

STATISTICAL AND RESEARCH DESIGN CONSIDERATIONS CONCERNING  
INDUSTRIAL RESPIRATOR RESEARCH

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A major aim of scientific investigation is the precise description of phenomena, and more importantly their relationships, in order that accurate forecasts of future events and happenings become possible (5,8). In astronomy eclipses are predicted with a high degree of accuracy. In chemistry the properties of a compound are stated before the substance is actually in existence. In psychology and sociology the scientist seeks to understand human behavior. While it is unlikely that future behavior of humans will ever be completely predictable, scientific research and sophisticated statistical analysis have been used advantageously to forecast the actions and reactions of individuals and groups. It is indeed evident that without proper implementation of appropriate scientific methods, knowledge and understanding do not progress in any substantive manner. The research questions before the International Respirator Research Workshop are important and extremely meaningful ones to large numbers of living, breathing human beings. These questions can only be answered effectively if appropriate scientific methods and analysis are utilized to answer them.

Unfortunately, as noted in our review (11), the investigations into the physiological and psychological aspects of respirator wear have been limited from a design point of view. Specifically, much of the data has been collected on too few subjects and in fact the results of the data have been used incorrectly to set all encompassing standards for respirator performance (11). For example, our present day performance standards for respirators at high work loads have been developed from the data of Silverman and co-workers (12) collected on six or eight subjects, yet we utilize these standards to predict performance standards for thousands of workers. A somewhat inappropriate use of predictive statistics and the true physiological data.

Basically the questions proposed can be simplified to: 1) What are the changes in pulmonary function and work performance capabilities in the worker as a result of wearing an industrial respirator? 2) What are the psychological changes in the worker as a result of wearing the industrial respirator? 3) What are the performance criteria necessary for an industrial respirator? The scientific answers to these questions will provide information for several basic questions. Can the worker do his job? How long can he do his job? Can he do a different job? Certainly, to the worker and his employer these are important points.

#### A RESEARCH DILEMMA

The point of this presentation is to provide some basic recommendations as to the types of research and statistical analysis that may be required to provide the empirical answers. Before delineating these recommendations it is necessary to explore an important issue that confronts the statistician and the physiologist in their desire or lack of desire to work together. In practical terms it usually goes along this direction. The physiologist says that he has collected an enormous amount of data which includes ventilation, maximal oxygen consumption, anaerobic threshold, perceived exertion, heart rate, and blood lactates. The statistician replies that it is fantastic and naturally you have five times as many subjects as variables. The physiologist answers that it is impossible to measure that many subjects due to time and expense. The statistician answers that it is impossible to analyze so many variables with so few subjects. An argument is probable.

We have taken hopefully, a light-hearted approach to this problem but it is a serious one that confronts the objectives of this group. A large number of variables measured on a small number of subjects will not provide the definitive answers to the research questions. A large amount of data should refer to a large number of subjects measured on the important and meaningful variables. Thus, the power of the resulting statistical tests will be assured (6,7). Of course, expenses of time, effort and funds will be great if this is to be accomplished. It is indeed a practical problem but the importance of the research warrants the expense.

#### RECOMMENDED RESEARCH

The most obvious and important recommendation is that cooperative and coordinated large sample studies should be employed to answer the paramount research questions. Individual researchers and their laboratories should become a research team with one multiple location laboratory. Specific laboratories and researchers could represent specific areas and would be assigned specific responsibilities. Primary among these responsibilities should be that an assigned number of subjects need to be measured within predetermined timelines. Data collection procedures need to be standardized so that reliability and validity are maintained for all variables across the entire multiple location laboratory. An important component of the research team may be a supervisory group that will rigorously supervise and evaluate the entire laboratory in terms of data collection procedures. (This could be NIOSH or one of the National Scientific Laboratories, figure 1).

The second recommendation deals with a clear understanding of the variables of interest to the research team. The ability of the worker to perform his job related tasks, which is effected by physiological and psychological changes produced by wearing the respirator, really forms the actual criterion variable of importance. In order to accurately predict those changes, sensitive data must be collected in the critical profession of interest. Using laboratory measures to predict laboratory data and then inferring those predictions to the work place is excellent, in lieu of nothing, but it is very weak when compared to using laboratory measures to predict actual on the job performance. For example, pulmonary function may be used to predict exercise response in an effective manner. The researcher then may infer this estimation to work response. The more accurate procedure would be to have pulmonary function and exercise response predict actual work performance. If this is to be accomplished then bio-telemetry of physiological and psychological response in the workplace could be used to collect the appropriate data.

The final recommendation in this area is to use previous research and findings as pilot studies that direct these culminating researches to deal with the sensitive variables and appropriate populations. This will minimize the expenses in time, effort, and funds by excluding unnecessary measurements, analysis, and subjects.

## RECOMMENDED ANALYSIS STRATEGIES

The appropriate use of statistical inference will be mandatory if conclusive results are to be achieved. Two basic analysis approaches seem justified. The first would be to determine the percentage changes in the physiological and psychological functions as a result of wearing the industrial respirator. The second should be to determine the relationships between laboratory measurements and actual work data so that prediction of work performance may be possible. Important in producing effective results from either of these approaches is the realization that we are dealing with a multidimensional, multivariate phenomena. No single variable or measurement will explain the worker's ability to function with an industrial respirator. Thus, univariate statistics will be of limited use in explaining our phenomena of interest.

In relation to the first overall statistical approach we recommend that multivariate, analysis of variance (manova) and post hoc discriminant analysis be used as the central analysis techniques (4,14). We yield to qualified medical, psychological, and physiological researchers to determine the sensitive dependent variables. Suggested independent variables could be impairment level, type of work, use or non-use of industrial respirator, success or failure of job completion, and time of work with the respirator. These independent variables could be studied separately or combined into a factorial design (4,14). Repeated significance testing of dependent variables would be avoided as well as inflated levels of significance (14). Figure 2 depicts an example of a study whose purpose is to determine the relationship between a matrix of dependent variables coming from the appropriate sciences and two independent variables such as subjects who are impaired or not impaired and who work with or without the industrial respirator.

If a significant difference is found between the levels of the independent variable then post hoc discriminant analysis could be used to determine the most powerful dependent variables in contributing to that difference. This can be done by calculating the standardized discriminant weights for the dependent variables (4). Also the correlations between the dependent variables and the discriminant space might provide additional insight (4). Most statistical programs for computer application calculate these values.

After Manova and discriminant analysis have delineated differences and the sensitivity of the dependent variables, a composite score for each subject could be calculated over the sensitive variables. Any recognized standard score methods, such as the T-score, would be acceptable for this purpose (2,10). These composite scores could be related to individuals who can successfully complete their assigned duties. A specific composite score might indicate or provide a standard for potential successful or unsuccessful job performance with industrial respirators.

The second overall statistical approach was to establish the relationship between laboratory measures and work performance data. Again the multivariate approach will be the most fruitful. Thus, multiple regression and canonical correlation are the appropriate statistical techniques (4,9). As in figure 3, the multiple regression approach would involve using laboratory measurements as predictors of work performance while wearing an industrial respirator. While the predictor variables are straight forward and comparatively easily measured, the criterion variable should be actual work performance. Since we have already mentioned this concern we will not be repetitive. However, rigorous cross-validation procedures of resulting prediction equations are necessary (9). These involve utilizing screening and calibration samples to develop the most accurate predictions. The change in multiple  $R^2$  from the screening to the calibration sample will be a prime indicator of effectiveness of the prediction approach.

Canonical correlation is a more difficult technique to understand and therefore, to use appropriately. It is used to determine the multivariate relationship between domains of variables (4). In the research problem before us the two domains would be laboratory data and actual work data or possibly pulmonary function data and exercise measurements. Post hoc calculations should include redundancy coefficients and correlations between the variables of one domain and the canonical variate that represents the other domain (4,13). The canonical correlation allows understanding of the relationship of the two domains with all variables functioning which is a reflection of the true situation confronting the worker who is using an industrial respirator.

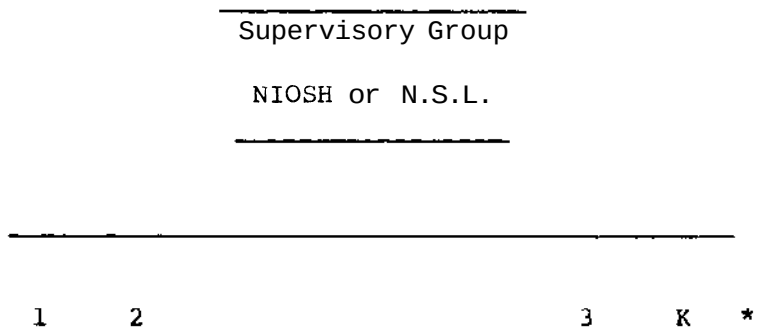
#### CONCLUSION

Dotson (3) has presented theoretical arguments that support our recommendations. This very important area of research, the effects of industrial respirators on work performance, warrants conclusive, culminating research endeavors. To accomplish this goal coordinated, cooperative, large sample studies are needed. Before data collection begins research questions, objectives, assignments, and timeliness should be established through comprehensive agreement of all participants involved. Sophisticated multivariate statistics applied to data gathered from large samples will have the greatest chance of providing the definitive research answers.

#### REFERENCES

1. American National Standard Practices for Respiratory Protection. 1969. American National Standard Institute. New York, NY 10018, 1969.
2. Baumgartner, T., and Jackson, A.S. Measurement for evaluation in physical education. Boston: Houghton Mifflin Co. 1975.
3. Dotson, C. "Logic of questionable density." Research Quarterly for Exercise and Sport. 1980, 51, 23-36.
4. Cooley, W., and Lohnes, P. Multivariate data analysis. New York: Wiley and Sons. 1971.
6. Glass, G. and Stanley, J. Statistical methods in education and psychology. Englewood Cliffs: Prentice Hall. 1970.
7. Hays, W. Statistics for the social sciences. New York: Holt Rhinehart and Winston. 1964.
8. Kerlinger, F. Foundations of behavioral research. New York: Holt Rhinehart and Winston. 1964.
9. Kerlinger, F., and Pedhazur, E. Multiple regression in behavioral research. New York: Holt Rhinehart and Winston. 1973.
10. Mood, D. Numbers in motion. Palo Alto: Mayfield. 1980.
11. Raven, R.B., Dodson, A.T. and Davis, T.O. The physiological consequences of wearing industrial respirators: a review. American Industrial Hygiene Association Journal. 1979, 40, 517-534.
12. Silverman, L., Lee, G., Plotkin, T., Sawyer, L.A., and Yancy, A.R. Airflow measurements on human subjects with and without respiratory resistance at several work rates. American Industrial Hygiene Association Journal. 1951, 3, 461.
13. Stewart, D. and Love, W. A general canonical correlation index. Psychological Bulletin, 1968, 70, 160-163.
14. Tatsuoaka, M. Multivariate analysis. New York: Wiley and Sons. 1971.

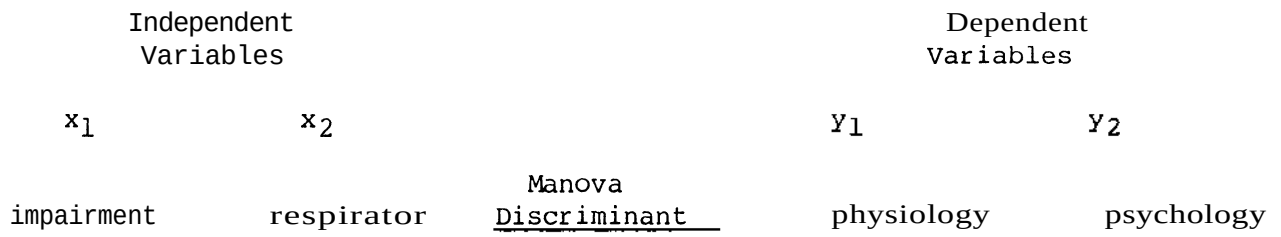
Figure 1  
Multiple Location Laboratory



\*Sub-Laboratories

\*Selected by geographical area and research speciality  
such as work, environment, age and disease.

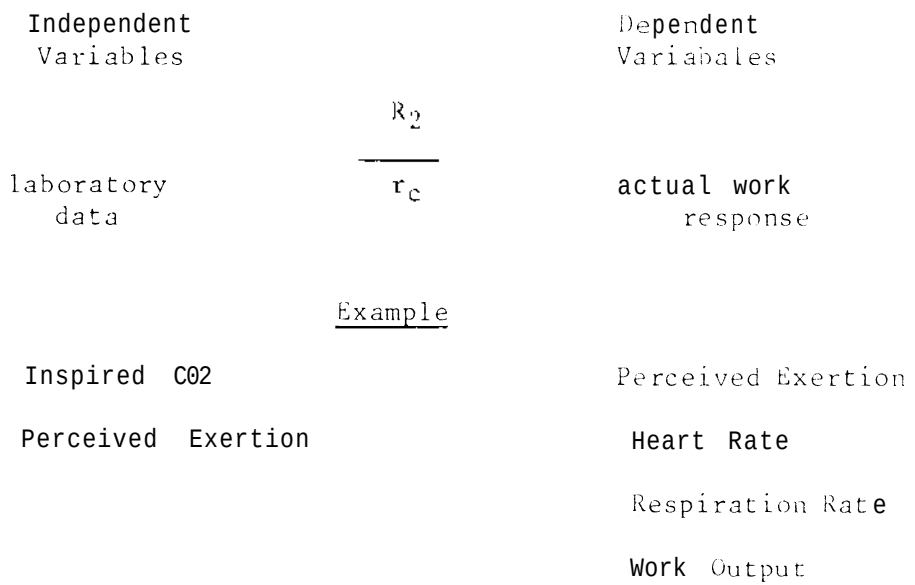
Figure 2



For Example:

|            |               |                          |
|------------|---------------|--------------------------|
| Impaired   | Non Impaired  | Inspired CO <sub>2</sub> |
| Respirator | No respirator | Heart Rate               |
|            |               | Perceived Exertion       |

Figure 3



$R_2$  - multiple correlation

$r_c$  - canonical correlation