small forces and the method has to be modified. The level in the reservoir *B* is adjusted to make advancing and receding rates identical at one pressure. Rates at other pressures are measured at this new "dynamic" hydrostatic height. They are often slightly dissimilar, but they may be averaged to give a single value for plotting.

Figure 2 shows how water compares with eight aqueous solutions of surface-active agents. Water produces a rate-pressure line that crosses the origin, as it should. The others miss the origin to produce intercepts on the pressure axis. Note that all flow lines are parallel to the one for water. This fact suggests that meniscal resistance due to dissolved agents is not affected by variations in velocity. (The solutions named in Fig. 2 have viscosities very nearly that of water.)

The magnitude of "true" meniscal resistance depends on the concentration of the dissolved reagent. Figure 3 shows that sharp maxima occur. For the three substances shown, and for many others of similar molecular weight, the maxima lie near a concentration of about ¼ to ½ g per liter. Note that meniscal resistance falls rapidly with increasing concentration after the maxima. For example, maximum resistance for Aerosol OT is at ¼ g per liter, but it falls to zero at 2 g per liter. Sodium oleate follows a similar pattern but fails to reach zero.

True meniscal resistance is associated with elastic recoil, progressive slowing of flow, and apparent soiling of the wall. Elastic recoil is always greater in the direction of the advancing meniscus.

It appears that a quasi-rigid structure composed of solvent, solute, wall, and air forms within the three-phase contact at the meniscus. Whether this phenomenon will be found generally in nonaqueous systems has not been determined. Calderwood *et al.* found that soiled walls could raise meniscal resistance to 25 dyne/cm of meniscus periphery (*3*). We have found that "true" meniscal resistance in sodium oleate solution (½ g/l) reaches 22 dyne/cm of meniscus periphery. Blood serum shows about 18 dynes and plasma about 20. These values were calculated from intercepts on the pressure axis for a tube 0.25 mm in diameter.

It is apparent that surface tension is not primarily involved because true meniscal resistance rises to a maximum and falls again through a concentration range in which surface tension falls steadily. Pure water, at maximum surface tension, has negligible meniscal resistance, but reagents that lower surface tension are able to cause considerable meniscal resistance.

Doubtless a clear distinction should be made between the meniscal resistance described by Jamin, which is due to soiled walls, and the "true" meniscal resistance described here that is due to dissolved reagents. The latter exhibits "apparent" soiling of the wall with certain active agents at concentrations when meniscal resistance is highest.

Meniscal resistance introduces an adventitious friction into procedures where a meniscus is in motion. If it is "true" meniscal resistance, it will remain in spite of the most painstaking preparation of apparatus and reagents. The peculiar behavior of dilute hexyl resorcinol solutions in a capillary described by Washburn and Dunning (*5*) seems to be an example (*6*).

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Application of a Time Series Statistic to Physiology and Psychology

Abstract. A statistic describing variability for continuously collected time-ordered data with changing mean level is presented. The Mean Square Successive Difference, developed by von Neumann, was employed in the analysis of basal levels of galvanic skin potential recorded for 40-minute periods.

The quantification of time-ordered data has been a persistent problem in physiological and psychological research. The need for statistical treatment of such data has become more apparent with recent advances in behavioral and physiological recording techniques. Many researchers are interested in evaluating change and difference in cumulative response rates (*1*) and in continuously recorded physiological response levels (*2*). In the past the evaluation of change and difference in the curves obtained has depended on visual inspection. Quantitative comparison has rarely been attempted except over short time periods.

Table 1. Consistency of galvanic skin potential basal level in 15 female subjects across five group situations on mean ($\bar{X}$), variance (s^2), and Mean Square Successive Difference (δ^2).

Correlations	p	Number of correlations, Spearman Rank Order		
		$\bar{X}$	s^2	δ^2
$>.59$	$<.01$	1	5	10
.45–.59	$<.05$	1	2	0
$<.45$	N.S.	8	3	0

In 1941 von Neumann *et al.* (*3*) developed a statistic, the Mean Square Successive Difference, for describing the variability of a time series of observations. This statistic has particular application for continuous response data where the mean level is varying over time. It provides a description of variability between successive points of a continuously changing function. If X_i is a time series of a continuous variable, sampled at times $i = 1, 2, \ldots, n$, where the sampling rate can have any constant value, then δ^2 is defined as

$$\delta^2 = \frac{\sum_{i=1}^{n-1} (X_i - X_{i+1})^2}{n-1}.$$

The conventional statistics, mean,

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n},$$

and variance,

$$s^2 = \frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n-1},$$

describe the overall central tendency of the series and the variability around it. Where there is a trend in the changing level, $\bar{X}$ and s^2 may not be sufficiently descriptive.

The ratio of δ^2 to s^2, according to von Neumann (*4*), may be used to test for randomness or trend in a time series. It bears a linear relationship to the serial correlation (R) between X_i and X_{i+1}, $i = 1, 2, \ldots, n-1$. It can be shown that δ^2/s^2 when n is large is approximately equal to $2(1-R)$. This ratio is closely related to the autocorrelation function used in neurophysiological research (*5*), where millisecond sampling rates are employed. The application of these statistics and other

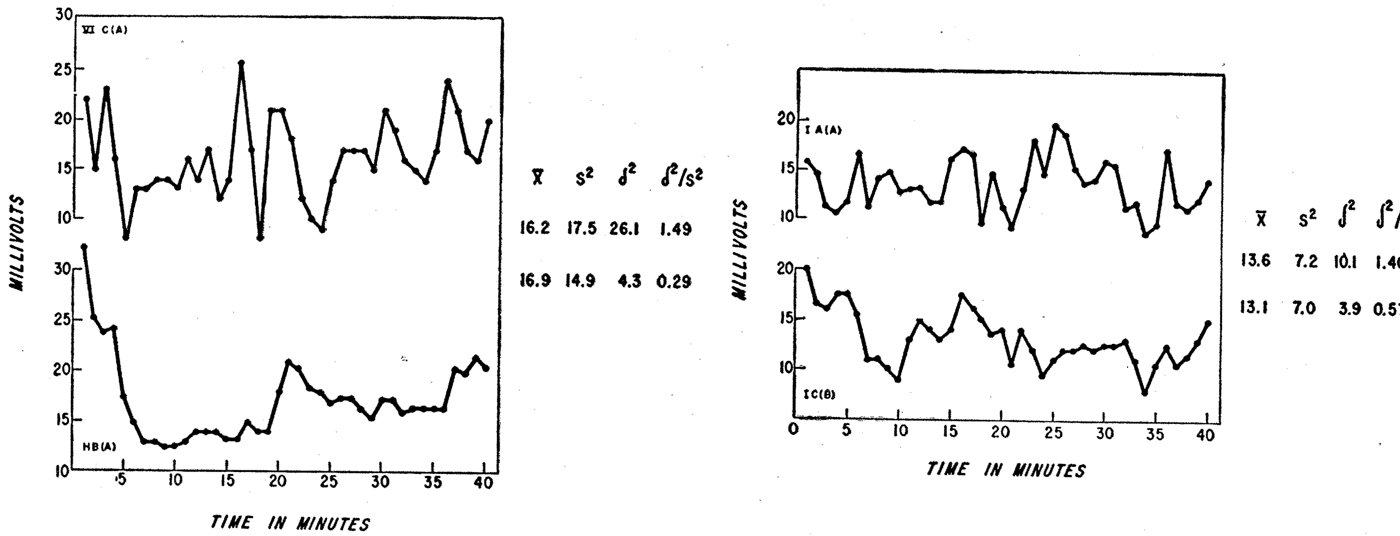

Fig. 1. Comparison of the galvanic skin potential basal level sampled at 1-minute intervals for two pairs of subjects. Each pair of curves was matched on mean ($\bar{X}$) and variance (s^2).

time series functions, with sampling rates of the order of seconds, minutes, and hours, may prove extremely valuable in the study of slowly changing physiological and psychological processes.

As an example of the use of a time series statistic (δ^2) for physiological data, continuous basal level data for galvanic skin potential were analyzed. Mean ($\bar{X}$) and variance (s^2) were computed for the same data. The basal level was measured as a d-c potential difference between left palmar and left dorsal forearm electrodes placed 20 cm apart. The data were recorded continuously on an Offner type R transistorized dynagraph throughout a 40-minute experimental period. The experimental period was preceded and followed by 15-minute rest periods. The basal level was sampled at 1-minute intervals. This sampling rate was parallel to the rate of behavioral change in the experiments. Leiderman and Shapiro (*6*) have outlined details of the experimental procedures and sampling techniques.

The statistic (δ^2) was computed by averaging the squared deviation between each successive 1-minute reading. To illustrate how δ^2 and s^2 differ, two pairs of curves were selected, each with approximately equal mean and variance (Fig. 1). As may be noted, the upper curve in each pair appears to be more variable than the lower, even though the variances are the same. The obtained values for δ^2, however, are not the same, showing that δ^2 provides an appropriate index of variability for time-ordered data changing in mean level.

As an example of the usefulness of the δ^2 statistic, we present results of an empirical study of 15 women, each of whom appeared in five 40-minute sessions under the same general social conditions. The three statistics ($\bar{X}$, s^2, δ^2) for the 15 subjects were each rank ordered in each of the five situations. Ten intercorrelations were computed across situations for each statistic (Table 1). The statistic ($\bar{X}$) showed little consistency for subjects in the different situations. Only two out of ten correlations were significant at the .05 level. The two variability statistics showed greater evidence of individual consistency. In the case of s^2, five were significant at the .01 level and two at the .05 level. For δ^2, all ten correlations were statistically significant below the .01 level.

As a second example of the use of this statistic, the δ^2 was compared to the s^2 for 54 women, each of whom appeared in two different situations. In the first situation each woman appeared alone performing a simple task. In the second situation each woman performed the same task as a member of a group of three. The rank order correlation between individual and group situations for δ^2 was $+.65$ ($p < .001$) while for s^2 it was $+.20$ ($p > .05$). In contrast, within each individual and group situation, the correlation between (δ^2) and (s^2) was $+.78$ and $+.70$, respectively. Although the two measures of variability are not unrelated within situations, the findings indicate the greater individual consistency for δ^2 across different experimental conditions. Thus the Mean Square Successive Difference (δ^2) describes an important aspect of variability for basal level.

In summary, a time series statistic, the Mean Square Successive Difference, was applied to the study of GSP basal levels collected continuously for relatively long time periods. This statistic appears to describe an important aspect of an individual's variability of level of response which is differential and highly consistent under different experimental conditions. It takes into account the fact of changing base level so often encountered in psychological and physiological research. It undoubtedly has general applicability in the analysis of variability and trend in cumulative behavior curves as well as in curves of physiological adaptation (*7*).

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