESPONSE GROUPS*

	<u>RESISTIVE LOADING</u>	<u>ELASTIC LOADING</u>
M E N	achievement	ACHIEVEMENT
	AGGRESSION	AGGRESSION
	autonomy	autonomy
	cognitive structure	---
	defendence	defendence
	endurance	---
	EXHIBITION	EXHIBITION ¹
	harmavoidance	harmavoidance
	IMPULSIVITY	IMPULSIVITY ¹
	nurturance	NURTURANCE
	order	ORDER ¹
	PLAY	play
	---	DESIRABILITY
W O M E N	ACHIEVEMENT	achievement
	AFFILIATION	AFFILIATION
	AGGRESSION	aggression
	autonomy	autonomy
	defendence	defendence
	---	endurance
	HARMAVOIDANCE	HARMAVOIDANCE
	IMPULSIVITY	IMPULSIVITY
	nurturance	nurturance
	order	ORDER
	DESIRABILITY	DESIRABILITY
	---	play ¹

*UPPERCASE indicates that the efficient response group scored higher on the PRF scale relative to the inefficient response group. Lowercase indicates that they scored below the inefficient response group. The profiles expressed, therefore, are for the slow/deep resistive response group and the rapid/shallow elastic response group.

¹The PRF scale appeared in the TV and RR group profiles in the same direction, but disappeared in the pattern group profiles.

profile similarity between slow/deep breathers and those low on CO₂ sensitivity. For example, in the male sample the slow/deep resting group and the rapid/shallow resistive load group scored relatively higher on Aggression than their counterparts. By itself, this indicates that resting slow/deep breathers may tend to reverse their breathing pattern in response to resistive loads, and vice-versa. On Exhibition, however, the slow/deep resting group and the slow/deep resistive load group both scored relatively higher than their counterparts. From this perspective, slow/deep breathers may tend to maintain or enhance their resting pattern during resistive loading. These personality profile results are consonant with the lack of correlation between parameters for resting and loaded respiratory behavior.

Comparing the respective personality profiles for resistive and elastic load behavior reveals three interesting patterns. (1) For the majority of the personality scales (such as Aggression and Autonomy for the men, and Affiliation and Autonomy for the women), the higher scoring group in each of the loads is the one with the more efficient respiratory response. (2) For a smaller number of personality scales (e.g., Achievement and Order for both men and women), the higher scoring group in each load is the one with the same respiratory response, a response that is efficient in the context of one type of load only. (3) Several personality scales appear to discriminate between the extreme response groups only for one type of load. This perhaps indicates two mutually exclusive dimensions along which the respiratory response to mechanical loads varies, with the possible modifying influence of a load-specific factor.

The first group of personality scales appears to reflect a

stimulus-oriented dimension of respiratory behavior, with individuals altering their response according to the specific characteristics of the mechanical impediment. The two ends of the continuum are characterized by efficient vs. inefficient respiratory alterations. The second group of personality scales appears to reflect a response-oriented dimension, i.e., alteration in respiratory response would be the same no matter the nature of the mechanical impediment. The extremes of such a stereotyped response are slow/deep and rapid/shallow breathing. Like a broken clock that is right twice a day, they would be included in the efficient response group for one type of load even though they would have responded, not to the specific nature of the respiratory constraint, but to the general challenge to their ventilation.

The personality profiles that characterize the extreme load-response groups, then, would appear to reflect three dimensions of respiratory response. The major component expresses variation along the stimulus-oriented dimension, a smaller component is associated with variation along the response-oriented dimension, and the final component comprises personality characteristics associated with respiratory variation specific to one type of load. The prototypic profile for each component is diagrammed in Table 19. To see if the subjects falling at the extremes of each of the two response dimensions form an appropriately discriminable sub-group on the relevant personality scales, the subjects were identified and the sub-group personality scale average scores compared.

Subjects who had responded efficiently to each load -- i.e., whose respiratory response to resistive loads was categorized as slower/deep-

TABLE 19: EXPECTED RELATIVE PROFILES ASSOCIATED WITH
THE THREE PROPOSED LOAD-RESPONSE PROFILE COMPONENTS

	<u>STIMULUS-ORIENTED</u> ¹	<u>RESPONSE-ORIENTED</u> ²	<u>LOAD-SPECIFIC</u> ¹
M E N	AGGRESSION	achievement	<u>Resistive:</u>
	autonomy	PLAY	cognitive st.
	DEFENDENCE	nurturance	endurance
	harmavoidance	order	
	EXHIBITION		<u>Elastic:</u>
	IMPULSIVITY		DESIRABILITY
W O M E N	AFFILIATION	ACHIEVEMENT	<u>Resistive:</u>
	autonomy	AGGRESSION	(none)
	defendence	order	
	HARMAVOIDANCE		<u>Elastic:</u>
	IMPULSIVITY		endurance
	nurturance		play
	DESIRABILITY		

¹UPPERCASE indicates that Efficient Adapters should score higher on the PRF scale relative to Inefficient Adapters. Lowercase indicates that they should score below Inefficient Adapters.

²UPPERCASE indicates that Slow/Deep Responders should score higher on the PRF scale relative to Rapid/Shallow Responders. Lowercase indicates that they should score below Rapid/Shallow Responders.

er or slower¹/moderate TV change, and to elastic loads as faster/shallower or moderate RR change/shallower¹ -- were designated Efficient Adapters. Their dimension counterparts were Inefficient Adapters. Subjects whose respiratory response to resistive loads was slower/deeper or slower¹/moderate TV change, and to elastic loads was slower/deeper or deeper¹/moderate RR change, were Slow/Deep Responders. Their dimension counterparts were Rapid/Shallow Responders. The male subjects in these categories are: 5 Efficient Adapters, 1 Inefficient Adapter; 5 Slow/Deep Responders, 3 Rapid/Shallow Responders. The female subjects in these categories are: 3 Efficient Adapters, 3 Inefficient Adapters; 5 Slow/Deep Responders, 6 Rapid/Shallow Responders.

The expected relationships within each profile component in Table 19 can be compared with the actual results (Figs. 4-5). The women show somewhat stronger results. Six of the seven scales defining the stimulus-oriented group discriminate between the Efficient and Inefficient Adapters in the expected directions, while the two response-oriented groups tend to cluster together. Two of the three response-oriented scales discriminate between the Slow/Deep Responders and their counterparts in the expected directions, while the two response-oriented groups tend to cluster together. Both of the elastic load-specific scales discriminate between Efficient and Inefficient Adapters in the expected direction. One of them also fulfills these conditions for the Slow/Deep and Rapid/Shallow Responders.

For the men, four of the six scales defining the stimulus-oriented group discriminate as predicted between the Efficient and Inefficient

¹The parameter directly relevant to the constraint imposed by the load.

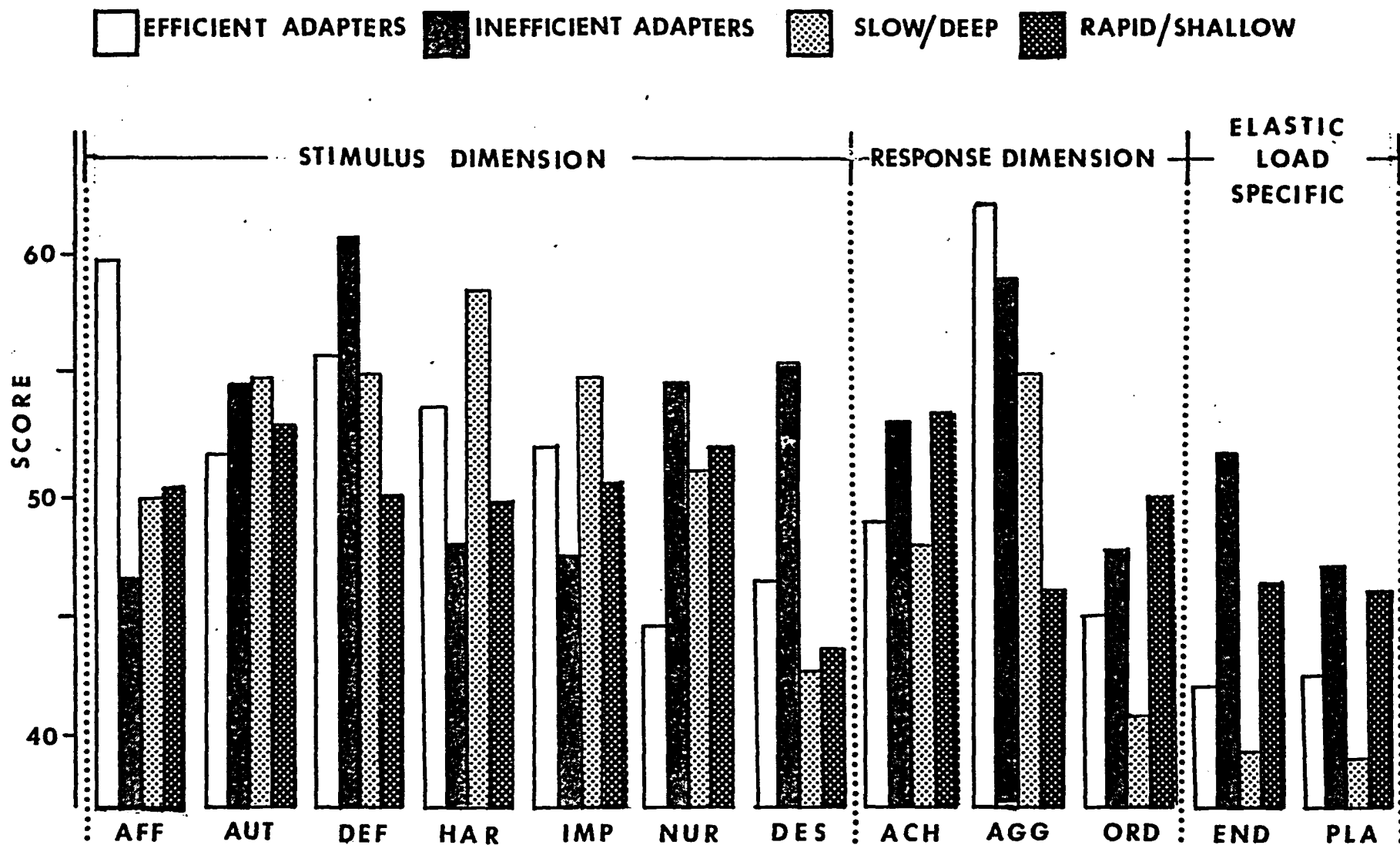


FIGURE 4: PERSONALITY PROFILE COMPONENTS FOR LOAD-RESPONSE ORIENTATIONS FOR FEMALE SUBJECTS

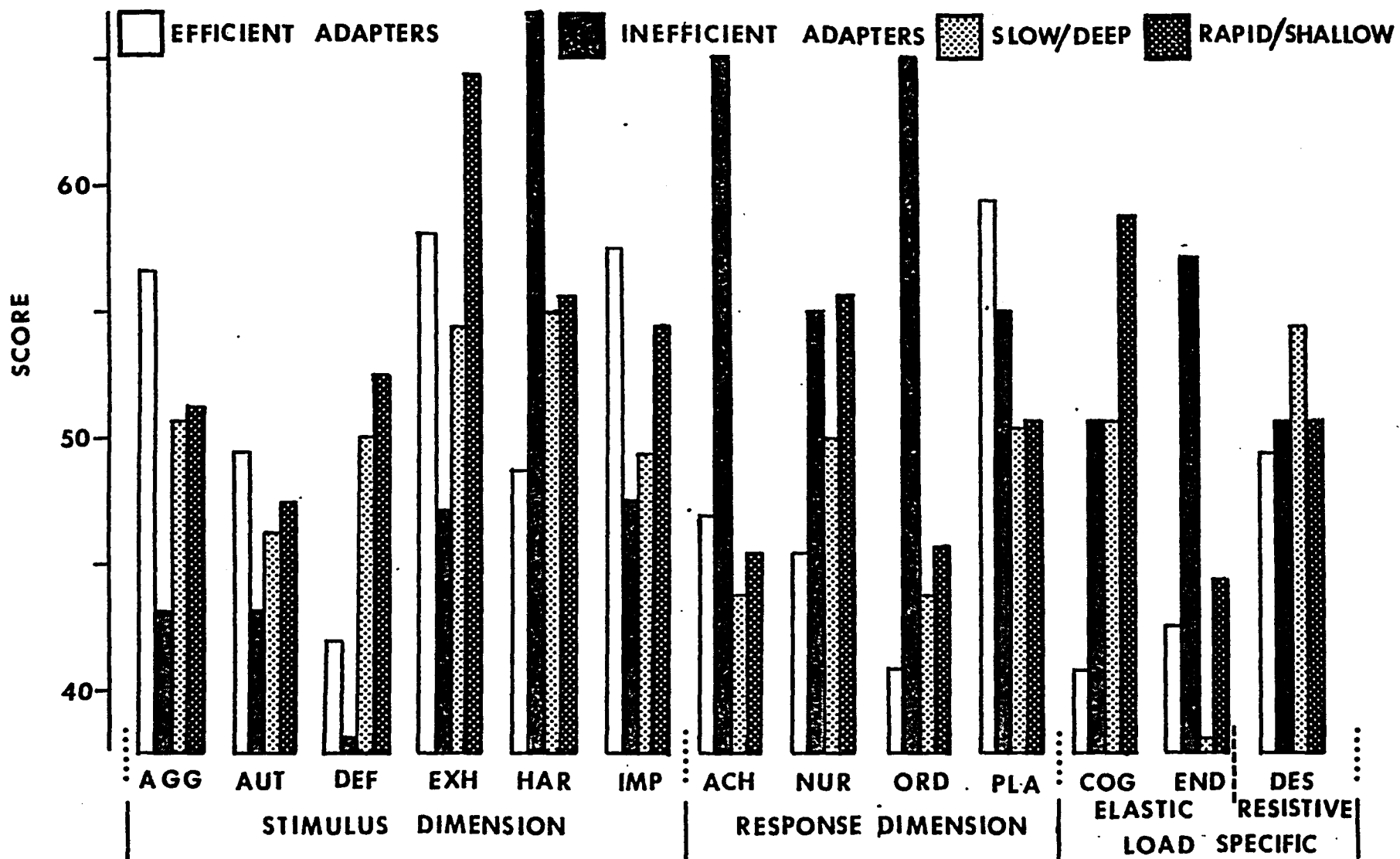


FIGURE 5: PERSONALITY PROFILE COMPONENTS FOR LOAD-RESPONSE ORIENTATIONS FOR MALE SUBJECTS

Adapters. The scores of the two response-oriented groups tend to cluster. Three of the four response-oriented scales discriminate as expected between the two response-oriented groups, with the stimulus-oriented groups tending to cluster. The two resistive load-specific scales discriminate in the expected direction for all four groups, while the elastic load-specific scale doesn't separate any of them.

Although the number of subjects in these four loaded-response dimension categories is very small, the results are supportive of approaching individual differences in personality and respiratory load-responses in terms of the respiratory response orientations or styles indicated by these data.

For a given individual, the influence of personality factors on the respiratory response to mechanical loads may well be the net result of the interplay, or balance, between the various degrees to which he approximates either of the contrasting group profiles along the two primary dimensions plus the degree to which he approximates the profile component reflecting a load-specific influence.

EYSENCK PERSONALITY DIMENSIONS AND RESPIRATORY BEHAVIOR

Eysenck's Extraversion (E) and Neuroticism (N) personality dimensions did not correlate with any of the parameters for women's respiratory behavior (Table 6). There were only a few small correlations in the male sample. E correlated with three highly interrelated resistive load parameters and, after elastic loading, with change in ventilation on the first unloaded breath. N correlated negatively with resting TV, and positively with change in both TV and ventilation on the first breath after resistive loading.

Subjects were classified as high or low on E and N using Eysenck's criteria¹ (Eysenck & Eysenck, 1968). A series of chi-square analyses was performed in relation to all the categorized respiratory parameters, including respiratory pattern. There were no significant results in the female sample. Classification on E and N was not related to classification along any of the respiratory parameters, whether singly or combined in breathing pattern.

Some significant results emerged for the male subjects, but not all in line with past findings or predictions. There were no relationships with E, not even for CO₂ sensitivity. For resting respiratory rate, Normal subjects predominated among the slower breathers (74% instead of the expected 40%) and Neurotics predominated among the faster breathers (75% instead of 60%) ($P < .01$). As a consequence, for resting respiratory pattern 83% of the slow/deep breathers were Normals (instead of the expected 40%), and 75% of the rapid/shallow breathers were Neurotics (instead of the expected 60%) ($P < .02$). Respiratory rate change in response to elastic loading showed a significant relationship to N ($P < .01$), but with Neurotics predominating among those who decreased or maintained their rate. The predominance of Neurotics among males with the greatest rate increase to resistive loading was just below significance ($P < .06$). (In each instance, therefore, Neurotics were more frequent in the group with an inefficient loaded respiratory response.) Neurotics also predominated among those with the greatest rate increase on the first breath following resistive

¹For Form A of the EPI, which was used in this investigation, subjects were divided at the median on each scale.

loading ($P < .05$), but the rate change after elastic loading did not show any relationship.

The weak relationships between Eysenck's Neuroticism personality dimension and respiratory behavior are not fully consistent with what would be expected from his hypothesis. To begin with, they do not apply to the female sample. This difference might be a reflection of a male-female differential response to working with a female Experimenter. The Neuroticism scale is a commonly used measure of Manifest Anxiety. The absence of any relationship between Neuroticism and female respiratory behavior and the modest presence of such a relationship in the male sample might indicate that the men were significantly more anxious in the presence of a female Experimenter.

Although Eysenck's finding of a higher resting respiratory rate among Neurotics is supported in the male sample, his prediction of greater respiratory rate lability in response to stimulation is only partially supported.

This lack of any strong or consistent pattern possibly indicates the inappropriateness of Neuroticism for attempting to understand relationships between individual differences in personality and respiration. Perhaps it is a consequence of his misconception of autonomic innervation of the respiratory system, which may well have led him to formulate too simplistic a view of respiratory behavior.

Despite previous support for the expectation that subjects more sensitive to CO_2 would be those with a higher Extraversion score, it did not obtain for the men and women in this study. Different techniques were used, however, for assessing CO_2 sensitivity. The previous studies on normal men and women used the Read rebreathing method, and

the current study used a steady state technique. Comparisons of measurements obtained by these two techniques, however, indicate that there is no difference in slope for either normal or COPD subjects (Nunn, 1977). The curve is merely somewhat displaced to the right in using the Read rebreathing technique. The previous work is small in number but highly consistent, so further testing using the steady state technique would be required before a firmer statement can be made about the relationship -- or lack of same -- between Extraversion and CO₂ sensitivity.

ROD AND FRAME AND RESPIRATORY BEHAVIOR

No correlations emerged to indicate a relationship between field independence and either sensitivity to CO₂ or the occurrence of appropriate respiratory adjustment to mechanical loads (Table 5). The negative correlation for women with TV change during resistive loading, although in the expected direction, is very small and does not appear in the elastic load-response. Comparing average Rod and Frame scores for slow/deep breathers and rapid/shallow breathers in resting and load conditions does not reveal any significant differences in either sample. Average Rod and Frame score does not distinguish at all between male stimulus-oriented and response-oriented subjects, and the difference between the women is not significant (Table 20).

SUMMARY OF FINDINGS

The male and female samples can be considered equal in terms of the background variables, personality characteristics and parameters of respiratory behavior examined in this study. The Edwards Persona-

**TABLE 20: ROD AND FRAME SCORES
AND LOAD-RESPONSE ORIENTATIONS**

	<u>STIMULUS-ORIENTED GROUP: AVERAGE SCORE</u>	<u>RESPONSE-ORIENTED GROUP: AVERAGE SCORE</u>	<u>P < *</u>
MALE:	30.0	30.0	NS
FEMALE:	63.7	49.5	NS

* 2-tailed t-tests were performed.

lity Inventory scales correlated too highly with the Personality Research Form to be of use, and were dropped from the analysis. Simple correlations between personality and respiratory variables did not reveal any strong relationships or interpretable patterns. The Rod and Frame did not relate to any parameters of respiratory behavior. In a chi-square analysis the Eysenck Personality Inventory dimensions did not relate to female respiratory behavior. For the males, the only consistent significant relationships were between resting breathing behavior and Neuroticism.

A Multiple Regression of the personality traits in the Personality Research Form on each of the respiratory parameters demonstrated that a configuration of personality traits substantially increased the amount of variance explained from an average of 5-6% to 23-26%. A Profile Analysis generated the following: (1) Examining respiratory behavior in terms of breathing pattern was considerably more productive than looking separately at the two components of breathing pattern; (2) In each respiratory condition a configuration of personality traits successfully distinguished between the extreme respiratory groups; (3) There was a striking congruence in the groupings of traits for males and females, and for each of the respiratory conditions; (4) Within each respiratory condition there was a marked male-female correspondence in the relationships expressed in the profiles between individual traits and respiratory behavior.

There was a pronounced similarity in content and relationship between the personality profiles characterizing the slow/deep breathers in the resting condition and those minimally responsive to CO₂ (and, of course, between the counterpart profiles in both conditions). The

two groups did not contain a large number of the same subjects, though, and the similarity proved to be in content and shape and not so much in strength of response. Dissecting the extreme CO₂ response groups further provided tentative evidence that their profiles are capable of reflecting a possible physiological interaction between resting respiratory pattern and CO₂ sensitivity. In both the male and female samples, subjects who were slow/deep breathers and also minimally sensitive to CO₂, or rapid/shallow breathers and also maximally sensitive to CO₂, tended to have the most extreme scores in the appropriate direction on the personality traits common to the two personality profiles.

The reduced similarity in the relationships between personality traits and respiratory behavior in going from resting to load-response personality profiles was consonant with the lack of predictability of loaded respiratory response from resting respiration. The seemingly contradictory nature of the relationship between respiratory change and elements of the resistive and elastic load-response personality profiles appeared to reflect two dimensions of orientation along which respiratory responses to mechanical loads may vary, as well as possible load-specific personality concomitants. This concept of response orientations also accounts for the fairly weak correlation pattern between respiratory responses to the two types of mechanical loads.

DISCUSSION

COMPARISON OF CURRENT AND PREVIOUS FINDINGS

A basis of comparison between previous and current data exists only in respect to work in CO₂ sensitivity. The current data do not support prior findings.

1. In a much smaller group of normal men and women than studied here, the men were more sensitive to CO₂ although their broader response range meant the least sensitive man fell below the least sensitive woman (Saunders, Heilpern & Rebuck, 1972). In the current study, the parameter of Slope at the Steady State gives the reverse picture.

2. The positive relationship between CO₂ sensitivity and Eysenck's dimension of Extraversion (Arkininstall et al, 1974; Clark & Cochrane, 1970; Saunders, Heilpern & Rebuck, 1972) was not duplicated. As stated above, the contribution, however unlikely, of differences in technique for assessing CO₂ sensitivity must be ruled out by further research.

3. Arkininstall et al (1974) found a significant correlation between the frequency response and Eysenck's Neuroticism dimension. No such relationship emerged in this study.

4. They also found a relationship between ventilatory increase and the Aggression scale on the Personality Research Form as a function of environmental influence on CO₂ sensitivity. The current study was not designed to assess personality characteristics as a reflection of genetic vs. environmental influence. However, no correlation was found between Aggression and any of the parameters assessing CO₂ sensitivity, nor did Aggression appear in the profile of personality traits defining the extreme response groups.

STRENGTH OF THE RELATIONSHIPS

Some may question this study's findings by asking why the observed relationships between personality traits and respiratory behavior are not substantially stronger. There are a number of factors tending to dilute the observed relationships, particularly since each subject could be tested on only one occasion.

Certain error factors were due to unavoidable constraints imposed upon the experimental design. The resources available for the conduct of this study precluded the time and money for a thorough subjective evaluation of personality dynamics. Although the Personality Research Form is the best objective instrument available, it is, nonetheless, a crude personality measure. Furthermore, a degree of measurement error is built in to any correlational design that samples behavior on one occasion only. Based on recent work assessing the effect of this sampling procedure on correlations between personality inventory responses and behavior (Epstein, 1979), the relationships in the current study would have been considerably greater if each subject's respiratory responses could have been sampled frequently over time and then averaged. Certainly whatever dilution was contributed by initial differences in response to the testing situation -- e.g., subjects who were consistently relaxed vs. those who were initially or periodically apprehensive -- would have had an opportunity to diminish appreciably if the investigation could have encompassed many repetitions.

Another constraint was imposed by the large number of subjects to be tested and the substantial amount of time required with each one. Testing took place over close to a year's time, beginning in early summer and ending in late spring. It is certainly possible that there were

differential effects from summer and winter temperatures, spring and fall pollen allergies, vacation vs. mid-semester timing, etc.

The subjects contributed additional factors capable of diluting observed relationships. During the post-testing interview it became apparent that some subjects, but not others, were extremely concerned about being good subjects. They wanted to be cooperative, and didn't want to do anything they felt might "ruin" the data. This could have been more of a post hoc attempt to explain their respiratory behavior to themselves, or it could have been an independent influence that led these subjects to alter their behavior from what it would otherwise have been. Subjects also differed in their motivation for participating in the study, despite attempts to recruit them from similar sources. Some were interested primarily in the subject matter. Of those who came strictly for the fee, many became highly interested once they learned more about the study, but others did not. Finally, some subjects are never consistent, and ability to predict their behavior does not rise much beyond zero no matter how extensively it is sampled (Epstein, 1979).

In actuality, then, the strength and consistency of the relationships that emerged despite all of these countervailing factors is further evidence for the validity of these results.

WHAT DO THE PERSONALITY PROFILES MEAN?

With the identification of personality trait profiles that significantly distinguish the extreme behavioral groups in each respiratory condition, the inevitable question is -- what do these profiles mean? The literature previously reviewed on personality and respiration is

not sufficiently comparable to this investigation to provide any answers, nor is the scant literature on personality and respiratory disease. Work in this latter area tended to rely on the MMPI (particularly with COPD patients) or an informal subjective assessment of patient anxiety and family problems (particularly with asthmatics).

One must turn to an analysis of the Personality Research Form itself. Nesselroade and Baltes (Jackson, 1967) extracted eight unnamed factors (Table 3, Appendix). Several of these factors are found, in whole or in part, in the personality trait profiles defining the extreme respiratory behavioral groups. In the following discussion it is important to keep in mind that the profiles reflect the subjects as they described themselves, not as they were evaluated by an objective outsider.

Resting Respiratory Pattern: The personality profiles of the slow/deep breathing males and females contain Factors: II (all three traits); III (four of six traits); V (two of four traits/males, three of four traits/females); and VI (three of five traits/males, all five traits/females). The trait adjectives defining the respective PRF scales (Jackson, 1967) produce the following condensed portrait of the resting slow/deep breather. He/she is an ambitious, independent person who enjoys a sense of mastery over the physical and social environments. Such a person is out-going and giving, dislikes restrictions, is adventurous, and physically and intellectually active. The reverse portrait, i.e., the rapid/shallow breather, is that of a cautious, insecure, shy, passive, fearful and dependent individual. The several profile traits not accounted for by the above factors do not seriously jar with these portraits. The two "left-over" traits from the men's

personality profile describe the male slow/deep breather as a less aggressive, not easily hurt or mistrustful individual. For the female slow/deep breathers, the four "left-over" traits describe an aggressive, serious woman who likes order and structure in her life.

The slow/deep breathers describe themselves as strong, stable, dynamic, highly confident individuals who are very much in control of their own lives. The rapid/shallow breathers, on the other hand, see themselves as shy and fearful people very much dependent on others for a sense of self and security.

Sensitivity to CO₂: Males low on CO₂ sensitivity are represented by two of the three traits in Factor II. Both the men's and women's profiles are represented by Factor III (three of the six traits/men, four of the six traits/women). There are four "left-over" traits for the men and four for the women. The low sensitive male is out-going and sensuous, independent and disliking of restrictions, tolerant of ambiguity and disorder (or disorderly), and not easily hurt or overly humble. The low sensitive female is independent, somewhat of a loner, adventurous, and dislikes restrictions. She is hard-working and serious, and likes order in her life. To turn it around, the highly sensitive men can be termed shy, easily hurt and mistrustful, passive, dependent people with a poor self-image. The highly sensitive women are passive, fearful, dependent, disorderly (or tolerant of disorder), and give up easily.

The males and females minimally sensitive to CO₂ describe themselves as confident people who have a sense of involvement in and control over their lives. The maximally sensitive individuals see themselves as passive, cautious and dependent people.

Response to Mechanical Loads: The group responding inefficiently to a resistive load, i.e., a rapid/shallow alteration of breathing pattern, is described in part by Factor I. This factor is complete in the men's personality profile, and three of the six traits are in the women's personality profile. Factor I describes a passive, cautious, fearful and serious person with a need for structure and order. The "left-over" personality traits in the men's profile describe a nurturant person who likes attention but is easily hurt and mistrustful, and who dislikes restrictions. The remaining traits in the women's profile refer to a nurturant, easily hurt and mistrustful person who dislikes restrictions and who, in addition, enjoys excitement and is unambitious.

Reversing the picture characterizes the efficient resistive load responder (i.e., slow/deep) as a stable, out-going, spontaneous individual tolerant of ambiguity and disorder, and unafraid of risk or anger. The efficient male is, in addition, shy and less nurturant but not overly easy to offend, and not bothered by restrictions. The efficient female is, in addition, less nurturant, less easily offended, less bothered by restrictions and less attracted to adventure and excitement than her counterparts.

The elements of these qualitative profiles are not as cohesive as those delineated for the other respiratory conditions. The male efficient response group, to take one example, is both shy and out-going. This disparity is consistent with the possibility raised earlier that the extreme load-response groups comprise at least two sub-groups. The overall impression, though, is that the efficient responders to resistive loads see themselves as relatively stable, social individuals who

are not bothered by restrictions. The inefficient responders, on the other hand, appear to see themselves as easily hurt, passive people who find it difficult to accept restrictions.

The personality profiles associated with the elastic load extreme response groups do not lend themselves conveniently to the PRF factor structure. None of the factors are embedded in the men's profile. The individual traits draw a picture of the inefficient (i.e., slow/deep) response group as unambitious, disorderly (or tolerant of disorder), very passive and cold, cautious, yet liking in excitement and social activities and disliking restrictions. The efficient (rapid/shallow) male response group is, in the reverse, ambitious, less passive, out-going and spontaneous, nurturant, and adventurous.

The inefficient (slow/deep) women's profile yields three of the five traits in Factor VI, describing an ambitious, persevering woman who enjoys adventure and risk. The remaining traits describe her further as aggressive but cautious and easily offended, a loner who chafes strongly under restrictions, a disorderly (or tolerant of disorder) and less serious person than her counterpart. Her counterpart, the efficient (rapid/shallow) responder, is less ambitious, less of a loner, less aggressive, less disliking of restrictions, less easily hurt, less cautious, less nurturant, more serious and orderly, and less adventurous.

Again, although some of the elements of these portraits are in conflict, an overall impression does emerge. The male efficient responders to elastic loads appear to see themselves as relatively stable, strong and involved individuals, tolerant of restrictions. The inefficient males see themselves as passive but chafing under restrictions.

The efficient group of women tends to appear more stable, more social, and tolerant of restrictions. Their counterparts are aggressive, mistrustful and cautious loners who chafe strongly under restrictions.

Conclusion: Certain elements, or basic orientations to life, consistently oppose each other in these portraits. In every case the primary contrast is between the stable, capable and confident individual vs. the cautious, easily hurt, usually passive and dependent individual. This could be construed as a positive vs. a negative orientation to new experience, it not to life in general. A second contrast is between those who chafe under restrictions vs. those who tolerate them particularly well. In the resting breathing and CO₂ sensitivity conditions a dislike of restrictions appears with a positive orientation, which characterizes the slow/deep breathers and those minimally sensitive to CO₂. In both mechanical load conditions a dislike of restrictions appears with a negative orientation, which characterizes the inefficient response groups in both cases.

This attempt to extract the underlying meaning of the various personality profiles raises, in turn, a question as to the nature of the individual differences in respiratory behavior recorded and discussed here. Are they primary, i.e., do they reflect real-life breathing patterns, degrees of CO₂ sensitivity, etc.? Or are they, instead, secondary, i.e., a physiological manifestation of the response of a positively or negatively oriented person to the kind of unfamiliar and possibly threatening experiences encountered in the laboratory? There is no documentation as to the reproducibility of respiratory responses to artificial mechanical loads. However, the evidence indicating reproducibility of breathing pattern (Schaefer, 1958) and CO₂ sensitivity (Bulow,

1963; Schaefer, 1958) over extended periods of time favors viewing these laboratory recordings as reflections of primary behavior.

Bulow's work in particular involved such extensive testing that one can safely assume that the laboratory environment became familiar and non-threatening to his subjects.

Firm substantiation of this respiratory behavior as a real-life sample, though, would not preclude the possibility of some situational influences. The testing situation involved a strange, possibly threatening, environment and direct interaction with the Experimenter. Possible situational effects cannot yet be discounted because of the fairly consistent appearance in the personality profiles of the traits of Defence (concerning mistrust of others, ease of being hurt), Social Recognition (need for approval from others), Desirability (desire to project a positive image on the test itself), and Harmavoidance (fear of adventure, physical danger, etc.).

In this study, for example, the resting rapid/shallow breather is higher on Harmavoidance than the slow/deep breather. Do individuals with a heightened sense of physical vulnerability become rapid/shallow breathers only in what they perceive as a threatening environment, or does this heightened sense of vulnerability permeate their daily coping with their psychological and physical environments to a degree that results in its reliable association with a rapid/shallow resting pattern outside the laboratory as well?

A possible situational factor not controlled for in this study is interaction between sex of subject and sex of Experimenter. The Experimenter was a woman although the subjects were evenly divided between male and female. Replications of this investigation controlling

for sex interaction will be required to know whether or not it has any influence on respiratory behavior in this kind of laboratory setting.

A second important question raised in attempting to understand the relationship between the personality profiles and respiratory behavior concerns the level of causality. Does personality influence respiratory behavior, or are both personality and respiratory differences simply different reflections of more basic central nervous system differences? As stated in the Introduction, both personality theorists and respiratory physiologists have separately hypothesized that individual differences in their respective domains are a function of organizational or functional differences in the reticular system.

LOOKING AT RESPIRATORY BEHAVIOR

Several highly important points emerged concerning the perspective for viewing respiratory behavior. The consequences extend both to the conduct of research and to attempts at understanding the nature of the process that relates personality and respiration (and perhaps between personality and other physiological systems).

To begin with, looking at the *pattern* of respiratory behavior (i.e., the combination of respiratory rate and tidal volume) instead of each component in isolation was far more productive in uncovering the configuration of personality traits that distinguished the extreme behavioral groups. It makes intuitive sense, in that "pattern" is the real-life phenomenon and looking at only rate or volume without considering the other is an artificial state of affairs. In addition, the development, action and interaction of personality traits are dynamic processes; therefore, when personality is looked at in relation to behavior, such behavior should be defined in its dynamic terms. In

light of this, consider the vast number of experiments in which respiratory rate, or sometimes tidal volume, is the index of respiratory behavior. One cannot be meaningfully considered in the absence of the other.

Change in ventilation (and such related measures as slope) makes good sense in studying CO_2 sensitivity. In general, however, ventilation is an inadequate substitute since it is incapable of reflecting any respiratory alteration in which rate and volume change inversely. The parameter should become *respiratory pattern* or *pattern of respiratory change*. Hopefully, respiratory pattern will eventually be quantified. This would greatly simplify classification and comparison of individuals, and would broaden the range of parametric statistical techniques available.

Resting respiratory behavior has not previously been a focus of interest. Studying respiration as a reflection or function of psychological processes has been geared to recording change (usually in respiratory rate) as a result of a stimulus -- fear, drugs, pain, etc. In the current investigation, the personality profiles characterizing the extreme groups with respect to resting respiratory pattern achieved the greatest separation in terms of personality scores and provided the richest characterizations of all the respiratory conditions. They were followed by the personality profiles characterizing the extreme groups in CO_2 sensitivity.

Distinct personality profiles emerged after the decision was taken to look only at the extreme behavioral groups. Is it that the overall amount of noise due to various sources of error was so great that only by narrowing focus to the extremes could underlying patterns become

visible? Or is it only extreme respiratory behavior that reflects a relationship with personality traits, with moderate respiratory behavior indicating the lack of any personality-related modification? Although the respiratory behavior would form a continuum, the relationship with personality factors would be discontinuous.

IMPLICATIONS FOR REHABILITATION MEDICINE

Understanding the relationships between personality characteristics and respiratory behavior has direct implications for the application of Rehabilitation Medicine to pulmonary problems. Efforts to prevent pulmonary complications in patients recovering from chest or abdominal surgery should be still more effective due to the ability to modify the application of chest physical therapy in accordance with the specific psychological factors influencing the individual patient's respiratory behavior. This ability to identify and constructively use the psychological factors affecting individual respiratory behavior would be equally valuable in designing rehabilitation programs for patients suffering from the various pulmonary pathologies.

In the area of pathology, though, the relevance of such studies as the present one is even more direct. The respiratory loads used in this investigation are analogies of the consequences of pathological processes. The obstructive pathologies, such as emphysema and chronic bronchitis, add a permanent increased resistive load to the respiratory system. The restrictive pathologies, such as kyphoscoliosis and fibrosis, add a permanent increased elastic load to the respiratory system. A significant increase in CO_2 is a basic symptom of Obesity-Hypoventilation Syndrome, and is found in the advanced stages of the

other pathologies. As noted earlier, there is no physiological explanation for the common observation that different patients respond differently to the same type and degree of pulmonary impairment (Clark & Cochrane, 1974; Lourenco, 1969). A working understanding of the relationships between load response and personality factors may well hold the key, not only to understanding what sets these patients apart from the middle of the road and from each other, but to working more successfully with all of them than is now possible.

CONCLUSIONS

The results of this study demonstrate convincingly that there are relationships between individual differences in personality and respiratory behavior. Relationships emerged in all of the respiratory conditions studied: resting respiration, response to increased CO₂, and response to mechanical loads. Similarities rather than differences between the male and female samples dominated these results. It proved essential to take a dynamic view of both personality and respiratory behavior, i.e., configurations of personality traits rather than single traits, and respiratory pattern rather than its individual components. In addition, focus was on the extremes of respiratory behavior rather than the entire response continuum.

Although further work is needed to replicate, clarify and amplify the relationships that emerged here between configurations of personality traits and respiratory behavior, the hallmarks of this investigation have immediate consequences for the conduct of any research involving respiratory behavior. This would affect experimental design, data analysis and interpretation of results. Perhaps these implications extend, as well, to all work attempting to integrate psychological and physiological phenomena.

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APPENDIX

BACKGROUND: FOR ALL SUBJECTS

The purpose of this experiment is to gain a greater understanding of the relationship between physiological functioning and psychological functioning by studying the relationships between how people breathe and various personality characteristics. One of the reasons responsible for my particular interest in respiration is that some of the differences in how different people breathe don't have any physiological explanation. The procedures that I am using in this experiment are straightforward -- there is no deception and no stress situations.

Your breathing will be recorded during different conditions using standard equipment and procedures for this purpose. You may find that breathing through this equipment is sometimes a little different than what you are used to, and that you occasionally might have to work somewhat harder in breathing.

The information to determine psychological traits will be gathered in several ways. I will ask you a few general questions, and I will also conduct a brief perceptual test with you. The remaining tests you do by yourself, filling in your answers on an answer sheet. There are two things that I want to emphasize about all of these "tests":

(1) They are not "tests" that have right-or-wrong, good-or-poor answers. All that these tests do is describe a person; they do not make any judgements about him. I am interested only in how these tests describe you, and I will not be making any judgements based on these descriptions.

(2) Your name will not be recorded on any of your test materials, including the record of your breathing and the questions that I will ask you, so that your results will be anonymous. Your papers will be marked with a code number so that I know the sex of the subject and so that the papers won't get separated, but to ensure your privacy there will be no record of whose name goes with which code number.

If you would like to know the results of the study that you are participating in, I will send you a summary of my findings and what I think they mean. I cannot, however, send you your individual tests results since I will have no way to identify them as belonging to you. If you are interested in receiving a copy of the results, fill in the attached mailing label and leave it with me.

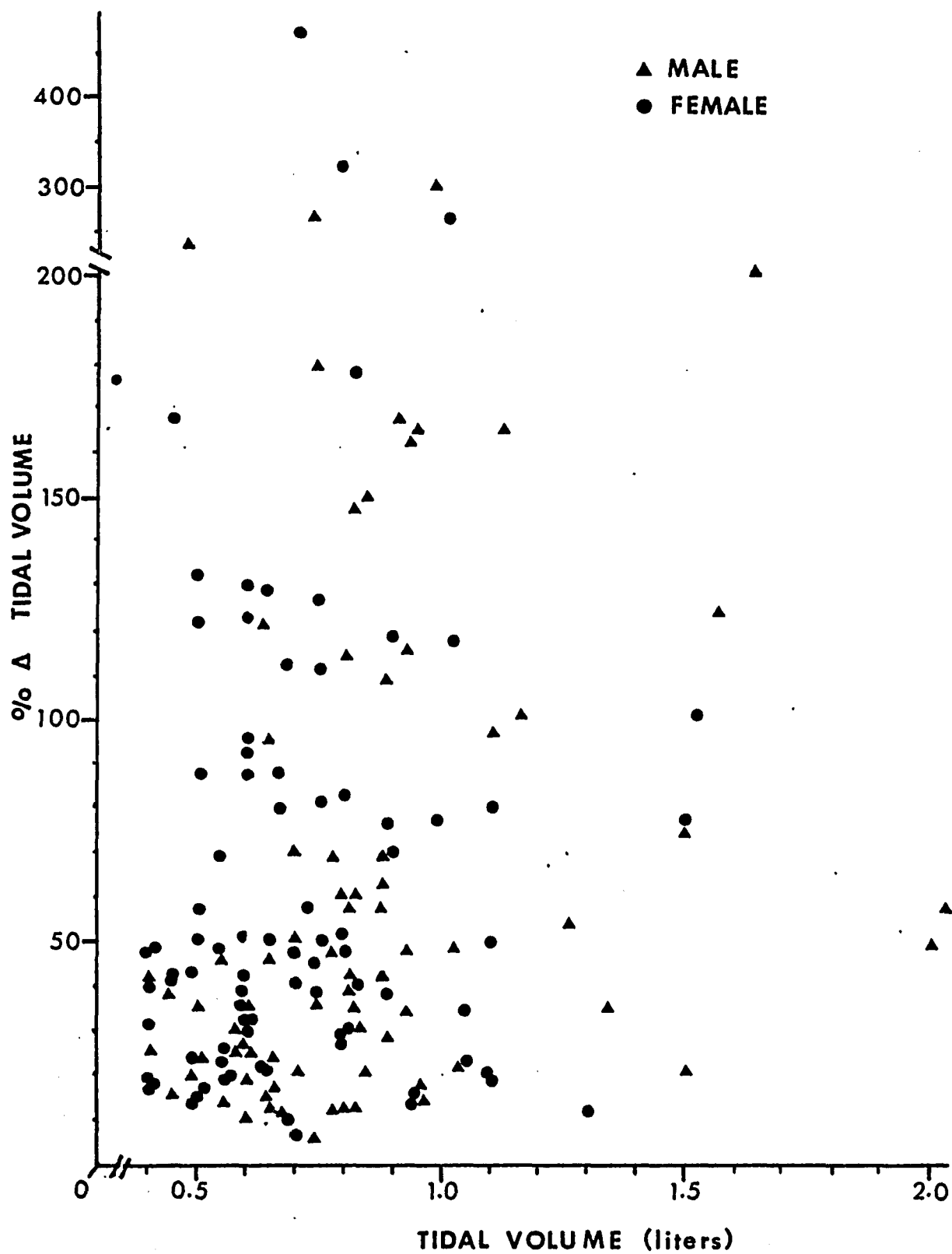
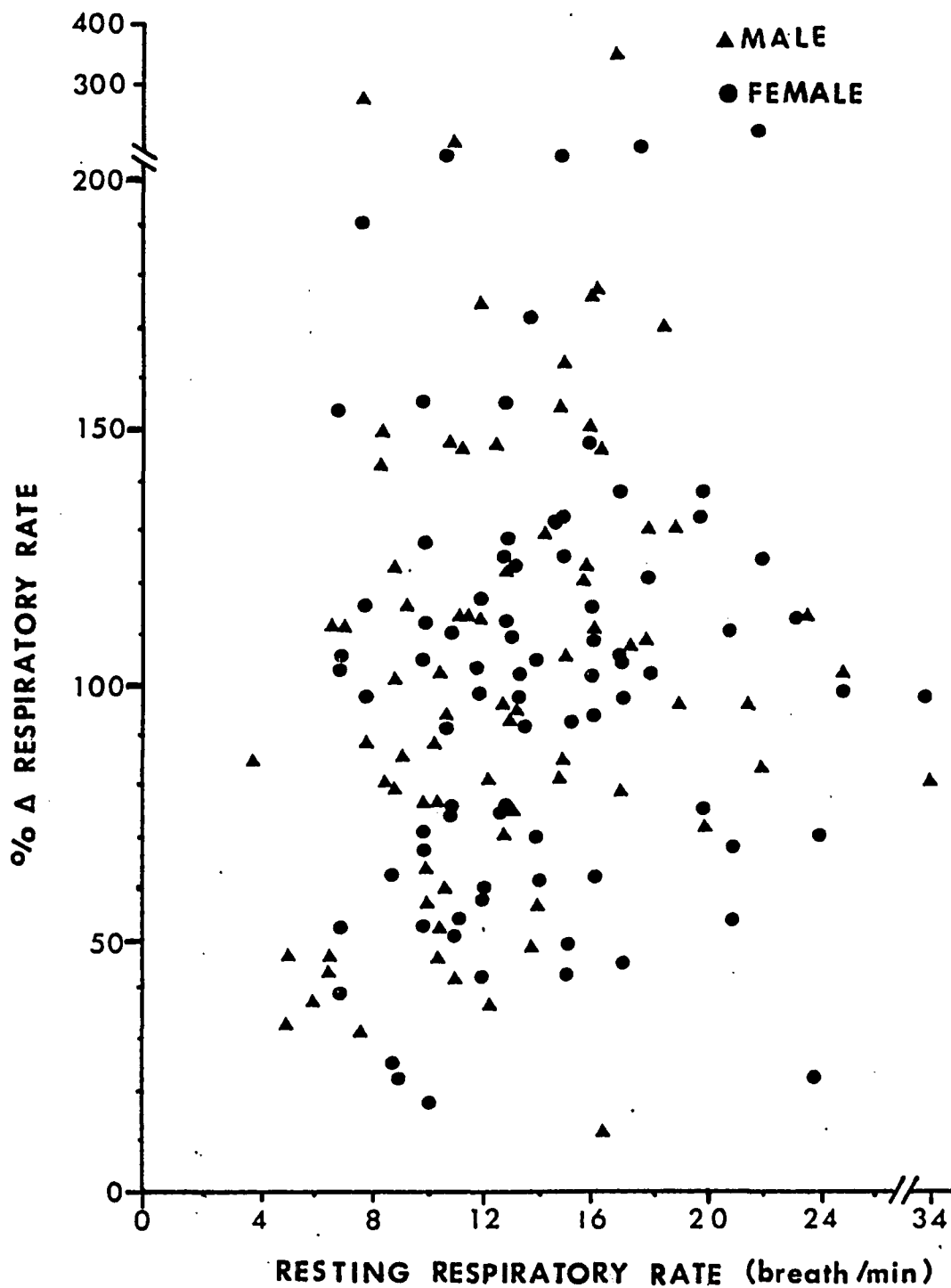


FIGURE 1: RESISTIVE LOAD--% TIDAL VOLUME CHANGE AGAINST RESTING TIDAL VOLUME



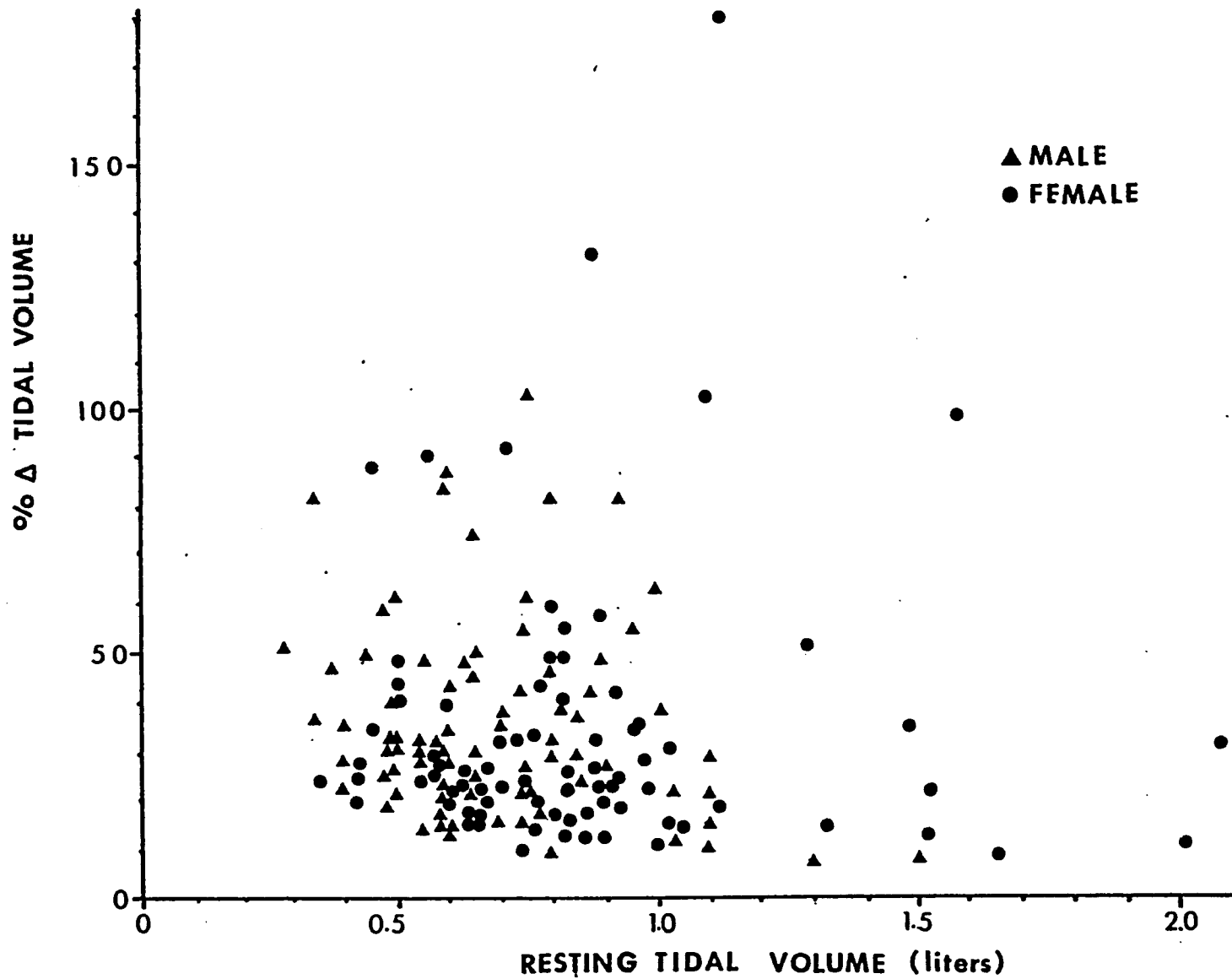


FIGURE 3: ELASTIC LOAD--% TIDAL VOLUME CHANGE AGAINST RESTING TIDAL VOLUME

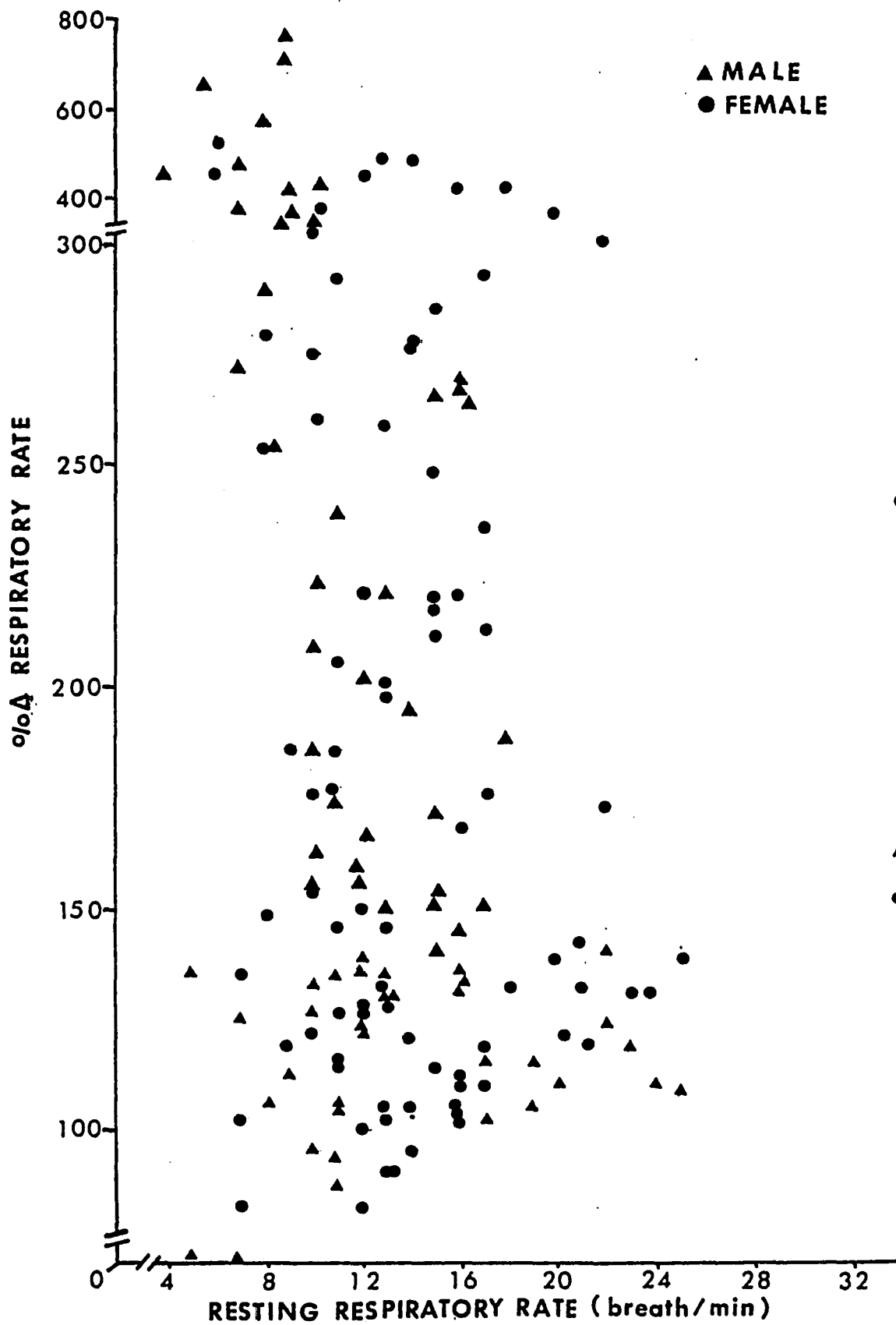


FIGURE 4: ELASTIC LOAD--% RESPIRATORY RATE CHANGE AGAINST RESTING RESPIRATORY RATE

TABLE 1: MALE SAMPLE--MULTIPLE REGRESSION
OF PRF SCALES ON RESPIRATORY VARIABLES

<u>RESPIRATORY VARIABLES</u>	<u>PRF SCALES IN MODEL AND CORRELATION SIGN</u>	<u>R²</u>	<u>F</u>	<u>P <</u>
RESTING TV	Abasement -	.28	2.45	.01
	Achievement -			
	Aggression +			
	Autonomy -			
	Change -			
	Defendence -			
	Harmavoidance -			
	Nurturance +			
	Social Recog. -			
	Succorance -			
	Understanding +			
RESTING RR	The overall F-statistic never achieved significance.			
RESTING VENTILATION	Achievement +	.16	2.26	.05
	Aggression +			
	Defendence -			
	Exhibition -			
	Harmavoidance -			
	Social Recog. -			
RESTING CO ₂	Affiliation +	.23	2.67	.01
	Change +			
	Dominance -			
	Play +			
	Sentience -			
	Social Recog. +			
	Understanding -			
	Desirability +			
CO ₂ SENSITIVITY	Abasement +	.28	2.39	.01
	Achievement -			
	Affiliation +			
	Cognitive St. +			
	Defendence +			
	Dominance -			
	Endurance +			
	Nurturance -			
	Order +			
	Sentience -			
	Social Recog. +			

TABLE 1 - Continued

<u>RESPIRATORY VARIABLES</u>	<u>PRE SCALES IN MODEL AND CORRELATION SIGN</u>	<u>R²</u>	<u>F</u>	<u>P <</u>	
RESISTIVE LOAD-TV	Abasement	+	.27	3.26	.003
	Aggression	+			
	Autonomy	-			
	Cognitive St.	-			
	Defendence	-			
	Exhibition	+			
	Harmavoidance	-			
	Nurturance	-			
RESISTIVE LOAD-RR	Achievement	-	.26	2.37	.02
	Affiliation	-			
	Aggression	-			
	Change	+			
	Cognitive St.	+			
	Defendence	+			
	Endurance	+			
	Exhibition	-			
	Nurturance	+			
	Desirability	+			
RESISTIVE LOAD- VENTILATION	Abasement	+	.18	2.27	.04
	Autonomy	-			
	Cognitive St.	-			
	Exhibition	+			
	Harmavoidance	-			
	Nurturance	-			
	Order	+			
RESISTIVE LOAD-Ti	Abasement	-	.26	2.71	.009
	Affiliation	+			
	Change	-			
	Defendence	-			
	Impulsivity	+			
	Nurturance	+			
	Order	-			
	Social Recog.	+			
	Desirability	-			
RESISTIVE LOAD-Te	Abasement	-	.28	2.75	.007
	Autonomy	+			
	Change	-			
	Defendence	-			
	Dominance	+			
	Exhibition	-			
	Nurturance	+			
	Order	-			
	Social Recog.	+			
	Desirability	-			

TABLE 1 - Continued

<u>RESPIRATORY VARIABLES</u>	<u>PRE SCALES IN MODEL AND CORRELATION SIGN</u>	<u>R²</u>	<u>F</u>	<u>P <</u>
RESISTIVE LOAD-TV/Ti	Achievement +	.17	2.14	.05
	Autonomy -			
	Cognitive St. -			
	Defendence -			
	Exhibition +			
	Social Recog. +			
	Desirability -			
ELASTIC LOAD-TV	The overall F-statistic never achieved significance.			
ELASTIC LOAD-RR	Abasement -	.19	2.07	.05
	Autonomy -			
	Change +			
	Cognitive St. +			
	Defendence -			
	Impulsivity +			
	Social Recog. +			
	Succorance -			
ELASTIC LOAD- VENTILATION	The overall F-statistic never achieved significance.			
ELASTIC LOAD-Ti	Aggression -	.25	2.65	.01
	Change -			
	Defendence -			
	Dominance +			
	Nurturance +			
	Order -			
	Play -			
	Social Recog. +			
	Desirability -			
ELASTIC LOAD-Te	Autonomy +	.19	2.11	.05
	Change -			
	Exhibition -			
	Impulsivity -			
	Nurturance +			
	Order -			
	Social Recog. +			
Succorance +				

TABLE 1 - Continued

<u>RESPIRATORY</u> <u>VARIABLES</u>	<u>PRF SCALES IN MODEL</u> <u>AND CORRELATION SIGN</u>	<u>R²</u>	<u>F</u>	<u>P <</u>
ELASTIC LOAD-TV/Ti	Abasement -	.24	2.18	.03
	Affiliation +			
	Aggression -			
	Change -			
	Cognitive St. -			
	Dominance +			
	Nurturance +			
	Sentience +			
	Social Recog. +			
	Desirability -			

TABLE 2: FEMALE SAMPLE--MULTIPLE REGRESSION
OF PRF SCALES ON RESPIRATORY VARIABLES

<u>RESPIRATORY VARIABLES</u>	<u>PRF SCALES IN MODEL AND CORRELATION SIGN</u>	<u>R²</u>	<u>F</u>	<u>P <</u>	
RESTING TV	Abasement	-	.36	3.20	.001
	Affiliation	+			
	Autonomy	+			
	Change	-			
	Defendence	-			
	Endurance	+			
	Impulsivity	-			
	Play	-			
	Sentience	+			
	Social Recog.	+			
	Succorance	+			
	Desirability	-			
	RESTING RR	Abasement			
Aggression		-			
Autonomy		-			
Change		+			
Cognitive St.		-			
Defendence		+			
Exhibition		-			
Play		+			
Sentience		-			
Succorance		-			
Understanding		+			
Desirability		-			
RESTING VENTILATION		Achievement	-	.35	2.46
	Affiliation	+			
	Aggression	-			
	Autonomy	-			
	Cognitive St.	-			
	Defendence	-			
	Dominance	+			
	Endurance	+			
	Exhibition	-			
	Order	+			
	Play	-			
	Social Recog.	+			
	Understanding	+			
Desirability	-				

TABLE 2 - Continued

<u>RESPIRATORY VARIABLES</u>	<u>PRE. SCALES IN MODEL AND CORRELATION SIGN</u>	<u>R²</u>	<u>F</u>	<u>P <</u>
RESTING CO ₂	Affiliation -	.39	3.21	.0009
	Aggression +			
	Autonomy +			
	Change -			
	Dominance -			
	Exhibition +			
	Harmavoidance +			
	Impulsivity +			
	Order -			
	Play +			
	Sentience -			
	Succorance -			
	Desirability +			
CO ₂ SENSITIVITY	Achievement +	.24	2.44	.02
	Dominance -			
	Harmavoidance +			
	Nurturance -			
	Play +			
	Social Recog. +			
	Succorance +			
	Understanding +			
	Desirability -			
RESISTIVE LOAD-TV	Cognitive St. -	.12	2.66	.04
	Defendence -			
	Harmavoidance +			
	Sentience +			
RESISTIVE LOAD-RR	Affiliation -	.15	2.23	.05
	Defendence +			
	Harmavoidance -			
	Order +			
	Sentience -			
	Succorance +			
RESISTIVE LOAD VENTILATION	The overall F-statistic never achieved significance.			
RESISTIVE LOAD-Ti	Affiliation +	.21	2.71	.01
	Aggression +			
	Change +			
	Defendence -			
	Endurance -			
	Impulsivity +			
	Play -			

TABLE 2 - Continued

<u>RESPIRATORY VARIABLES</u>	<u>PRE. SCALES IN MODEL AND CORRELATION SIGN</u>	<u>R²</u>	<u>F</u>	<u>P <</u>
RESISTIVE LOAD-Te	Defendence -	.12	2.62	.04
	Endurance -			
	Impulsivity +			
	Understanding +			
RESISTIVE LOAD-TV/Ti	Change +	.14	2.47	.04
	Cognitive St. +			
	Defendence -			
	Impulsivity +			
	Sentience -			
ELASTIC LOAD-TV	Abasement -	.32	2.23	.02
	Affiliation -			
	Aggression -			
	Change +			
	Cognitive St. +			
	Defendence +			
	Dominance -			
	Endurance +			
	Exhibition +			
	Order -			
	Play +			
	Succorance -			
	Understanding -			
	Desirability +			
ELASTIC LOAD-RR	Achievement -	.31	2.12	.02
	Affiliation +			
	Change -			
	Defendence -			
	Endurance -			
	Harmavoidance +			
	Impulsivity +			
	Nurturance +			
	Order +			
	Play -			
	Sentience +			
	Succorance -			
	Understanding +			
	Desirability -			

TABLE 2 - Continued

<u>RESPIRATORY VARIABLES</u>	<u>PRF SCALES IN MODEL AND CORRELATION SIGN</u>	<u>R²</u>	<u>F</u>	<u>P <</u>
ELASTIC LOAD- VENTILATION	Abasement -	.28	1.93	.04
	Affiliation -			
	Aggression -			
	Change +			
	Defendence +			
	Endurance +			
	Exhibition +			
	Harmavoidance +			
	Impulsivity +			
	Nurturance +			
	Sentience +			
	Succorance -			
Understanding -				
ELASTIC LOAD-Ti	The overall F-statistic failed to achieve significance.			
ELASTIC LOAD-Te	Affiliation -	.33	2.50	.008
	Autonomy -			
	Change +			
	Cognitive St. +			
	Defendence -			
	Dominance -			
	Exhibition -			
	Harmavoidance -			
	Order -			
	Sentience -			
	Succorance +			
	Understanding +			
	Desirability +			
ELASTIC LOAD-TV/Ti	Change +	.13	2.74	.03
	Defendence -			
	Impulsivity +			
	Sentience -			

TABLE 3: FACTORS EXTRACTED FROM
PERSONALITY RESEARCH FORM

<u>FACTOR I</u>	<u>FACTOR II</u>	<u>FACTOR III</u>	<u>FACTOR IV</u>
-Aggression	+Dominance	+Autonomy	-Abasement
+Cognitive St.	+Exhibition	+Change	+Aggression
-Impulsivity	+Sentience	-Harmavoidance	+Defence
+Order		-Social Recog.	+Understanding
-Play		-Succorance	
+Harmavoidance		+Understanding	
<u>FACTOR V</u>	<u>FACTOR VI</u>	<u>FACTOR VII</u>	<u>FACTOR VIII</u>
+Nurturance	+Achievement	+Affiliation	+Change
+Sentience	+Dominance	+Change	+Defence
+Succorance	+Endurance	+Exhibition	+Impulsivity
+Understanding	-Harmavoidance	+Play	
	+Understanding	+Understanding	

REFERENCES

- Alexander, Franz & Saul, Leon J. "Respiration and personality -- a preliminary report: Part I. Description of the curves." Psychosom. Med., 1940, 2, 110-118.
- Arkininstall, W. W. et al. "Genetic differences in the ventilatory response to inhaled CO₂." J. Appl. Physiol., 1974, 36, 6-11.
- Axen, Kenneth. Personal communication, 1974.
- Barkley, Russell A. & Jackson, Thomas L. "Hyperkinesis, autonomic nervous system activity and stimulant drug effects." J. Child Psychol. & Psychiatr. & Allied Disc., 1977, 18, 347-357.
- Berg, Irwin A. & Adams, Henry E. "The experimental bases of personality assessment." IN: Arthur J. Bachrach (Ed.). Experimental Foundations of Clinical Psychology. New York: Basic Books, 1962.
- Brady, Joseph V. "Psychophysiology of emotional behavior." IN: Arthur J. Bachrach (Ed.). Experimental Foundations of Clinical Psychology. New York: Basic Books, 1962.
- Bram, Charles Goldwater. "The law of initial value: A theoretical and experimental evaluation." Dissert. Abstr. Int., 1970, 30 (10-B), 4813-B.
- Bulow, Knut. "Respiration and wakefulness in man." Acta Physiol. Scand., 1963, 59, Suppl. 209, 1-110.
- Bundy, Robert S. "Genetic components of autonomic stimulus-response and individual-response stereotypy: A twins study." Dissert. Abstr. Int., 1976, 36 (9-B), 4661.
- Carey, Charles R., Schaefer, K. E. & Delgado, J. M. R. "Influence of various CO₂ concentrations on electrical activity and excitability of the brain in the waking monkey." Fed. Proc., 1955, 14, 25.
- Claridge, Gordon S. Personality and Arousal. London: Pergamon Press, 1967.
- Clark, T. J. H. "Pathogenesis of CO₂ retention." IN: L. D. Pengelly, A. S. Rebeck & E. J. M. Campbell (Eds.). Loaded Breathing. Edinburgh: Churchill Livingstone, 1974.
- Clark, T. J. H. & Cochrane, G. M. "Effect of personality on alveolar ventilation in patients with chronic airways obstruction." Br. Med. J., 1970, 1, 273-275.

- Dudley, Donald L. et al. "Changes in respiration associated with hypnotically induced emotion, pain, and exercise." Psychosom. Med., 1964, 26, 46-57.
- Dudley, Donald L. et al. "Psychophysiological studies of experimentally induced action-oriented behavior." J. Psychosom. Res., 1965, 9, 209-221.
- Eisele, John H., Eger, Edmond I. & Muallem, Musa. "Narcotic properties of carbon dioxide in the dog." Anesthesiology, 1967, 28, 856-865.
- Epstein, Seymour. "The stability of behavior: I. On predicting much of the people most of the time." J. Pers. Soc. Psychol., 1979, 37, 1097-1126.
- Eysenck, H. J. The Biological Basis of Personality. Springfield, Ill.: Charles C. Thomas, 1967.
- Eysenck, H. J. & Eysenck, S. B. G. Manual: Eysenck Personality Inventory. San Diego, Calif: Educational and Industrial Testing Service, 1968.
- Eyzaguirre, Carlos & Fidone, Salvatore J. Physiology of the Nervous System, 2nd ed. Chicago: Yearbook Medical Publishers, 1975.
- Finesinger, Jacob E. "The effect of pleasant and unpleasant ideas on the respiratory pattern (spirogram) in psychoneurotic patients." Amer. J. Psychiatr., 1943-44, 100, 659-667.
- Finesinger, Jacob E. & Mazick, Sarah G. "The respiratory response of psychoneurotic patients to ideational and to sensory stimuli." Amer. J. Psychiatr., 1940-41, 97, 27-48.
- Gellhorn, E. "The physiological basis of the carbon dioxide therapy of psychoneuroses." J. Ment. Sci., 1953, 99, 357-373.
- Golla, F. L. & Antonovich, S. "The respiratory rhythm in its relation to the mechanism of thought." Brain, 1929, 52, 491-509.
- Howell, J. B. L. "Effects and associations of disturbed airways resistance and ventilatory control." IN: L. D. Pengelly, A. S. Rebeck & E. J. M. Campbell (Eds.). Loaded Breathing. Edinburgh: Churchill Livingstone, 1974.
- Jackson, Douglas N. Personality Research Form Manual. Goshen, N. Y.: Research Psychologists Press, 1967.
- Klorman, Rafael, Wiesenfeld, Alan R. & Austin, Mary L. "Autonomic responses to affective visual stimuli." Psychophysiol., 1975, 12, 553-560.
- Lacey, John Irving. "Changes in cardiac and respiratory activity in states of frustration." Psych. Bull., 1941, 38, 581-582.

- Landis, Carney & Gullette, Ruth. "Studies of emotional reactions. III. Systolic blood pressure and inspiration-expiration ratios." J. Comp. Psychol., 1925, 5, 221-253.
- Larson, J. A. & Haney, G. W. "Cardio-respiratory variations in personality studies." Amer. J. Psychiatr., 1932, 11, 1035-1081.
- Liberson, Cathryn Walters & Liberson, W. T. "Sex differences in autonomic responses to electric shock." Psychophysiol., 1975, 12, 182-186.
- Lourenco, Ruy. "Diaphragm activity in obesity." J. Clin. Invest., 1969, 48, 1609-1614.
- McCollum, Mary, Burch, Neil R. & Roessler, Robert. "Personality and respiratory responses to sound and light." Psychophysiol., 1969, 6, 291-301.
- Malmo, Robert B. "Activation." IN: Arthur J. Bachrach (Ed.). Experimental Foundations of Clinical Psychology. New York: Basic Books, 1962.
- Milic-Emili, J. Talk on loaded breathing given at Brookhaven Laboratories in Brookhaven, N.Y. on July 14, 1976.
- Miller, Barbara V. & Bernstein, Douglas A. "Instructional demand in a behavioral avoidance test for claustrophobic fears." J. Abn. Pers., 1972, 80, 206-210.
- Morrison, Donald F. Multivariate Statistical Methods. New York: McGraw-Hill, 1967.
- Murray, Henry A. "Studies of stressful interpersonal disputations." Amer. Psychol., 1963, 18, 28-36.
- Nunn, J. F. Applied Respiratory Physiology, 2nd ed. Boston: Butterworks, 1977.
- Patton, Harry D. "The autonomic nervous system." IN: Theodore C. Ruch & Harry D. Patton (Eds.). Physiology and Biophysics, 19th ed. Philadelphia: W. B. Saunders, 1966.
- Pope, Helen, Holloway, R. & Campbell, E. J. M. "The effects of elastic and resistive loading of inspiration on the breathing of conscious man." Respir. Physiol., 1968, 4, 363-372.
- Prystav, Gunther H. "Autonomic responsivity to sensory stimulation in drug addicts." Psychophysiol., 1975, 12, 170-178.
- _____. "Electrodermal, cardiac and respiratory activity to repeated cold pressor stimulation in drug addicts." J. Gen. Psychol., 1976, 94, 259-270.

- Rebuck, A. S., Rigg, J. R. A., Kangalee, M. & Pengelly, L. D. "Control of tidal volume during rebreathing." J. Appl. Physiol., 1974, 37, 475-478.
- Saunders, N. A., Heilpern, Sandra & Rebuck, A. S. "Relation between personality and ventilatory response to carbon dioxide in normal subjects: A role in asthma?" Br. Med. J., 1972, 1, 719-721.
- Schaefer, Karl Ernest. "Group differences in carbon dioxide response of human subjects." Fed. Proc., 1954, 13, 128.
- _____. "Respiratory pattern and respiratory response to CO₂." J. Appl. Physiol., 1958, 13, 1-14.
- Schaefer, K. E., Cornish, E. R. & Stuntz, S. E. "Effect of increased alveolar carbon dioxide tensions on various physiological functions." Fed. Proc., 1952, 11, 138.
- Sersen, Eugene A., Clausen, J. & Lidsky, A. "Autonomic specificity and stereotypy revisited." Psychophysiol., 1978, 15, 60-67.
- Shershow, John C., King, Allen & Robinson, Sumner. "Carbon dioxide sensitivity." Psychosom. Med., 1973, 35, 155-160.
- Smith, Orville A., Jr. "Cardiovascular integration by the Central Nervous System." IN: Theodore C. Ruch & Harry D. Patton (Eds.). Physiology and Biophysics, 19th ed. Philadelphia: W. B. Saunders, 1966.
- Stevenson, Ian & Riplay, Herbert S. "Variations in respiration and in respiratory symptoms during changes in emotion." Psychosom. Med., 1952, 14, 476-490.
- Tenney, S. M. & Lamb, T. W. "Physiological consequences of hypoventilation and hyperventilation." IN: Wallace O. Fenn & Hermann Rahn (Eds.). Handbook of Physiology, Section 3: Respiration (Vol. II). Washington, D. C.: American Physiological Society, 1965.
- Vellutino, Frank R. "Verbal response stereotypy as a function of psychological and physiological drive." Percept. Mot. Skills, 1971, 33, 851-858.
- Wilder, Joseph. "Basimetric approach (law of initial value) to biological rhythms." Ann. N. Y. Acad. Sci., 1962, 98, 1211-1220.
- Young, Allan C. "Neural control of respiration." IN: Theodore C. Ruch & Harry D. Patton (Eds.). Physiology and Biophysics, 19th ed. Philadelphia: W. B. Saunders, 1966.

GLOSSARY

CHEMICAL LOADING: involves altering the blood gas composition, either by reducing O_2 and/or increasing CO_2 . Changes in O_2 concentration are sensed by the carotid bodies in the carotid arteries; changes in CO_2 concentration are sensed primarily by medullary chemoreceptors. Because the system is substantially more sensitive to changes in CO_2 than in O_2 , CO_2 is far easier to work with experimentally. (See also CO_2 Sensitivity, Respiratory Loading.)

CO_2 SENSITIVITY: there are broad, stable individual differences in the responsiveness of the medullary chemoreceptors to alterations in CO_2 . These differences, which are not fully explainable by anatomical and physiological factors, are held by a growing number of respiratory physiologists to be associated with personality differences.

ELASTANCE: expansion impediment due primarily to the elastic nature, and consequent recoiling tendency, of the lungs and chest wall. When the lungs and chest wall are inflated they "want" to return to their resting position and, like a rubber band, the further they are stretched the stronger is this recoil force. The stiffer the pulmonary system, the greater its elastance (a thick, hard-to-stretch rubber band); the more compliant the system, the less its elastance (a worn out rubber band). The elastance inherent in the pulmonary system due to its elastic nature is assumed equal for all individuals with normal lungs and chest, and is expressed in terms of cmH_2O/L .

END-TIDAL CO_2 : the percent of CO_2 in the final portion of expired air, reflecting the concentration of CO_2 in the alveolar air. The concentration of CO_2 in the alveolar air parallels that in the arterial blood. End-tidal CO_2 , therefore, reflects the adequacy or inadequacy of ventilation.

MECHANICAL LOADING: involves a simulated increase in the intrinsic impediments against which the respiratory muscles normally work. The two types of load involve: (1) airflow resistance, which alters the effort involved in maintaining one's respiratory rate, and (2) the elastic properties of the lungs and chest wall, which alter the effort involved in maintaining one's tidal volume. A mechanical load can be imposed during inspiration only, during expiration only, or during the complete cycle.

An increased resistive load is simulated by requiring room air to be drawn through a narrow tube placed at the mouth. This resistance is expressed in terms of $cmH_2O/L/sec.$, an index of the pressure the subject must exert to maintain his normal rate of airflow. An efficient response to a resistive load is one resulting in the minimum increase in resistance for a given ventilation. Since resistance increases as rate of airflow increases (which is a function of RR), an efficient response is a marked decrease in RR with a complementary increase in TV, i.e., adopting a much slower/deeper respira-

tory pattern. A rapid/shallow pattern requires significantly more work to achieve the same ventilation. Individuals differ in both the degree to which they maintain their ventilation and in the breathing pattern adopted, differences not fully explainable on physiological grounds.

An increased elastic load is simulated by requiring room air to be inspired from a rigid container. As air is withdrawn from the container a continuously increasing vacuum is created against which the subject must work to continue increasing his tidal volume, thereby adding to the elastance that the inspiratory muscles must work against. This elastance is expressed as $\text{cmH}_2\text{O/L}$, a measure of the pressure that the subject must exert in order to maintain his normal tidal volume. An efficient response to an elastic load is one resulting in the minimum increase in elastance for a given ventilation. Since elastance increases as TV increases, an efficient response is a marked decrease in TV with a complementary increase in RR, i.e., adopting a much rapider/shallower respiratory pattern. A slow/deep pattern requires significantly more work to achieve the same ventilation. Individuals differ both in the degree to which they maintain their ventilation and in the breathing pattern adopted, differences not fully explainable on physiological grounds.

(See also Elastance, Resistance, Respiratory Loading.)

READ REBREATHING TECHNIQUE: involves rebreathing air from a closed bag for several minutes. The air initially contains a moderate CO_2 concentration with a large percentage of O_2 so that a subject will not diminish the oxygen supply below what is normally available to him in the atmosphere. As the air is rebreathed, the CO_2 concentration rises. The air in the bag is periodically sampled for CO_2 concentration, and the concurrent respiratory rate and tidal volume recorded. One can plot ventilation against increasing CO_2 concentration for each individual, and compare individual differences in ventilatory response at any given CO_2 concentration.

RESISTANCE: airflow impediment due primarily to the diameter of the smaller airways through which air is pulled; the narrower the diameter the greater the resistance. The resistance inherent in the pulmonary system, created as air is drawn through the bronchi and bronchioles, is assumed equal for all individuals with normal lungs. Resistance is expressed in terms of $\text{cmH}_2\text{O/L/sec}$.

RESPIRATORY LOADING: an external constraint, either chemical or mechanical, placed on the respiratory system requiring respiratory adjustment to maintain adequate ventilation. Loaded breathing techniques have recently been introduced in respiratory physiology to study the mechanics of breathing. (See also Chemical Loading, Mechanical Loading.)

RESPIRATORY RATE: the frequency of breaths, usually expressed as breaths/min. One breath is a full inspiration + expiration cycle. The average RR at rest is approximately 10/min.

TIDAL VOLUME: the volume (or depth) of each breath, usually expressed in terms of litres (l.) or millilitres (ml.). Average resting "tidal" (like the tides, it moves back and forth over the same path) volume is about 600 ml./breath.

VENTILATION: this is the average volume of air inspired during one minute. "Minute ventilation", a commonly used term for this volume, is calculated by $RR \times TV$. The average resting ventilation of the lungs, therefore, is about 6 l./min. (10 breaths/min. \times 600 ml./breath). A given ventilation may be achieved by a continuum of RR-TV combinations.

Resting ventilation in the healthy adult utilizes merely 10% of his total respiratory capability, ensuring a substantial and flexible safety margin for the far greater demands posed by severe stress, vigorous exercise and potential pulmonary impairment. The demands made by the moderate respiratory loads used in this investigation fall well within this margin.

VITAL CAPACITY: the maximum useful volume of air that an individual's lungs can hold. This volume is measured by spirometry as the subject first inspires to his maximum, then forcefully pushes all of the air from his lungs into the spirometer. The recorded displacement of the spirometer bell, expressed in litres, is his Vital Capacity. The average VC, adjusted for size and sex, is approximately 5 litres.