

Research on Psychological Reactions to Wearing Respirators

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While most research conducted on the design and use of respirators has involved physiological or engineering measurements, there is general agreement that quantifying psychological responses is also important. The problem has been the lack of suitable psychometric tools. Indeed, development of psychological measures for quantifying cognitive and subjective responses of humans to wearing respirators has been slow, to say the least. Presumably, this is due to the interests and training of the researchers, the limited number of behavioral specialists in the respiratory protection field, and the lack of parallel development in other fields. Regardless, it is time to expedite this process. One means of facilitating rapid development is making readily available the history of empirical attempts that have used behavioral variables. Such a literature review would permit researchers, engineers, managers, and others concerned with respiratory protection to benefit from previous successes and failures. Therefore, the purpose of this paper is to present some of the respirator research that has used psychological measures and to solicit information for building a subsequent, more comprehensive listing.

The research list presented in this article contains all of the papers published in the *Journal*

of the International Society for Respiratory Protection that have employed psychological-dependent measures, as well as some key papers from other journals. A more comprehensive listing is still needed. Therefore an appeal is made to those who have employed psychological measures in their respirator experiments or review papers to send a copy of your manuscript to the author, along with any comments you feel are relevant. Particularly important is information on the strength and weaknesses of the criterion measures employed. Materials received will be included in subsequent literature reviews.

Table 1 contains a chronology of respirator research that has employed psychological measures. Each publication was selected because it describes respirator research or peripheral studies on respirator design variables involving human psychological reactions. Research variables, psychomotor measures, and subjective measures used in each paper are abbreviated to provide a sense of the contents. At the end of the table are definitions of each abbreviation. Review articles are indicated by an asterisk (*) following the authors' names. Readers are encouraged to refer to original manuscripts for details.

References

- Burse, R.L., and Strong, L.H. (1985). Low-temperature tests of rescue breathing apparatus. *Journal of the International Society for Respiratory Protection*, 3(1), 1-48.
- Dahlback, G.O. (1987). Physiological evaluation of a gas saving deep diving apparatus. *Journal of the International Society for Respiratory Protection*, 5(2), 1-8.
- Dahlback, G.O., and Fallhagen, L. (1987). A novel method for measuring dead space in respiratory protective equipment. *Journal of the International Society for Respiratory Protection*, 5(1), 12-17.

- Dahlback, G.O., and Jorfeldt, L. (1986). Work performance when using closed-circuit oxygen breathing apparatus. *Journal of the International Society for Respiratory Protection*, 4(2), 95-123.
- DuBois, A.B. (1987). Comfort and acceptability of respiratory protection devices. Personal communication, John B. Pierce Foundation Laboratory, Department of Epidemiology and Public Health, Yale University School of Medicine, 290 Congress Avenue, New Haven, CT 06519 (manuscript in preparation).
- Epstein, Y., Keren, G., Lerman, Y., and Shefer, A. (1982). Physiological and psychological adaptation to respiratory protective devices. *Aviation, Space, and Environmental Medicine*, 663-665.
- Gallagher, S., and Vercruyssen, M. (1986). Interaction of temperature and humidity of inspired air on tissue temperatures of the tongue and hard palate. *Journal of the International Society for Respiratory Protection*, 4(2), 20-44.
- Gallagher, S., Vercruyssen, M., and Deno, N.S. (1985). Hot air breathing: Effects of elevated wet bulb temperatures on tissue temperatures of the mouth. *American Industrial Hygiene Association Journal*, 46(6), 332-335.
- Gwosdow, A.R., Nielsen, R., Berglund, L.G., DuBois, A.B., and Tremmi, P.G. (1989). Effects of thermal conditions on the acceptability of respiratory protective devices on humans at rest. *American Industrial Hygiene Association Journal*, 50(4), 188-195.
- Hodous, T.K., Boyles, C., and Hankinson, J. (1986). Effects of industrial respirator wear during exercise in subjects with restrictive lung disease. *American Industrial Hygiene Association Journal*, 47(3), 176-180.
- Love, R.G. (1983). Acceptable breathing resistance for respirator use. *Journal of the International Society for Respiratory Protection*, 1(3), 47-66.
- Love, R.G. (1987). Physiological studies of respiratory protective equipment (RPE) for escape and rescue. *Journal of the International Society for Respiratory Protection*, 5(1), 9-11.
- Morgan, W.P. (1983a). Psychological problems associated with the use of industrial respirators: A review. *American Industrial Hygiene Association Journal*, 44(9), 671-676.
- Morgan, W.P. (1983b). Psychological problems associated with the wear of industrial respirators: A review. *Journal of the International Society for Respiratory Protection*, 1(3), 67-107.
- Morgan, W.P. (1983c). Psychometric correlates of respiration: A review. *American Industrial Hygiene Association Journal*, 44(9), 677-684.
- Morgan, W.P., and Raven, P.B. (1985). Prediction of distress for individuals wearing industrial respirators. *American Industrial Hygiene Association Journal*, 46(7), 363-368.
- Nielsen, R., Gwosdow, A.R., Berglund, L.G., and DuBois, A.B. (1987). The effect of temperature and humidity levels in a protective mask on user acceptability during exercise. *American Industrial Hygiene Association Journal*, 48(7), 639-645.
- Raven, P.B. (1983). Respirator research: Where it needs to go. *Journal of the International Society for Respirator Protection*, 1(1), 49-65.
- Raven, P.B., Davis, T.O., Shafer, C.L., and Linnebur, A.C. (1977). Maximal stress test performance while wearing a self-contained breathing apparatus. *Journal of Occupational Medicine*, 19(12), 802-806.
- Raven, P.B., Dodson, A.T., and Davis, T.O. (1979). The physiological consequences of wearing industrial respirators: A review. *American Industrial Hygiene Association Journal*, 40, 517-534.

Raven, P.B., Jackson, A.W., Page, K., Moss, R.F., Bradley, O., and Skaggs, B. (1981). The physiological responses of mild pulmonary impaired subjects while using a "demand" respirator during rest and work. *American Industrial Hygiene Association Journal*, 42, 247-257.

Raven, P.B., Bradley, O., Rohm-Young, D., McClure, F.L., and Skaggs, B. (1982). Physiological response to "pressure-demand" respirator wear. *American Industrial Hygiene Association Journal*, 43(10), 773-781.

Sharratt, M.T., Norman, R.W., Meyer, P.F., and Eckenrath, M.F. (1987). Physiological assessment of respirators during work in the heat. In S.S. Asfour (Ed.), *Trends in Ergonomics / Human Factors IV: Proceedings of the Annual International Industrial Ergonomics and Safety Conference*, New York: North Holland, 429-435.

Sheehy, J.B., Kamon, E., and Kiser, D. (1982). Effects of carbon dioxide inhalation on psychomotor and mental performance during exercise and recovery. *Human Factors*, 24(5), 581-588.

Shimozaki, S., Harber, P., Barrett, T., and Loisides, P. (1988). Subjective Tolerance of respirator loads and its relationship to physiological effects. *American Industrial Hygiene Association*, 49(3), 108-116.

Van de Linde, F.J.G. (1988). Loss of performance while wearing a respirator does not increase during a 22.5-hour wearing period. *Aviation, Space, and Environmental Medicine*, 59, 273-277.

Vercruyssen, M. (1984). *Carbon dioxide inhalation and information processing: Effects of an environmental stressor on cognition*. Doctoral dissertation, Pennsylvania State University, University Park, PA 16802.

Vercruyssen, M. (1985a). SCBA research: Mental dysfunction caused by breathing 4% carbon dioxide. *Proceedings of the International Society for Respiratory Protection Conference*, York, UK.

Vercruyssen, M. (1985b). Behavioral research on the maximum allowable concentration of carbon dioxide in self-contained breathing systems. In I.D. Brown, K. Goldsmith, K. Coombes, and M.A. Sinclair (Eds.), *Ergonomics International* 85, London: Taylor and Francis, 739-741.

Vercruyssen, M., Hancock, P.A., and Mihaly, T. (1988). Behavioral toxicology: Effects of breathing 4% carbon dioxide on cognition. *Ergonomics International* 88, London: Taylor and Francis, 508-510.

Vercruyssen, M., and Kamon, E. (1983). High CO₂ tolerance during one hour of physical work. *Proceedings of the First Conference of the International Society for Respiratory Protection*.

Vercruyssen, M., and Kamon, E. (1984a). Behavioral effects of one-hour breathing of high concentrations of CO₂ and O₂ while doing physical work. *Journal of the International Society for Respiratory Protection*, 2(1), 63-90.

Vercruyssen, M., and Kamon, E. (1984b). Behavioral effects of breathing 3% and 4% carbon dioxide during and following physical work. *Proceedings of the 1984 International Conference on Occupational Ergonomics*, 20-24.

Vercruyssen, M., and Kamon, E. (1985). Simultaneous measurement of physiological, psychological, and emotional reactions to multiple SCBA stressors. *Abstracts of the U.S. Army Chemical Research and Development Center: 1985 International Symposium on Respirator Test Technology*, reproduced by the International Society for Respiratory Protection.

Vercruyssen, M., Kamon, E., and Hancock, P.A. (1989). Effects of carbon dioxide inhalation on psychomotor and mental performance during exercise and recovery, II. *Human Factors*, in press.

Vercruyssen, M., Turner, N., Mihaly, T., Hodgson, J., and Kamon, E. (1987). Behavioral effects of multiple SCBA stressors: Safety research for recommending federal standards. *Proceedings of the Human Factors Society 31st Annual Meeting*. Santa Monica, CA: Human Factors Society, 931-935.

- Vercruyssen, M., Turner, N., and Mihaly, T. (1987). SCBA stressor effects on mental abilities and emotional states. *Journal of the International Society for Respiratory Protection*, 5(3), 42.
- Vercruyssen, M., Turner, N., and Mihaly, T. (1989). Protective equipment design: Behavioral effects of multiple respirator stressors during 3.2 km maximal exertion runs. *Ergonomics*, in review.
- Vercruyssen, M., Yard, S., White, M.K., Turner, N., Mihaly, T., and Sever, S. (1987). Research methodology: Quantifying subjective reactions to wearing respirators. *Journal of the International Society for Respiratory Protection*, 4(3), 43.
- White, M.K., and Hodous, T.K. (1987). Physiological and subjective responses to working in disposable protective coveralls and respirators commonly used by the asbestos abatement industry. *Journal of the International Society for Respiratory Protection*, 4(3), 43.
- White, M.K., and Hodous, T.K. (1988). Physiological responses to the wearing of fire fighter's turnout gear and neoprene and GORE-TEX barrier liners. *American Industrial Hygiene Association Journal*, 49(10), 523-530.
- White, M.K., Hodous, T.K., and Vercruyssen, M. (1989). Effects of temperature and chemical protective clothing on work tolerance, physiological responses, and subjective states. *American Industrial Hygiene Association Journal*, in press.
- White, M.K., Vercruyssen, M., and Hodous, T.K. (1987). Effects of chemical protective clothing and respirators worn during work on the interrelationships between workers' physiological and subjective reactions. *Journal of the International Society for Respiratory Protection*, 4(3), 44.
- White, M.K., Vercruyssen, M., and Hodous, T.K. (1989). Physiological and subjective responses to protective clothing and respirators during physical work. *Ergonomics*, in press.
- Wilson, J.R., Morgan, W.P., and Raven, P.B. (1986). Psychophysical screening for respirator wear. *Journal of the International Society for Respiratory Protection*, 4(1), 34-61.
- Wilson, J.R., Raven, P.B., Jackson, A.W., Garmon, R.O., and Morgan, W.P. (1985). Physiological responses to respirator wear during short term and long term maximal work performance. *Abstracts of the U.S. Army Chemical Research and Development Center: 1985 International Symposium on Respirator Test Technology*, reproduced by the International Society for Respiratory Protection.
- Wilson, J.R., Raven, P.B., Morgan, W.P., Zinkgraf, S.A., Garmon, R.G., and Jackson, A.W. (1989). Effects of pressure-demand respirator wear on physiological and perceptual variables during progressive exercise to maximal levels. *American Industrial Hygiene Association Journal*, 50(2), 85-94.

Table 1. Chronology of Research on Psychological Reactions to Wearing Respirators

Year	Authors	Research Variables	Psychomotor Measures	Subjective Measures
1977	Raven, Davis, Shafer, & Linnebur	SCBA, work, physio, weight, pos press, work tolerance, smoking		leg pain, fatigue, dry throat, CSI, breath diff, lack of air, resist, claustrophobia, discomfort, hot mask
1979	Raven, Dodson, & Davis *	physio, resist, amb temp, amb humid, vent, work, dead space, pos press, wave form, work tolerance		breath discomfort, breath diff, claustrophobia, leg pain, fatigue, hot mask, dry throat, headache, dyspnea, CSI, fatigue, anxiety, depression
1981	Raven, Jackson, Page, Moss, Bradley, & Skaggs	physio, CO ₂ , vent, mask press, work, lung impaired		RPE, breath diff, dyspnea
1982	Epstein, Keren, Lerman, & Shefer	adaptation, CO ₂ , physio, work, resist		dyspnea, discomfort, breath diff, diff on physical performance
	Raven, Bradley, Rohm-Young, McClure, & Skaggs	physio, work, resist, CO ₂ , dead space, work tolerance		discomfort, breath diff
	Sheehy, Kamon, & Kiser	CO ₂ , O ₂ , work	ART, CRT, tracking, memory, reasoning	

1983	Love *	resist, air temp, air humid, training, pulm func, physio		discomfort, breath diff, acceptability
a	Morgan *	elastance, work, sigh resp, pulm func, resp distress, CO ₂ , vent, hypnotic suggest, personality		dyspnea, RPE, discomfort, CSI, anxiety, hypervent , neurosis, depression, extroversion
b	Morgan *	SCBA, fitness, personality, STAI, smoking, work, CO ₂ , resist, weight		RPE, CSI, discomfort, hypervent, dyspnea
c	Morgan *	work, O ₂ , CO ₂ , STAI, physio, training, vent, personality,		discomfort, RPE, dyspnea, CSI, claustrophobia, breath diff, lack of air, fatigue, vigor, hypervent
	Raven	SCBA, work, mask pres, vent, pulm func		leg pain, fatigue, claustrophobia, hot mask, lack of air, dry throat, breath diff, CSI
	Vercruyssen & Kamon	CO ₂ , work, physio, O ₂	tracking, CFF, memory, reasoning, CRT, ART, arithmetic, balance	CSI, SSCM
1984	Vercruyssen *	CO ₂	SCRT	CSI, headache
a	Vercruyssen, & Kamon *	CO ₂ , O ₂ , work	CRT, tracking, balance, memory, reasoning, arithmetic	exertion, discomfort, dry throat, headache, dizziness, weakness, CSI

b	Vercruyssen & Kamon	work, CO ₂ , O ₂	reasoning, memory, CRT, tracking, balance, arithmetic	headache, dry throat, weakness, CSI, dizziness
1985	Burse & Strong	physio, air temp, CO ₂ , work, resist		breath diff, visual diff, mask comfort, temp, subjective tolerance
	Gallagher, Vercruyssen, & Deno	air temp, air humid, physio, work		mouth discomfort
	Morgan & Raven	distress predict, STAI, work, SCBA		breath diff, stiff/sore legs, tight mask, lump in throat, dyspnea, anxiety, breath distress
a	Vercruyssen	SCBA, CO ₂	SCRT, CRT, balance, memory, CFF, reasoning, tracking	SSCM, CSI
b	Vercruyssen	CO ₂ , O ₂ , work, SCBA	memory, CRT, tracking, SCRT	
	Vercruyssen & Kamon	CO ₂ , work, SCBA, hot air, resist, pos press	balance, RT, time estimation, memory, attention, coordination	disorientation, RPE, discomfort, CSI
	Wilson, Raven, Jackson, Garmon, & Morgan	vent, work, physio, SCBA, resist, work tolerance		RPE, discomfort
1986	Dahlback, Jorfeldt	physio, resist, work	arithmetic	RPE, gas temp, work load, sweat
	Gallagher & Vercruyssen	air temp, work, air humid, physio		mouth discomfort

	Hodous, Boyles, & Hankinson	work, pulm func, lung disease, physio, smoking	dizziness, fatigue, discomfort
	Wilson, Morgan, & Raven *	work, CO ₂ , pulm func, vent, resist, STAI, SCBA, MMPI	discomfort, anxiety, dizziness, claustrophobia, panic
1987	Dahlback	dead space, deep dive, work, physio, resist, vent, AGA, gas temp, ACSC, CO ₂	RPE, breath diff, cold, work, breath resist
	Dahlback & Fallhagen	dead space, CO ₂ , vent, work	RPE, breath diff, breath resist, breath temp, breath humidity
	DuBois	air temp, air humid, physio, skin wettedness, skin temp, work	comfort, body temp, acceptability, breath diff, therm sens
	Love	SCBA, weight, resist, amb temp, CO ₂ , CO, fitness	breath resist
	Nielsen, Gwosdow, Berglund, & DuBois	mask temp, mask humid, physio, work	acceptability, therm sens, discomfort, skin wettedness, sweat, breath diff, work of breath
	Sharratt, Norman, Meyer, & Eckenrath	amb temp, work, physio, resist	RPE, breath diff

	Vercruyssen, Turner, & Mihaly	SCBA, physio, CO ₂ , resist, pos press, hot air	CRT	SSCM, CSI,
	Vercruyssen, Turner, Mihaly, Hodgson, & Kamon	work, resist, CO ₂ , pos press, hot air, physio	SCRT	RPE, headache, CSI
	Vercruyssen, Yard, White, Turner, Mihaly, & Sever	SCBA, respirators, stressors		SSCM, CSI
	White & Hodous	cloth, SCBA, work, physio		cloth comfort, mask comfort, appeal, ease of breath, cloth temp, perspiration
	White, Vercruyssen, & Hodous	work tolerance, work, cloth, SCBA, amb temp, physio		RPE, RPE legs, RPE chest, therm sens, perspiration
1988	Shimozaki, Harber, Barrett, & Loisides	resp load, physio, dead space, work tolerance, resist, weight		subjective tolerance, RPE, breath diff, dead space, breath discomfort, dyspnea
	Van de Linde	perf, work	memory, concentration, vision, coordination	breath diff, discomfort
	Vercruyssen, Hancock, & Mihaly	SCBA, CO ₂ , work, method	SCRT	headache, CSI

	White & Hodous	cloth, SCBA, physio, work, work tolerance		RPE, comfort, cloth breathability, temp, perspiration
1989	Gwosdow, Nielsen, Berglund, DuBois, & Tremmi	air temp, amb temp, amb humid, physio		therm sens, resp therm sens, resp discomfort, skin moisture, breath diff, acceptability, sweating, skin wettedness
	Vercruyssen, Kamon, & Hancock	work, CO ₂ , O ₂ , skill	reasoning, tracking, arithmetic, balance	CSI, dry throat, headache, dizziness
	Vercruyssen, Turner, & Mihaly	work, resist, CO ₂ , hot air, pos press, physio, vent, SCBA	scrt	CSI, SSCM, headache, RPE, breath diff
	White, Hodous, & Vercruyssen	work, cloth, SCBA, amb temp, work tolerance, physio		RPE, breath diff, mask temp, cloth temp, mask humid, cloth sweat
	White, Vercruyssen, & Hodous	cloth, SCBA, work, physio, work tolerance		RPE, RPE legs, RPE chest, breath diff, perspiration, therm sens,
	Wilson, Raven, Morgan, Zinkgraf, Garmon, & Jackson	press-demand, work, physio, resist, toler- ance, vent,		RPE, breath diff, discomfort, dyspnea
	Wilson, Raven, Zinkgraf, Morgan, & Jackson	physio, work, vent, work tolerance, resist		RPE, breath diff, breath tolerance, work of breathing, exhaustion, breath distress, dyspnea

Table Abbreviations

AGA, ACSC	semiclosed demand apparatus	O ₂	oxygen
air humid	inspired air humidity	perf	performance
air temp	inspired air temperature	physio	physiological variables
amb humid	ambient (room) humidity	pos press	positive pressure
amb temp	ambient (room) temperature	pulm func	pulmonary function
ART	auditory reaction time	resist	resistance breathing
breath diff	breathing difficulty	RPE	rating of perceived exertion
breath distress	breathing distress	RT	reaction time
breath resist	breathing resistance	SCBA	self-contained breathing apparatus
CFF	critical flicker fusion	SSCM	subjective state change measures
CO ₂	carbon dioxide	SCRT	serial choice reaction time
CRT	choice response time	STAI	State-Trait Anxiety Inventory
CSI	clinical symptoms inventory	temp	temperature
distress predict	respirator distress prediction	therm sens	thermal sensation
fitness	physical fitness	tolerance	tolerance; staytime; threshold limit
hypervent	hyperventilation	vent	ventilation characteristics
hypnotic suggest	hypnotic suggestibility	weight	respirator weight
MMPI	personality inventory	work	physical work; exercise intensity