JOURNAL OF RESEARCH IN PERSONALITY 7, 88-101 (1973)

Individual Differences in Habituation: Some Methodological and Conceptual Issues[1]

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The personality correlates of habituation were investigated. A moderate intensity tone was presented 20 times on each of three sessions, and skin conductance and heart rate were recorded. There were no relationships between individual differences in rate of habituation and any of the personality dimensions assessed (which included, among others, manifest anxiety and introversion-extraversion). Some possible reasons are discussed for this lack of results, as well as for conflicting findings which fill the literature. Specifically, various methods of measuring habituation are examined and their interrelationships described. None of the measures derived showed adequate consistency either across sessions or over response modalities.

Habituation, which long has been recognized as one of the fundamental properties of biological systems, recently has become the subject of considerable theoretical and empirical research within the area of personality. Most interest has focused on the orienting reflex (OR) and its relationship to the personality dimensions of anxiety (or neuroticism) and introversion-extraversion (Eysenck, 1967). The results, however, have been disappointing. In some studies, for example, speed of habituation of

[1] The collection of data on which this report is based was made possible by grants to R. S. Lazarus, University of California, Berkeley, from the Rehabilitation Services Administration, Department of Health, Education, and Welfare (Grant No. RH-4) and the National Institute of Mental Health (Grant No. MH-2136). The data were collected while the third author (E. J. M.) was on a postdoctoral fellowship, No. 1-F2-MH-24, 818-01A2, from the National Institute of Mental Health.

the OR has been found to correlate negatively with anxiety (Lader & Wing, 1966) and neuroticism (Coles, Gale & Kline, 1971); in other studies, the reported relationship has been curvilinear (Epstein & Fenz, 1970) or positive (Fried, Friedman & Welch, 1967). Still other investigations have found no relationship (Galbrecht, Dykman, Rees, & Suzuki, 1965; Katkin & McCubbin, 1969; Koepke & Pribram, 1966; Martin, 1960). The results obtained with regard to introversion–extraversion have been little better (Coles *et al.*, 1971; Martin, 1960; Marton & Urban, 1966; Mundy-Castle & McKiever, 1953; Scott & Wilkinson, 1962).

There are numerous possible reasons for inconsistencies such as the above, including differences in method of personality diagnosis and the fact that anxiety and introversion–extraversion may interact in determining the rate of habituation (Mangan & O'Gorman, 1969). Other potential factors include (a) differences in the nature of the stimulus used to elicit a response; (b) differences in the measurement of habituation; and (c) a possible lack of consistency of individual differences in habituation, both across time (intersession) and across response systems (intermodality). The present report deals primarily with the last two problems, namely, measurement and consistency.

METHOD

The experiment consisted of three sessions, plus a preliminary meeting where *S*s met in small groups to fill out standard self-report personality inventories. The three laboratory sessions were identical, and involved the presentation of (a) a series of 20 tone stimuli; (b) a series of 20 identical scenes from a woodshop accident film; and (c) the entire accident film. The time between sessions varied, depending upon *S*s' class schedules, but was never less than 1 day nor more than 4. This report deals only with habituation to the tone stimuli; habituation to the complex emotional stimuli (movie scenes) has been discussed elsewhere (Averill, Malmstrom, Koriat & Lazarus, 1972).

Subjects and Stimuli

Male student *S*s (68) were recruited from posted sign-up sheets and paid $1.88 an hour. Tones of 1000 Hz and 3-sec duration were used to elicit the OR. Twenty such tones were tape-recorded and presented at a constant rate with a 30-sec interstimulus interval. Stimulus intensity was 75 db measured at *S*'s ear level.

Physiological Variables

Skin resistance and heart rate were recorded on a Beckman type-R Dynograph. Skin resistance was recorded from the thenar and hypothenar surfaces of the left palm, using Beckman Ag–AgCl electrodes 1 cm in diameter, and a cornstarch electrode paste (Edelberg, 1967). A modified Wheatstone bridge impressed a relatively constant 10-μA current across the electrodes. Before data analysis, all resistance measures were transformed to log skin conductance (SC). Beat-by-beat heart rate

(HR) was recorded from standard EKG electrodes on the left wrist and right leg, using a Beckman cardiotachometer.

Personality Variables

During preliminary group meetings, *S*s were given a booklet containing Eysenck's Personality Inventory, the L and K scales from the MMPI, Byrne's R-S scale, Barron's Ego-strength scale, the Self-control and Flexibility scales from the California Psychological Inventory, and Lykken's Activity Preference Questionnaire (a measure of fear proneness). In addition, the Gottschaldt Embedded Figures Test was given as a measure of field dependence-independence.

Procedure

At the preliminary group meetings, *S*s were informed that the rest of the experiment would involve the collection of psychophysiological data in individual sessions. They were instructed to get a normal amount of sleep the night before each session, not to take any drugs or alcohol for 24 hr, not to smoke or drink coffee for several hours before each session.

At the beginning of the first individual session, *S* was informed that he would listen to a series of tones and see two films, and that this same procedure would be followed for each of the three sessions. After obtaining consent to proceed, the HR and SC electrodes were attached and their function explained. *S* was then asked to relax, but not to sleep, for 5 min. At the end of that time, he was given a 15-sec warning that the series of tones would begin.

RESULTS AND DISCUSSION

The substantive findings of this study were largely negative when viewed in light of the original objectives, that is, the investigation of personality correlates of habituation. The results presented below thus focus primarily on methodological issues which might account for the negative findings, as well as for the inconsistencies so frequently reported in the published literature. The problem to be considered first is the derivation of appropriate scores to measure habituation. At present, there is no standard way of measuring habituation and the variety of commonly used scores may not all be measuring the same phenomenon.

Habituation of Heart Rate

Beat-by-beat HR was read beginning six beats prior to the start of each presentation of the tone and continuing for six additional beats during and after the stimulus. Figure 1 depicts the deviation of each post-stimulus beat from the mean of the six prestimulus beats. On the first presentation of the tone, cardiac deceleration predominated. With repeated trials, an accelerative component became increasingly apparent. The habituated HR response, generally achieved by trial 10, was biphasic—deceleration followed by acceleration. This pattern of habituation was

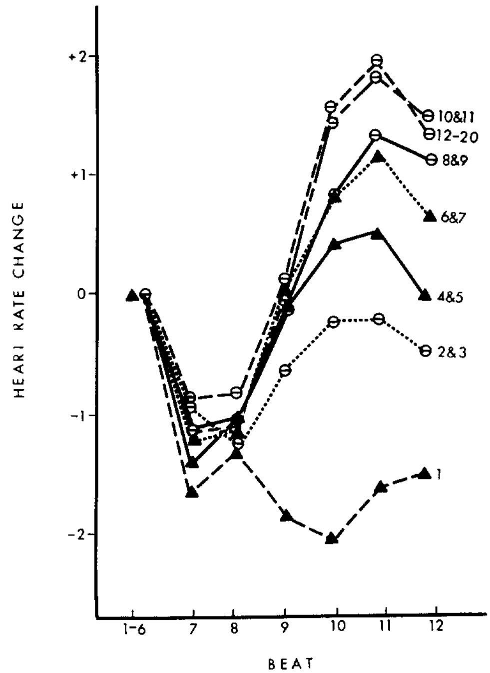

FIG. 1. Beat-by-beat changes in HR (deviations from mean of six prestimulus beats) during and after stimulus presentation. Reactions for the three sessions have been combined to provide average response curves for trial 1, trials 2 and 3, etc.

similar within each session and hence Fig. 1 presents the results for the three sessions averaged.

For purposes of statistical analyses, three scores were calculated for each presentation of the tone: *HR base*—the mean rate of the first six beats prior to tone onset; *Deceleration* (DEC)—the differences between HR base and the minimum rate observed during beats 7–10, with a negative score indicating deceleration; and *Acceleration* (ACC)—the difference between HR base and the maximum rate observed during beats 10–12.

To obtain an initial indication of the degree and manner of HR habituation, two-way (Sessions × Trials) analyses of variance were carried out on ACC and DEC scores, using either the first 10 trials or all 20 trials. The results will be summarized only briefly here for they overlap with other data to be presented below. There were no statistically significant effects for DEC. ACC scores, on the other hand, showed significant intra-session and intersession changes, but no Trials × Sessions interaction. The results obtained with Peak-to-Through scores, i.e., the difference between ACC and DEC appeared to be redundant with those obtained using the ACC scores alone. Thus, the accelerative phase of the HR response proved to be most sensitive to habituation.

Contrary to what might be expected, habituation was marked by an increase rather than a decrease in acceleration, both within and between sessions. These results are consistent with Stratton's (1970) findings, though the latter were obtained with neonates. Apparently, the natural evoked HR response to the type of discrete tonal stimulus used here is biphastic, with acceleration following deceleration. Initially, when the stimulus is still novel, the late-occurring acceleration seems to be masked by a prolongation of the prior decelerative phase. This is in keeping with the notion that cardiac deceleration is an aspect of the orienting response (Graham & Clifton, 1966).

Correction for base-level activity. There was no tendency for ACC or DEC scores to correlate with HR base scores on selected trials (viz., either the first or sixth presentation of the tone on each session), the correlations being calculated across *S*s. The standard correction for the so-called "law of initial values" was therefore unnecessary. *Within S*s, however, ACC, DEC, and HR base scores did tend to co-vary across trials, the average intraindividual correlation between HR base and ACC over the first 10 trials being -.52, -.51, and -.52 for the three sessions, respectively. The corresponding HR base-DEC correlations were -.51, -.49, and -.48. In one set of analyses, ACC and DEC scores were corrected for this within-individual dependency on HR base before measures of habituation were calculated. Results using these corrected scores, however, did not add to the findings and are not discussed further.

Individual differences in rate of habituation. Curves of habituation generally take the form of a negative exponential function between response amplitude and the number of stimulus presentations. Such a function implies a linear relationship between response amplitude and the log of the stimulus number, a relationship which has been reported for skin conductance and plethysomographic data (Lader, 1964; Lidberg, Schalling, & Levander, 1969; Montagu, 1963). In the present experiment, when the mean HR base, ACC, and DEC scores were plotted against log stimulus number there was no conspicuous deviation from linearity for the group as a whole on any of the three sessions. Therefore, in order to obtain measures of individual differences in habituation, linear regressions of HR base, ACC, and DEC on log stimulus number were calculated for each *S*. Only the first ten stimuli were used in these calculations, since habituation was virtually complete by that time.

In the linear regression equation ($Y = bX + a$) the intercept a of the regression line on the Y-axis is an estimate of initial reactivity, and the regression coefficient b is an estimate of the rate of habituation.[2] The

TABLE 1
MEAN AND STANDARD DEVIATION OF a AND b SCORES FOR HR VARIABLES ($N = 65$)

Measure		Session 1		Session 2		Session 3	
		a	b	a	b	a	b
Base	$\bar{\bar{x}}$	75.71	−2.54[b]	73.61	−.086	74.27	−1.04
	σ	12.24	5.80	8.09	6.00	10.34	5.54
ACC	$\bar{\bar{x}}$	1.74	2.35[b]	2.34	3.10[b]	3.03	1.91[b]
	σ	3.79	3.54	4.57	6.82	3.61	5.14
DEC	$\bar{\bar{x}}$	5.53	−1.32[a]	5.58	−1.63[a]	4.48	−.65
	σ	3.70	5.04	4.60	5.80	5.08	6.02

[a] Significantly different from zero at the .05 level (t test).
[b] Significantly different from zero at the .005 level (t test).

means and standard deviations of the individual a and b scores are presented in Table 1 for each session and for each variable. The mean slope of the regression line was different from zero for all three variables during session 1, and for ACC and DEC for session 2. By the third session, only ACC was still showing a significant amount of habituation. These results are in general agreement with those obtained using analysis of variance on the raw ACC and DEC scores.

It has frequently been reported that rate of habituation is in part a function of initial response amplitude. In terms of regression scores, this implies a relationship between the a and b scores described above. The interindividual correlations between a and b scores for HR base in the present study were −.40, −.22, and −.36 for the three sessions, respectively. The corresponding values for ACC were −.79, −.78, and −.83, and for DEC they were −.82, −.87, and −.90. Thus, there was only a moderate correlation between estimates of initial level and rate of habituation in the case of HR base; the correlations obtained for ACC and DEC, on the other hand, were very substantial. To obtain a measure of habituation which is independent of initial amplitude, the procedure suggested by Lader (1964) and others was followed. A new regression coefficient (designated b') was calculated according to the formula $b' = b - c(a - \bar{a}) + \bar{b}$, in which c designates the slope of the interindividual regression line of b on a scores, and $\bar{a}$ and $\bar{b}$ are the means of the a and b

[2] Some investigators (e.g., Stratton, 1970) have used the correlation coefficient, r, rather than the regression coefficient, b, as a measure of individual differences in habituation. However, since the correlation coefficient is influenced by the amount of variability around the regression line, and since individual data tend to show considerable variability from one stimulus presentation to another, the regression coefficient would seem to be the more appropriate measure. For group data, on the other hand, which tend to be more stable, the correlation coefficient may be acceptable.

scores, respectively. The mean of these corrected b' scores is, of course, the same as the mean of the respective b scores (see Table 1), although the variance is smaller.

Thus, within each session, three scores were calculated for each individual and for each variable: an estimate of initial activity—the a score; an estimate of the "simple rate of habituation"—the b score; and an estimate of what Montagu (1963) has called the "absolute rate of habituation"—the b' score. In the case of HR base, the b' score turned out to be redundant with the b score and is not discussed further.

Habituation of Skin Conductance

Procedures similar to those used with HR were employed to derive measures of SC habituation. Skin conductance was read at 2 points for each presentation of tone. The first reading, taken immediately preceding tone onset, provided a measure of *SC base*. The second reading represented the highest level of conductance reached during the 10 sec following tone onset. A *SC response* (SCR) was defined as the difference between this poststimulus reading and SC base (after a log transformation had been applied to both readings). Across *S*s, there was no tendency for SC base and SCR scores to co-vary.

Individual differences in rate of habituation. Inspection of the group data indicated no appreciable deviations from linearity when SC base and SCR scores were plotted against log stimulus number. Regression equations were therefore calculated for each *S* in order to obtain individual a and b scores. The means and standard deviations of these scores are presented in Table 2. For both SC base and SCR, the mean b score is significantly different from zero on each of the three sessions, with the rate of habituation diminishing during successive sessions.

The correlation between a and b scores, averaged over the three sessions, was −.04 for SC base and −.85 for SCR. This is a trend similar

TABLE 2
MEAN AND STANDARD DEVIATION OF a AND b SCORES FOR SC VARIABLES

Measure		Session 1		Session 2		Session 3	
		a	b	a	b	a	b
Base	$\bar{\bar{x}}$	1.016	−.098[b]	.910	−.071[b]	.822	−.073[b]
	σ	.203	.099	.306	.120	.281	.130
SCR	$\bar{\bar{x}}$	.057	−.048[b]	.032	−.029[b]	.016	−.009[a]
	σ	.037	.041	.039	.049	.023	.027

[a] Significantly different from zero at the .005 level (t test).
[b] Significantly different from zero at the .001 level (t test).

to that observed for HR, i.e., initial activity was highly related to the simple rate of habituation in the case of response measures but not in the case of base levels. To obtain an estimate of the absolute rate of habituation, b' scores also were calculated for SC response measures.

Relationship between Various Measures of Habituation

The regression scores derived above (a, b, b') are computationally complex and considerably removed from the raw data. Table 3 presents the correlations between them and some other, more easily derived measures, namely (1) *initial response*—the mean amplitude on trials 1 and 2; (2) *mean response*—the mean amplitude on trials 1–10; (3) *change in response*—the difference between initial response and final response, the latter defined as the mean amplitude on trials 9 and 10; and (4), for SCR only, *trials-to-extinction*—the number of the third consecutive trial (out of 20) with no response. The correlations presented in Table 3 have been averaged over the three sessions since the size of the correlations did not differ greatly between sessions.

TABLE 3
CORRELATIONS BETWEEN REGRESSION SCORES AND OTHER MORE SIMPLY DERIVED MEASURES OF HABITUATION

		Initial response[a]	Mean response[b]	Change in response[c]	Trials to extinction[d]
HR base	a	.97	.93	.31	—
	b	−.10	.06	−.87	—
HR ACC	a	.89	.38	−.73	—
	b	−.61	.28	.89	—
	b'	.16	.92	.51	—
HR DEC	a	.92	.56	.76	—
	b	−.74	−.07	−.87	—
SC base	b'	.12	.83	−.42	—
	a	1.00	.96	.04	—
	b	.04	.24	−.99	—
	a	.94	.65	−.80	.39
SCR	b	−.76	−.17	.94	−.14
	b'	.07	.74	.51	.41

Note. Each value represents the mean of three correlations, one for each session. The N for individual correlations was generally 65, although this varied slightly from variable to variable and session to session due to missing data.

[a] Mean level of activity on trials 1 and 2.

[b] Mean level of activity on trials 1–10.

[c] Difference between mean levels of activity on trials 1 and 2 and that on trials 9 and 10.

[d] The trial number (up to 20) on which there was no reactivity for three consecutive trials. Applicable to SCR only.

Table 3 shows that the regression estimate of initial level (a) were highly related to the actual response amplitude on trials 1 and 2, the correlations generally being above .90. The regression estimate of the simple rate of habituation (b) corresponds closely to the change in response from first to last trials, the correlations being in the .80's and .90's, but not to the mean response over all trials. The latter is more closely related to the regression estimate of the absolute rate of habituation (b'), with r's of about .80. Finally, in the case of SCR, the absolute rate of habituation was moderately related to trials-to-extinction ($r = .41$); the latter, however, was also related to the estimate of initial reactivity (a) and hence cannot be considered equivalent to the absolute rate of habituation.

Lidberg *et al.* (1969) have also found b' scores to be highly related to mean reactivity to tones, using changes in finger and pulse volume as dependent variables. Thus, the relationship between b' and mean response amplitude would seem to be quite general. Upon a little reflection, this relationship turns out to be a necessary by-product of the operations employed in the derivation of the b' score. It will be recalled that the uncorrected scores were correlated with initial level. The derivation of b' scores removes this correlation and substitutes for it a correlation with mean reactivity. This is due to the fact that when linear curves of different slopes are made to start at the same point, those with the steeper slope will have a lower overall mean than those with the shallower slope.

In short, although the b' scores have a certain face validity as measures of habituation, they are empirically and statistically roughly equivalent to mean reactivity over trials. Intuitively, the latter would seem to reflect a construct different than the "absolute rate of habituation." Two possible interpretations are open at this point: first, that b' is little more than an indirect measure of mean reactivity and reflects habituation only in the trivial sense that habituated responses are fewer and smaller, say, than nonhabituated responses; or, second, that mean reactivity itself can serve as a measure of absolute rate of habituation. These two interpretations are not mutually exclusive, although they possess different theoretical—if not substantive—connotations. In this connection, it might be pointed out that constructs such as "amplitude of the orienting response" (Mangan & O'Gorman, 1969), "autonomic lability" (Lacey & Lacey, 1958), or "autonomic reactivity" (Steinschneider & Lipton, 1965), which have been used in the study of individual differences in psychophysiological reaction, may also be related to habituation, depending upon how the latter is measured. At present there does not seem to be any theoretical formulation which is general enough and well-articulated enough to permit the construct validation of various measures of individual differences in habituation, and to distinguish these from other commonly used measures of autonomic reactivity.

Another issue raised by this analysis concerns the correction of b scores for dependence on initial level. There is little need to point out that the observed correlation between initial response amplitude and slope does not, by itself, justify the adjustment of the latter for its dependence on the former. A statistical adjustment of b scores would be warranted if it is assumed that a different process underlies the a than the b scores, and that slope and initial level are only fortuitously related, with the latter setting up limits for the former. In fact, this very correlation has been taken by some investigators, working within a Pavlovian framework (cf. Mangan & O'Gorman, 1969), to signify that initial OR amplitude must be determined, at least in part, by the same property of the nervous system which underlies rate of habituation. The recommended practice of adjusting rate of habituation for dependence on initial amplitude is, of course, inconsistent with this theoretical conclusion. It should be noted, however, that for both SC and HR the correlation between a and b scores was substantial only for response measures (i.e., ACC, DEC, SCR), but not for base levels. This might indicate that habituation of base-level activity reflects, at least in part, a different process than does the habituation of phasic reactivity.

Intersession Reliability and Intermodality Consistency of Habituation

If habituation varies, in part, as a function of stable individual differences in personality, then measures of habituation should show some stability over time. Surprisingly, few attempts have been made to test this assumption. Also, the concept of habituation—in any sense that would be relevant to personality theory—refers to changes in some central state, not simply to changes in peripheral response systems. This implies some intermodality consistency among measures.

Stability of individual differences in habituation over time. The intersession reliability coefficients of the a, b, and b' scores for HR and SC are presented in Table 4. Overall, reliability was disappointingly low. Estimates of initial activity (a), especially for HR and SC base levels, showed a moderate degree of stability, but for none of the variables did the simple rate of habituation (b) show any reliability. When the latter was corrected for initial level, the resulting b' scores did achieve some degree of stability, albeit quite modest. The absolute rate of habituation would thus appear to be the most adequate measure of individual differences if one uses test–retest reliability as a criterion. Obviously, however, the reliability of the b' score does not guarantee its construct validity (cf. preceding discussion).

In general, the SC measures of habituation showed less reliability than did the corresponding HR measures. This may have been due, in part, to the fact that there was considerable between—as well as within—session

TABLE 4
RELIABILITY OF a, b, AND b' SCORES FOR HR AND SC MEASURES

Measure		Intersession correlations		
		1–2	1–3	2–3
HR Base	a	.40[b]	.54[b]	.37[b]
	b	−.07	.06	.10
HR ACC	a	.26[a]	.08	−.03
	b	.24	.07	−.02
	b'	.34[b]	.43[b]	.39[b]
HR DEC	a	.21	.29[a]	.07
	b	.00	.01	−.08
	b'	.06	.34[b]	.26[a]
SC Base	a	.16	.45[b]	.52[b]
	b	.03	.22	.10
SCR	a	.16	.07	.52[b]
	b	−.18	−.07	.30[a]
	b'	−.18	.32[a]	.27[a]

[a] $p < .05$.
[b] $p < .01$.

habituation in the case of SC base and SCR. Crider and Lunn (1971) have reported a reliability coefficient of .70 for the habituation of skin potential responses over two sessions. They used a criterion of habituation three consecutive trials with no response. The reliability of a similar trials-to-extinction score in the present experiment was .42 between sessions 1 and 2, considerably less than that reported by Crider and Lunn. (The correlations between sessions 1 and 3, and between sessions 2 and 3 on this measure were .33 and .19, respectively.) Two possible reasons why Crider and Lunn obtained greater reliability than that found in the present experiment are that they used a more intense stimulus (90 db as opposed to 75 db) and also perhaps a more sensitive measure of electrodermal activity (skin potential as opposed to skin resistance).

Intermodality consistency of individual differences in habituation. The a, b, and b' scores for HR base, ACC, and DEC were correlated with those for SC base and SCR. The results can be summarized very briefly. There was a small but statistically significant relationship between HR base and SC base in terms of initial level (a scores), the mean correlation across the three sessions being .28. All other relationships were negligible or in the wrong direction. In other words, individual differences in habituation as indicated, say, by HR, were for all practical purposes unrelated to individual differences as indicated by SC. Actually, this lack of intermodality consistency in habituation is not surprising; the response specificity which plagues other areas of psychophysiological assessment (Averill & Opton, 1968) is undoubtedly operating here also.

The Relationship between Habituation and Personality

In view of the poor intersession reliability and intermodality consistency just described, it would be surprising to find any relationships between habituation and personality variables—and, indeed, none was found worth discussing. Potential relationships were explored in two ways. First, scores on all the personality tests (which included, it will be recalled, measures related to extraversion, neuroticism, defensive style, ego-strength, self-control, flexibility, anxiety, field dependence) were correlated with the regression scores (a, b, b') for HR base, ACC, DEC, SC base, and SCR, and also the trials-to-extinction criterion for SCR. Only a smattering of these correlations reached conventional levels of statistical significance, approximately the number that might be expected by chance; moreover, the pattern of correlations indicated no consistent trends.

In a second set of analyses, *S*s were divided into four groups depending upon whether they fell above or below the median on the introversion–extraversion and neuroticism scales of the Eysenck Personality Inventory. After the elimination of *S*s to form equal *n*'s, there were 14 *S*s per group. Three-way analyses of variance were then applied to the habituation scores just mentioned, with sessions forming the third factor. Of the 84 F ratios which involved a personality dimension, only one—a three-way interaction—was "statistically significant." It is reasonable to assume that this was a chance occurrence.

It is always dangerous to argue from negative findings and we do not wish to maintain that habituation is too unstable a phenomenon to be used in personality assessment. What the present results highlight is that reliability cannot be taken for granted. In most studies of personality correlates only a single index of habituation has been used, based on a single response modality and obtained in a single session. If indeed different measures of habituation show different properties, and if there is a lack of intersession reliability and intermodality consistency in responses as commonly measured, then reported correlations between personality and habituation are bound to be will-o'-the-wisps. The problem is further exacerbated by the fact that nonsignificant results seldom find their way into the literature, and are even more infrequently remembered or cited. This makes evaluation of positive findings all the more difficult. How many of the reported relationships between personality and habituation are chance or artifactual is impossible to say. If the present data are at all representative, perhaps more spurious relationships have been reported than most of us would care to admit.

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