Magnitude estimation of breath deprivation*

RICHARD SULLIVAN
New York University Medical Center, New York, N.Y. 10016
and
HELENE GREIFER and HAL ZENNER
The City College of the City University, New York, N.Y. 10031

Twenty-two Ss estimated the magnitude of their urgency to breathe following restriction of breath for various percentages of individual breath-holding capacities. The conditions of breath holding were voluntary restriction and relaxed inhalation. No attempt was made to extend the degree of urgency into the aversive range. Under these conditions, the judgments obtained a power function having an exponent of 1.05. Sexual differences were not found, and the slopes of smokers and nonsmokers did not differ significantly. However, breath-holding capacity of smokers and nonsmokers differed significantly. On the basis of extrapolated thresholds, smokers appear to have lower urgency thresholds than nonsmokers. The ability of Ss to estimate lawfully the magnitude of such experiences suggests that the power function may apply to interoceptive intensive continua.

As anyone who has held his breath for more than a few seconds can attest, the restriction in breathing is accompanied by a particular and gross feeling of discomfort. Following the first few seconds of breath deprivation (apnea), the urgency to breathe demonstrates a growth in magnitude which reaches an intolerable level in a relatively short span of time. The state of apnea may therefore be considered an intensive dimension of subjective experience which exhibits characteristic parameters (i.e., absolute and differential magnitudes) of other intensive continua (e.g., loudness, brightness, pain). Under most ordinary conditions of relaxed breathing (eupnea), the average adult rate of respiration is approximately 14-20 breaths/min. When breathing is restricted voluntarily during eupnea, the "breaking point" of involuntary intake is reached on the average in about 85 sec. Both the average rate of intake and the "breaking point" may be altered through manipulation of a number of concomitant variables such as the state of the lungs, their volume capacity, CO_2 tension in the blood, ambient and body temperature, heart rate, active and passive exercise, reactions to intense stimuli (e.g., pain), and alteration in emotional state. Under optimal conditions and after prolonged training, individuals have held their breath for up to 8 min (Kimber et al, 1955; Mitchell, 1956).

Due to the relatively short span of apnea, the accompanying changes in magnitude of discomfort present formidable problems of judgment within the classical framework of psychophysics. However, the "direct" methods of judgment (i.e., magnitude estimation and production, Stevens, 1958) provide a procedure for obtaining judgments of the discomfort of apnea. Assuming a monotonic increasing function in the relation between growth of discomfort and time elapsed since last breath intake, the growth of that magnitude may be depicted in terms of temporal duration. Due to individual differences in breathing rates and lung capacities, an appropriate temporal measure would be the ratio of any selected time interval, t_p, to the individual's maximum withholding time, t_{max}. If the "power law" of psychophysics (Stevens, 1970) applied to the growth of apnea discomfort over time, the function would be described by $\Psi = K(t_p/t_{max})^n$.

In an initial study of this relationship, the method of magnitude production (Stevens, 1958) was used and Ss submerged themselves in a pool of water for specified proportions of their maximum withholding capacities. The procedure was found to be unsatisfactory for a number of reasons (e.g., physical exertion, emotional reactions, etc.). It was decided also that long durations of apnea had strong aversive qualities which seemed to interfere with judgments. In the present study, a relaxed method of obtaining judgments was used and the requested periods of restricted breathing did not extend beyond the S's voluntary "breaking point" (i.e., judgments were confined to the nonaversive range of apnea magnitudes).

METHOD

Twenty-two undergraduates (12 males, 10 females; ages 19-27) served as Ss. Of the 22 Ss, 10 were smokers and 12 were nonsmokers. Following introduction into a darkened lab, the Ss were told that they were participating in a study of breathing. They were then given instructions that allowed for a determination of maximum breath-withholding capacity under relaxed conditions: "I want you to hold your breath for as long as you are able. There is no need to hyperventilate. That is, don't forcefully breathe before holding your breath. At the count of 1-2-3-Go, hold your breath." Most Ss initially took slightly deeper breaths. Following the S's return to relaxed breathing, a second determination of maximum withholding capacity was obtained. Individual maximum withholding times (t_{max}) were then divided into eight durations representing the respective proportions of the maximum duration (t_p), 12.5%, 25%, 37.5%, 50% (standard), 62.5%, 75%, 87.5%, and 100%. The presentation of stimuli (t_p) followed the procedure of magnitude estimation (Stevens, 1958). The S was presented with the standard duration (i.e., $t_{max}/2$) at the beginning of the series, asked to assign an arbitrary integer to represent its magnitude, and told to base subsequent estimations of "pressure" or "discomfort" on the standard magnitude and its assigned integer. A single trial consisted of S withholding his breath upon signal, following the passage of a chosen duration (t_p), and being told to relax by E. The S would then estimate the magnitude of the discomfort, rest for intervals varying from 3 min onward, and then begin another trial. The presentation of durations was randomized, and periods of rest differed depending upon Ss and duration of breath holding for any previous trial.

RESULTS

The average breath-holding capacity (t_{max}) under the stated conditions was 80.3 sec for nonsmokers and 43.6 sec for smokers. A t test of the difference in maximum breath-holding capacities of the two groups obtained statistical significance ($t = 15.5$, $df = 1,21$, $p < .001$). Male-female differences were not significant. Magnitude estimations of apnea discomfort of the 22 Ss were transformed to a common base by multiplying individual number assignments by a factor which resulted in a product equal to 10 and then changing all other estimates by the common factor. A plot of the geometric means of the transformed estimtes of discomfort as a function of temporal duration is presented on log-log coordinates in Fig. 1 (method of least squares fit; n slope = 1.05). On the basis of the least squares curve fitting, the threshold of discomfort was extrapolated. The intercept of the extrapolated curve is at the temporal

*This study was supported in part by USPHS-NIH Grant MH-16434.

duration of 5.5% of the relaxed maximum withholding capacity (Fig. 1). Considering the average withholding capacity of the entire group to be about 60 sec, the depicted threshold is close to the temporal value of the average adult inhalation-exhalation ratio for normal breathing (i.e., 3.0-4.2 sec). An analysis of covariance done to determine whether the slopes of the smokers (n = 1.13) and the nonsmokers (n = 1.03) differed from the common slope indicated insignificant differences in slopes ($F = 2.19$, $N_1 = 1$, $N_2 = 5$, $p > .20$) (Walker & Lev, 1953). However, the extrapolated thresholds of smokers and nonsmokers were 1.9 and 2.9 sec, respectively. This finding suggests that smokers experienced an onset of discomfort shortly before the nonsmokers.

DISCUSSION

The present findings suggest that the growth in magnitude of discomfort resulting from breath deprivation can be judged by Ss in a lawful and consistent manner. The difference in intercepts but not in slopes between the smokers and nonsmokers suggests that manipulation of the numerous variables which influence breathing would alter the intercept value (i.e., onset of discomfort) but not the slope of the judgments. It would appear on the basis of the present results that the physiological experience of shortness of breath has a corollary in the lower psychological threshold of apnea discomfort. However, it is possible that the results were due to Ss' judgements of temporal duration rather than discomfort. Both the lower and upper anchors were relatively fixed. As Torgerson (1960) has noted, magnitude estimation procedures are particularly susceptible to anchoring effects. In view of the possible effects of anchoring, it should be noted that the Ss were unaware that their maximum withholding capacity was being used as the upper anchor. The Ss could have been urged to go beyond the voluntary "breaking point."

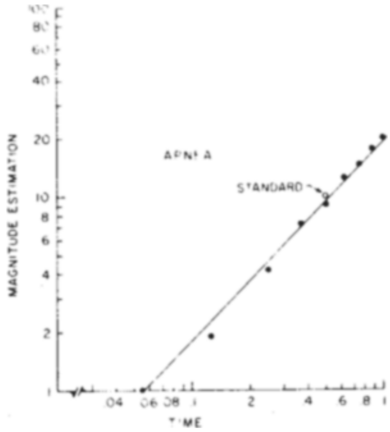

Fig. 1. A least-squares fit of the geometric means of estimated magnitudes of breath deprivation (apnea) as a function of percentage time of maximum period of breath withholding. Abscissa values are based on t_p/t_{max}. The intercept value was extrapolated on the basis of best fit for the eight data points (N = 22).

Furthermore, had the Ss based their judgments on the passage of time rather than on "discomfort," the bottom anchor would more likely have been at the saying of "Go." The extrapolated thresholds should then have had intercepts around the zero value. The derived thresholds for average breath-holding capacity and the difference in thresholds obtained for smokers and nonsmokers suggest that Ss judged magnitude of discomfort rather than time periods.

The present results are not surprising considering the extensive use of breath deprivation cues by individuals during exertion. Various degrees of the "loss of breath" are used as major cues in directing and terminating various activities. It would appear likely that other intensive interoceptive states which exhibit an urgency and a "breaking point" similar to that found with apnea (e.g., eliminative needs) could be lawfully judged on the basis of differential magnitudes. Indeed, with sufficient ingenuity, it would appear that the general class of "needs" and "drive states" are open to scaling through use of the "direct" methods of psychophysics. The validity and reliability of such estimations could be determined in a manner similar to that used in obtaining magnitude estimations of anxiety (Sullivan, 1971).

One further note on the slope of the judgments of apnea: It is possible that had the discomfort of apnea extended into the aversive range, the slope (i.e., judgments) would have been altered and the "power function" may not have applied. The aversive quality of breath deprivation has less to do with the actual physical discomfort than with the rate at which it increases. This is so for other intensive continua not usually associated with aversive reactions (e.g., brightness, loudness, taste) wherein rates of growth in stimulation may give rise to judgments that are different from those of absolute magnitudes of stimulation. The intensive states of apnea, anxiety, hunger, and thirst may differ in their respective aversive qualities due to differences in growth rates of magnitude.

REFERENCES

KIMBER, D. C., GRAY, C. E., STACKPOLE, C. E., & LEAVELL, L. C. *Textbook of anatomy and physiology.* New York: Macmillan, 1955.

MITCHELL, P. H. *A textbook of general physiology.* New York: McGraw-Hill, 1956.

STEVENS, S. S. Problems and methods of psychophysics. Psychological Bulletin, 1958, 54, 177-196.

STEVENS, S. S. Neural events and the psychophysical law. Science, 1970, 170, 1043-1050.

SULLIVAN, R. Magnitude estimation and relative aversiveness of anxiety: Phobia. Journal of Abnormal Psychology, 1971, in press.

TORGERSON, W. S. Quantitative judgment scales. In H. Gulliksen and S. Messick (Eds.), *Psychological scaling: Theory and applications.* New York: Wiley, 1960. Chap. 3.

WALKER, H. M., & LEV, J. *Statistical inference.* New York: Holt, 1953.