GENETIC COMPONENTS OF AUTONOMIC STIMULUS - RESPONSE AND INDIVIDUAL - RESPONSE SPECIFICITY: A TWINS STUDY

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ABSTRACT

GENETIC COMPONENTS OF AUTONOMIC STIMULUS-RESPONSE AND INDIVIDUAL-RESPONSE SPECIFICITY: A TWINS STUDY

By

Robert Stuart Bundy

The genetic components of autonomic nervous system activity were investigated in fifteen pairs of monozygotic and fifteen pairs of dizygotic twins. Twins were tested during a mental arithmetic task, a reaction time task and a rest period. The dependent variables were heart rate, skin conductance, and respiration. Results were analyzed for the presence of stimulus-response and individual-response specificity. Twin pairs tended to remain in the same relative point in the distribution from one stimulus condition to another, supporting an individual-response specficity interpretation. Heritability estimates were fairly high for most dependent measures. However, for many of the dependent measures differences in the distributions of the two populations made comparisons difficult. The differences in distribution were most likely a result of sampling error due to the small number of subjects used in the study.

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INTRODUCTION

Low correlations among various autonomic response measures have been a constant source of interest to psychophysiologists. Intrasubject correlations appear to be well below individual reliabilities of the various response measures (Lacey, 1956). For example, Elliott (1964) found correlations between heart rate and skin conductance of .46 for adults and .12 for children. Lazarus (1966) has reported similar figures even though several mathematical techniques were employed to increase the correlations.

Low correlations among autonomic response measures are particularly troublesome for activation theorists who tend to rely on a unitary concept of arousal. Whereas activation theorists (Duffy, 1972; Malmo, 1959; Selye, 1950) do not require that all physiological measures show perfect intercorrelations they have some difficulty explaining autonomic patterns which show stimulus-response specificity. In other words, different stimulus situations will often cause different patterns of physiological activity. Darrow (1929) noted

that "sensory stimuli" caused an increase in electrodermal activity and cortical arousal but caused a decrease in heart rate. In spite of the fact that Darrow's observation seems to contradict Cannon's (1928) notion of autonomic activation, psychologists continue to operate from an activation hypothesis. Although there have been several reports of stimulus-response specificity with such dimensions as fear and anger (Ax, 1953; Funkenstein, 1956; Schachter, 1957; Wolf & Wolf, 1947), simple stimulus properties (Davis, Buchwald, & Frankman, 1955), requirements for environmental intake or rejection (Lacey, Kagan, Lacey, & Moss, 1963; Obrist, 1963), and hunger and pain (Engle, 1959), not until Lacey (1967) argued that activation theory was in need of revision did psychophysiologists begin to seriously investigate the behavioral correlates of particular autonomic response patterns.

Lacey suggested that situations which require attention to the environment in the absence of cognitive processing were accompanied by an increase in electrodermal activity and a decrease in heart rate. This stimulus-response specificity has stimulated a considerable amount of research activity in recent years although investigators have tended to neglect electrodermal measures while concentrating on heart rate components

of attention, often using heart rate deceleration (Graham & Jackson, 1970) and reduction in variability (Porges, 1972) as measures of attention. Whereas the specific psychological dimensions that are related to heart rate deceleration have been debated (see Hahn, 1973) the empirical fact remains that during some kinds of attentional activities heart rate deceleration is accompanied by an increase in electrodermal activity. Activities such as mental arithmetic are associated with a high heart rate and high electrodermal activity while other activities such as rest are associated with low levels of both measures.

Another approach to explaining difference in patterns of autonomic activity is to examine individual differences in response patterns. This individual-response specificity has particular relevance to psychosomatic medicine since it is sometimes assumed that patients with psychosomatic complaints are overresponsive in a particular organ system. Several investigators have reported that people with psychosomatic complaints are more responsive in the affected organ than in other organs (Engle & Bickford, 1961; Malmo & Shagass, 1949; Moos & Engle, 1962). Lacey, Bateman, and Van Lehn (1963) were the first investigators to examine individual-response specificity in normal populations. They applied

a number of stimuli to more than 200 subjects. Response levels for three different measures -- heart rate, heart rate variability, and skin conductance -- were then rank ordered for each subject. The investigators found that the rank order for each response for each subject tended to remain the same in each stimulus situation. For example, a subject who had a heart rate in the 80th percentile during one stimulus situation would tend to have a heart rate in the 80th percentile in another stimulus situation while another response might rank consistently in the 30th percentile. These results were replicated and extended in a study in which blood pressure measurements were included (Lacey & Lacey, 1958). Thirty-nine of the 42 subjects showed statistically significant coefficients of concordance indicating that subjects tended to show the same pattern of autonomic activity even during different stimulus conditions.

The studies by Lacey and his associates only looked at level scores during the stimulus situations and did not look at change scores. That is, levels were not compared with pre-stimulus or baseline levels during rest to see if there were patterns to the change as well as to the level that is reached. Schnore (1959) extended the Lacey studies by looking at levels of several autonomic and muscle activity scores as well

as the changes in the activity levels attributable to the stimulus presentation. Results indicated high individual-response specificity. Coefficients of concordance for level ranged from .34 to .99 with a median of .80. The coefficients of concordance for the change scores were somewhat lower, .23 to .80 with a median of .51. In the studies by Lacey and his associates and by Schnore there was no evidence for stimulus-response specificity despite the fact that several different tasks were used. Similar studies by Engle (1960) and Engle and Bickford (1961) did find both individual-response and stimulus-response specificity when analysis of covariance designs were used. It should be pointed out that subjects in these experiments generally show individual-response stereotypy but there are many subjects who do not show stereotypy. Sternbach (1966) has suggested that the degree of stereotypy that a subject shows is itself an individual characteristic such that subjects can be classified according to the rigidness or randomness of their response patterns.

There is little evidence indicating the stability of individual-response specificity over time. Lacey and Lacey (1962) measured several autonomic responses in children to a cold pressor task and found reasonably stable response patterns over a 4-year-period. Oken et al. (1963) found very little relationship between

response patterns measured a few days apart but the stimuli were different for the two testing sessions. During the first day the stressor was a psychiatric interview and during the second day the stressor was simply an unpleasantly hot room. Thus, sessions were not entirely comparable and it is difficult to assess the effects of the different kinds of stimuli. Both of the longitudinal studies tested subjects on only two different occasions so it is difficult to determine whether changes in pattern were due to habituation or whether the patterns were, in fact, unstable. It is interesting to note that the study which showed the highest stability of response patterns (Lacey & Lacey, 1962) had the longest time between testing sessions and the subjects were children, a population that would usually be expected to have the greatest amount of change, especially over a four year period. It may be that separate tests conducted a few days apart is an inappropriate method to test for the stability of response patterns since any stabilities that exist may not show up until after several tests. It is very likely that much of the difference between the first session and the second session are due to habituation rather than instability. In the experiment by Lacey and Lacey (1962) each test session would be like a first session since four years had elapsed between sessions.

Engle (1960) has given three different but related definitions of stimulus-response specificity: "(1.) Maximal change occurs in the same function to a given stimulus in a set of subjects, (2.) Consistent rank orders of responses to a given stimulus occur in a set of subjects, and (3.) Consistent inter-response correlations to a given stimulus occur in a set of subjects." He has also given a set of parallel definitions for individual-response specificity: "(1.) Maximal change occurs in the same function within each subject to a set of stimuli, (2.) Consistent rank orders of responses occur within the same subject to a set of stimuli, and (3.) Consistent interresponse correlations occur within the same subject to a set of stimuli." According to Engle's viewpoint stimulus-response specificity is a population variable rather than an individual variable. It would not matter that individual subjects would show response patterns unlike the population as a whole as long as there were a reasonably reliable pattern for the entire population. Individual idiosyncratic response patterns are of little interest since there would be no way of telling in a single test whether the pattern was due simply to normal variation or whether the pattern was elicited reliably by a particular stimulus for a particular subject. Test-retest

should reveal whether individuals can show different patterns of stimulus response specificity but thus far no such studies have been conducted.

None of these studies have looked at heritabilities of the patterns although it is often assumed that such patterns are genetically influenced since psychosomatic disorders often run in families (Sternbach, 1966). To date, the twins method is the only technique used to study the heritability of autonomic activity.

Psychophysiological studies of twins

There have been several twin studies of autonomic activity with varied purposes and consequently varied paradigms. Tables 1 and 2 summarize these studies. In these tables, "r" refers to the intraclass correlation for the twin pairs. Intraclass correlations can be derived from an analysis of variance or by the standard Pearson product-moment correlation in which every pair is entered twice, once in each order. The effect of this procedure is to produce a regression equation with a slope of "r" and an intercept of 0.0. "F" refers to the ratio of the MZ to DZ within twin variances. Some of the studies have employed only MZ twins and many have measured only resting levels of autonomic activity. All of the studies have claimed to find heritable factors although such claims would be

TABLE 1.--Summary of twins studies using electrodermal measures.

Study	Measure and stimulus	MZ N	MZ r	DZ N	DZ r	F
Jost & Sontag, 1944	conductance level					
	rest	16	.72			
Rachman, 1960	resistance response					
	latency to habituation stimulus	7	.95			
	trials to 3 nonresponses	7	.07			
Vandenberg et al., 1965	resistance response magnitude to					
	flash of light	34		26		1.40
	bell 1	34		26		.74
	bell 2	34		26		1.39
	bell 3	34		26		.93
	hammer drop	34		26		1.00
Block, 1967	resistance, Conditioned discrimination					
	mean prestimulus level	21	.82			
	mean stimulus level	21	.81			
	mean response magnitude	21	.03			
	mean (S+) - (S-) magnitude	21	.46			
Lader & Wing, 1966	long conductance response					
	magnitude to 1st stimulus	11	.34			
	derived habituation score	11	.75			
Claridge et al., 1973	potential					
	level at rest, period 1	41	.37	48	.10	1.17
	level at rest, period 2	41	.19	47	.16	1.15
	response to 1st stimulus	35	.35	44	.12	1.10
	response to cold pressor	40	.29	46	.11	1.36

TABLE 2.--Summary of twins studies using heart rate measures.

Study	Stimulus	MZ N	MZ r	DZ N	DZ r	F
Jost & Sontag, 1944	rest	16	.64			
Mathers et al., 1961	balistocardiogram test	37	.58	19	.60	.96
Vandenberg et al., 1965	response magnitude to					
	flash of light	22		16		2.38
	bell 1	22		16		1.70
	bell 2	22		16		1.96
	bell 3	22		16		1.65
	hammer drop	22		16		2.93
Block, 1967	conditioned discrimination					
	mean prestimulus level	21	.73			
	mean poststimulus level	21	.73			
	mean response magnitude	21	.67			
	mean (S+) - (S-)	21	.69			
Claridge et al., 1973	rest period 1	37	.67	46	.33	3.91
	rest period 2	35	.65	45	.44	2.56
	magnitude of OR to 1st stimulus	23	.39	37	.42	1.89
	change to cold pressor	26	.41	38	.39	1.89
Shapiro et al., 1968	Stroop color test, prestimulus	12	.70	12	-.15	
	Stroop color test, stimulus	12	.52	12	.31	
	Stroop color test, change	12	.40	12	-.07	
	ischemic pain, prestimulus	12	.67	12	-.17	
	ischemic pain, stimulus	12	.45	12	.63	
	ischemic pain, change	12	.60	12	.84	
Lader & Wing, 1966	level at end of experiment	11	.78	12	-.38	
Lykken, et al., 1973	hypnotic induction	39	.67	27	.20	

difficult to justify in those studies using only MZ twins. Some of the studies used other psychophysiological measures but these measures are not reported in Table 1 and 2 since heart rate and electrodermal activity are of primary interest in the current study.

Despite the differences in the studies some general patterns emerge. Most of the studies show higher concordance in MZ than in DZ twins. Although heritability estimates are not usually reported, F ratios based upon the reported data are generally higher for the heart rate measures than for the electrodermal measures. The latency measure reported by Rachman (1960) is of little psychological interest since it is thought to primarily reflect the conduction rate of the sweat gland effector fibers and the migration of acetylcholine to the sweat glands (Edelberg, 1972). The generally lower heritabilities for electrodermal measures may reflect the wider variation of the measurement techniques which are employed and perhaps a lower reliability of the measure. All of the studies seem to be operating from an activation assumption since none of the studies looked for stimulus-response specificity. Moreover, none of the studies tested for heritable factors in individual-response stereotypy.

The present study was designed to examine heritabilities of stimulus-response and individual-response

specificity by assessing heart rate, electrodermal and respiration measures in MZ and DZ twins. The specific tasks employed were mental arithmetic, reaction time, and rest. Mental arithmetic has previously been demonstrated to elicit high heart rate and high electrodermal activity (Engle, 1960; Lacey, 1959). The reaction time paradigm yields reliable temporal changes in heart rate (Allen, 1973; Chase, Graham, & Graham, 1968; Fitzgerald & Porges, 1970; Obrist, Webb, Sutterer, & Howard, 1970) which are related to changes in respiration and heart rate variability (Headrick & Graham, 1969; Porges, 1972). The reaction time paradigm also requires attention which normally produces heart rate deceleration and increased electrodermal activity (Lacey, 1959; Obrist, 1963). Rest normally produces a low heart rate and low electrodermal activity (Lacey, 1959).

A genetic factor in individual-response stereotypy would be indicated by overall patterns of responses which, for any given stimulus condition, are more similar from MZ pairs than for DZ pairs. A genetic factor in stimulus-response patterns would be indicated by differences in patterns of responses across stimulus conditions which are more similar for MZ pairs than for DZ pairs.

METHOD

Subjects

The subjects were 15 MZ and 15 DZ twins. The sample was predominantly female. There were 6 male MZ pairs and 4 male DZ pairs. The twins were recruited from a list of all Michigan State University students who had identical last names and birth dates. Names were provided by the registrar's office. Zygosity for most pairs was determined by the Nichols and Bilbro (1966) questionnaire procedure. (See Appendix A). (See Appendix B for a discussion of zygosity determination). The height and weight of each twin was also measured at the time of the experiment. According to this procedure, twins are diagnosed at two different levels. If the twins fit any of the descriptions at the first level they are classified at that level. If none of the first level descriptions fit, the MZ and DZ points are added up according to the descriptions at the second level and the classification with the highest number of points determines the assignment of the twins. The diagnostic rules were as follows:

First Level

Diagnosis of Dz

Distinctly different hair color or curliness

Distinctly different eye color

Height differences of 3 inches or more

Both twins report that they are never mistaken by teachers

Diagnosis of MZ

Both twins report they were frequently mistaken by parents when young

Both twins report that they were frequently (or one frequently and the other occasionally) mistaken by parents recently

Both twins report that they are frequently (or one frequntly and the other occasionally) mistaken by close friends

Second Level

One point towards diagnosis of DZ

Slight differences in hair color, curliness, or texture

Slight differences in eye color

Height difference of one and one half inches or more

Weight differences of fifteen pounds or more

Either twin reports that they are never mistaken by casual friends

Twins agree that they are fraternal

One point towards diagnosis of MZ

Either twin reports that they were occasionally or frequently mistaken by parents when young

Either twin reports that they were occasionally or frequently mistaken by parents recently

Either twin reports that they are frequently mistaken by teachers

Either twin reports that they are occasionally mistaken by close friends

Either twin reports that they are frequently mistaken by casual friends

Twins agree that they are identical

One pair of twins was classified as MZ because they had previously participated in another twins study in which blood typing determination revealed that they were MZ's. Another pair who claimed to be MZ were classified as DZ because they said that they could not give each other blood transfusions since one was Rh+ and the other Rh-. The questionnaire data confirmed the classification of these two sets of twins.

In three cases there was either a tie or only one point of difference between the MZ and DZ classifications at the second level of the questionnaire so these pairs were classified by other criteria. One pair was

classified as MZ because they had birth marks of exactly the same shape and size. Another pair was classified as DZ because one had a fingerprint ridge count of 119 while the other had a count of 94. This was greater than any other MZ pair. The third pair was classified as DZ because they had entirely different birth marks and their dentist reported that their teeth were entirely different.

The correlations for height suggest that there were no gross errors in classification. The MZ twins correlation was .97 and the DZ correlation was .64. These figures are fairly close to those published by Lykken (1974) who reported correlations of .91 and .54 and those published by Newman, Freeman and Holzinger (1937) who reported correlations of .93 and .64 respectively.

Apparatus

Skin conductance, electrocardiogram, and respiration were recorded on a four channel Grass model 7 polygraph. For the skin conductance measure a constant voltage (0.5V) bridge was used which has an output of 1.0mV per 1.0 micromho of input. The polygraph channel was operated in the DC mode with the output reading directly in conductance units. The electrocardiograph channel was frequncy limited to provide

maximum output of the R wave and minimum output of the P and T waves, movement artifact, electrodermal signals and electromyographic signals. The output of the electrocardiograph channel then drove a recording pen and a beat interval counter. The beat interval counter provided a display of the interval between the last two R waves. Each second a printer printed out the number being displayed on the counter. Respiration was recorded by a bellows which was strapped around the subject's chest. The output of the bellows was attached by a plastic tube to a pressure transducer which in turn was attached to a DC channel of the polygraph.

A total of three active electrodes were attached to the subject. Two skin conductance electrodes were placed about 1.5 cm apart on the hypothenar eminence of the left hand. These two electrodes also served as the left arm electrode for the electrocardiogram. A third electrode attached to the volar surface of the right wrist served as the right arm electrode for the electrocardiogram. A ground electrode was also attached to the volar surface of the left wrist. Appropriate tests were performed to assure that there was no interaction between the heart rate and electrodermal measurements. All of the electrodes were of the silver-silver chloride type constructed according to Venables and Martin (1967). The electrolyte for the two skin conductance

electrodes was a Unibase preparation (Lykken & Venables, 1971). The electrolyte for the right arm and ground electrodes was Beckman electrode paste. Prior to applying each electrode the sites were cleaned with 70% ethanol and allowed to dry.

Design and Procedure

Immediately after arriving at the laboratory a short explanation of the experiment was given and the two conductance electrodes were attached. The subject was then given a copy of the instructions and asked to read the instructions. (See Appendix C for a copy of the instructions.) After the experimenter answered any questions, the subject was then seated in a sound attenuated booth, the remaining two electrodes were attached, and two practice trials of the reaction time task were given. A minimum of 10 minutes was allowed between the attachment of the conductance electrodes and the start of the first task to allow for skin hydration (Edelberg, 1972). The subject was allowed to relax in the booth with the door open until this 10 minute period was completed.

When 10 minutes had passed the subject was told that the first task would begin in about a minute and to wait for specific instructions over the speaker.

The door of the booth was closed and after a minute the tape recorder started. The voice on the tape recorder said "Okay, when I tell you to start you are to count backwards from 800 by 7's as fast as you can. You are to count to yourself. Everytime I say 'number' tell me what number you are on and then continue counting backwards to yourself. Remember you are to count backwards from 800 by 7's and speak only when I say 'number'. Okay, you may start - NOW." After 30 seconds and again after 60 seconds the voice on the tape recorder said "number."

Fifteen seconds after the last number was requested the voice on the tape recorder said "Okay, you may stop counting now. Please pick up the thumb operated reaction speed switch, hold it in your right hand and get ready for the reaction time test. Remember that this is a test of speed. You are to press the switch as quickly as possible after the ready light goes off and the go light goes on. The first trial will start in about a minute." The ready light was on 16 seconds for each trial with a randomly determined inter-trial-interval of 20, 25, or 30 seconds ($\bar{X}$=25 seconds). Immediately after the ready light went off the go light came on. The go light went off when the subject pressed the switch. There was a total of 15 trials.

Following the last reaction time trial the subject was instructed via the tape recorder: "That completes the reaction time task. All you have to do for the remainder of this experiment is sit back and relax for approximately 5 minutes. Following this rest period the experimenter will come in and disconnect the sensors."

Data Scoring

The analysis proceeded from the data collected during predetermined time periods. The data were derived from the three different measures; heart rate, skin conductance and respiration.

Mental arithmetic and rest. Data were collected from 20 second time periods during these two stimulus conditions. There were three sample periods during the arithmetic task, one ten seconds after the onset of the task, one ten seconds after the first "number" was requested, and one ten seconds after the last number was requested. The subjects did not verbalize during any of these periods. There were four sample periods during the rest condition. They were during the latter half of the second through the fifth minutes of the condition. The data which were analyzed included:

1. heart period
2. heart period variability

3. breathing rate
4. breathing depth in mm of pen deflection
5. electrodermal frequency, the number of positive pen deflections of the skin conductance measure
6. the sum of the heights of the positive deflections of skin conductance measure
7. the skin conductance level at the beginning and end of each sample period

Reaction time. Data were collected during 32 second time periods for each of the last 10 trials. The scoring period started 8 seconds before the start of each trial and was divided into four 8 second periods respectively designated prestimulus, orienting response, attend, and response.

The same 7 variables were analyzed as in the mental arithmetic and rest periods but for the heart rate data the periods for analysis were separated for each of the 8 second periods. In addition the following variables were analyzed:

8. the height of the skin conductance response to the onset of the READY LIGHT
9. the height of the skin conductance response to the respond signal

10. reaction time, the time from the offset of the READY LIGHT to the button press

RESULTS

Data analysis

The data for each variable and each stimulus condition were submitted to an analysis of variance routine (McNemar, 1962, 322-329). Sums of squares were used to find the variances, covariances and intra-class correlations. (See Appendix D for a summary of the means and sums of squares for each of the variables and stimulus conditons.) Means and sums of squares as well as variances and covariances are listed in all tables in unconverted scoring units. However, data reported in the figures are in normal units. Change scores were also computed for each subject by subtracting the mean during one stimulus condition from the mean of another stimulus condition. These data also were analyzed by the analysis of variance noted above.

The data were then converted to logarithmic units and the same analyses were performed. The data were converted to log units for two different reasons. The first reason was to counter the possibility that change score hereitabilities may have been influenced by the scaling procedure. If the amount of change from

one stimulus condition to another is a multiplicative function of the level, then the log transformation should equate the change scores for subjects who initially start at different levels. Log transformation of the data was selected since this is the most common transformation applied to physiological dependent variables.

The second reason for using log transformation was that examination of the two different heritability estimates suggested that some of the data were heteroscedastic. Log transformation should have reduced heteroscedasticity.

Heritabilities first were computed by the general formula

$$H_a^2 = 2(r_{MZ} - r_{DZ})$$

where "r" represents the intraclass correlation. For much of the data, variances of the MZ and DZ populations were quite different. Under these conditions it is difficult to compare the two correlations. Therefore, heritabilities were also computed by the formula

$$H_b^2 = \frac{(V_{wDZ} - V_{wMz})}{V_t}$$

which was derived by Dr. John Hunter for the purposes of this study. V_w represents the variance of the differences between the twin pairs and V_t represents the variance of the entire population. This formula is

equivalent to the first formula when the variances of the two populations are equal. The second formula assumes that the variance of the difference is unrelated to level (i.e. homoscedasticity). The variance of the difference was computed from the formula

$$V_w = 2(\text{Var.} - \text{Cov.}).$$

Finally, each twins score on one task was paired with the co-twin's score on another task and the correlation coefficient was computed. A typical example of these correlations is shown in Table 4. For example, in heart period the twin by co-twin correlation between mental arithmetic and reaction time was .41. Since each twin is entered twice, once for reaction time and once for mental arithmetic, each of these correlations is based on 30 pairs of data. For comparison purposes the intraclass correlations which are based upon 15 pairs of data points, are entered along the diagonal. In addition, each twin's score on one stimulus condition was paired with his score on another stimulus condition and the correlation was computed. These correlations, based upon 60 pairs of data points, are listed as "Total, subject by subject" correlations. The alpha coefficients are listed in parentheses along the diagonal.

One way to obtain an estimate of the relative genetic contributions of individual-response specificity and stimulus-response specificity is to compare the twin by co-twin correlations with the intraclass correlations. If the twin by co-twin correlations and intraclass correlations are approximately the same, no evidence for stimulus-response specificity would be obtained. However, if the heritabilities for the two stimulus conditions were high and the twin by co-twin correlations between stimuli were low, we would have evidence for a heritable factor in stimulus-response specificity. Each twin would have to remain in approximately the same point in the distribution during the two stimulus conditions for these correlations to be equal. This would indicate individual response specificity.

Heart period

The mean trial-by-trial heart rate is shown in Figure 1. Heart rate is fairly high for the mental arithmetic task but fairly low for the reaction time task. This is consistent with the observation that attention such as that required by a reaction time task is associated with relatively low heart rates.

Table 3 summarizes the descriptive statistics for heart period. Generally there is little difference between the correlations obtained for the untransformed

TABLE 3.--Descriptive statistics for heart period.

Measure	MZ			DZ			H_a^2	H_b^2
	r	Var.	Cov.	r	Var.	Cov.		
Heart period								
Mental arithmetic (MA)	.49	1.004	.493	.09	1.050	.091	.87	.87
Reaction time (RT)	.50	1.605	.808	.31	1.318	.408	.39	.16
Rest (RE)	.52	1.398	.724	.43	1.200	.520	.17	.01
Log heart period								
Mental arithmetic	.58	.026	.015	.06	.028	.002	1.05	1.11
Reaction time	.53	.027	.014	.26	.024	.006	.54	.42
Rest	.54	.023	.012	.45	.020	.009	.17	.03
Change, heart period								
MA-RI	.40	.648	.257	.15	.589	.088	.49	.35
MA-RE	.44	.771	.336	.14	.763	.105	.60	.58
RT-RE	.44	.288	.117	.01	.169	.001	1.01	.57
Change, log heart period								
MA-RT	.41	.012	.005	.06	.012	.001	.69	.64
MA-RE	.51	.017	.009	.04	.017	.001	.94	.90
RT-RE	.55	.004	.002	-.04	.004	-.000	1.18	.96

TABLE 4.--Correlations between stimuli for heart period.

Correlation	Heart period			Log heart period		
	Mental arithmetic	Reaction time	Rest	Mental arithmetic	Reaction time	Rest
MZ, twin by co-twin						
Mental arithmetic	.49	.41	.37	.58	.46	.38
Reaction time		.50	.47		.53	.48
Rest			.52			.54
DZ, twin by co-twin						
Mental arithmetic	.09	.17	.22	.06	.14	.21
Reaction time		.31	.37		.26	.35
Rest			.43			.45
Total, subject by subject						
Mental arithmetic	(.94)	.76	.68	(.95)	.77	.66
Reaction time		(.99)	.93		(.99)	.92
Rest			(.98)			(.98)

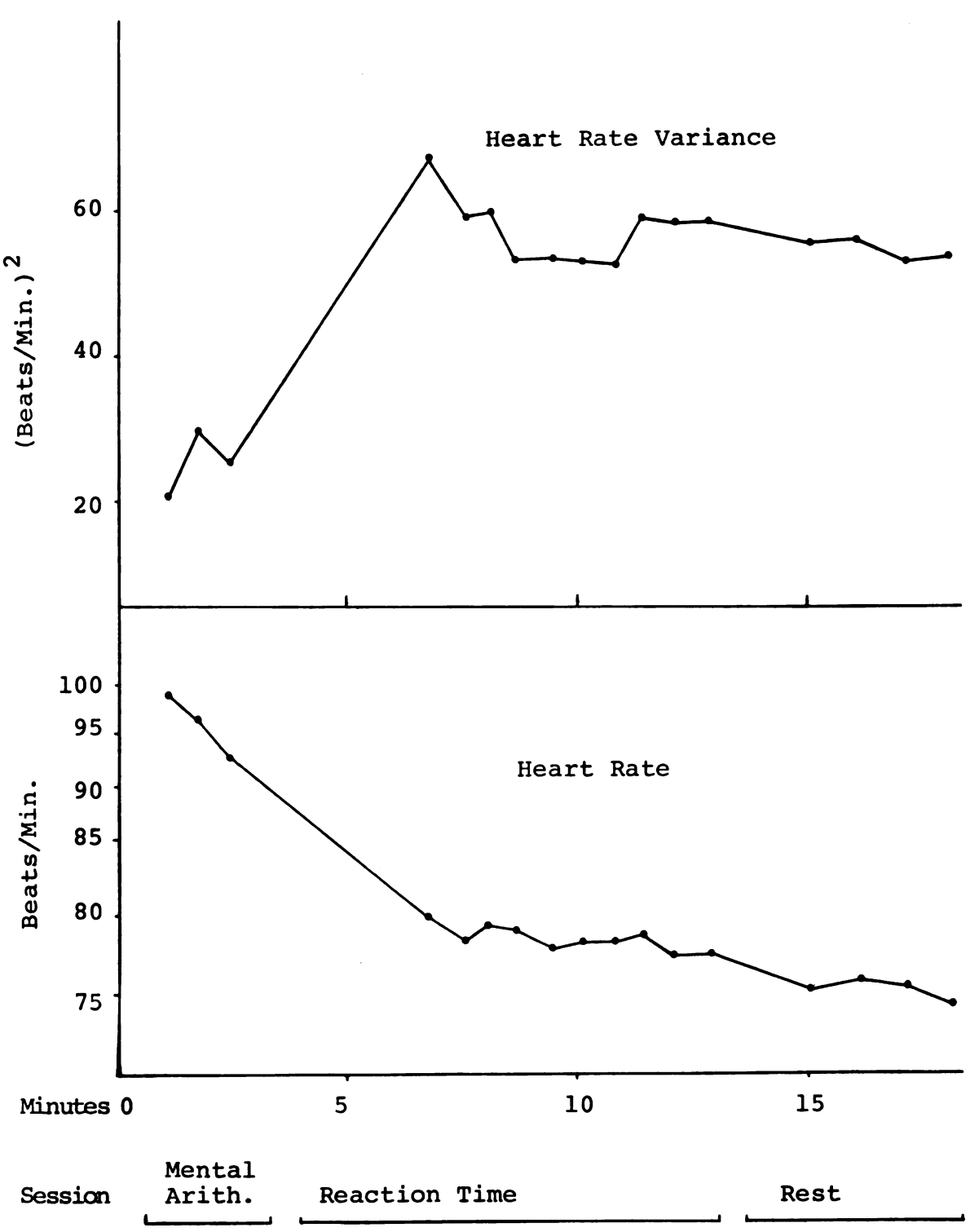

Figure 1.--Heart rate variance and heart rate averaged across subjects for all scoring periods.

scores and the log transformed scores indicating that within the restricted range of heart period scores, a log transformation does little to change the distribution. This is true of both level and change scores.

The most striking feature of the heart period data is that the intraclass correlation of DZ pairs are fairly low for the mental arithmetic task, somewhat higher for the reaction time task and approach the MZ correlations during the rest period. The resulting heritabilities are fairly high for the mental arithmetic task and progressively lower for the reaction time task and rest period. One is tempted to attribute a larger genetic component to resting levels than to more highly aroused levels. However, virtually the opposite data has been reported by Shapiro et al. (1968). In that experiment higher DZ correlations were evidenced during the prestimulus condition. As in the present experiment, however, the correlations for both the level and change scores for the MZ pairs were fairly stable. Part of the reason why DZ correlations seem to be so unpredictable may be that for smaller correlations, the confidence intervals are larger. For both the present study and Shapiro et al.'s study the average correlation for the DZ population were around .25. This correlation seems reasonable given that the MZ correlations are around .5, which is consistent with a heritability

estimate of about .5 for a polygenetically determined trait. The twin by co-twin correlations between stimuli summarized in Table 4 seem to confirm this trend.

The twin by co-twin correlations are nearly as high as the intraclass correlations. This indicates that there is little evidence for stimulus response specificity since the twin pairs are similarly distributed in each of the stimulus conditions.

Heart period variability

Heart period variability is a measure that rarely is used in psychophysiological research. Consequently, there is no a priori reason to predict any particular pattern of responses. Mean trial by trial heart period variability is summarized in Figure 1. High heart rate is apparently associated with low variability. Undoubtedly this is due to the fact that most of the variance in heart rate over a short period of time can be attributed to sinus arrhythmia. Sinus arrhythmia has little influence on variability during high heart rates. Inspection of the polygraph records tends to confirm this speculation.

Unfortunately, since there were several differences in the MZ and DZ populations (see Table 5) the heritabilities of heart period variability were difficult to estimate. The untransformed scores for reaction time and rest have much higher variances for

the DZ population than the MZ population. Assuming that the best variance estimate of the population of college students is the average of the MZ and DZ variances, one would expect that the correlation for MZ pairs would be underestimated and the correlation for DZ pairs would be overestimated. Thus, the heritability estimate H_b^2 probably yields the best estimate of the true heritability.

The differences between the correlations for the untransformed and the log transformed scores for the mental arithmetic task indicate that MZ and DZ populations may be heteroscedastic but that they are heteroscedastic in different ways. The log transformation actually increased the correlation for the MZ twins and decreased the correlation for the DZ twins. This suggests that the pairs with the largest differences were at the upper end of the scale for the MZ twins and at the lower end of the scale for the DZ pairs. This effect especially is noticeable for change socres where the log transformed correlations became even more negative.

The peculiar nature of these data becomes even more apparent when the twin by co-twin correlations between stimuli are examined (See Table 6). For DZ twins the twin by co-twin correlations are even higher than the intraclass correlations. That is, each twin

TABLE 5.--Descriptive statistics for heart period variability.

Measure	MZ			DZ			H^2_a	H^2_b
	r	Var.	Cov.	r	Var.	Cov.		
Heart period variability								
Mental arithmetic	.34	.297	.101	.35	.310	.109	-.02	.04
Reaction time	.38	.469	.180	.36	.961	.350	.04	.89
Rest	.40	.515	.206	.43	1.055	.450	-.05	.72
Log heart period variability								
Mental arithmetic	.47	1.249	.586	.13	1.353	.181	.67	.78
Reaction time	.32	.533	.168	.47	.885	.416	-.31	.29
Rest	.22	.767	.171	.40	1.124	.446	-.35	.17
Change, heart period var.								
MA-RT	.39	.389	.152	-.03	.505	-.016	.85	1.25
MA-RE	.36	.513	.186	-.12	.680	-.082	.96	1.36
RT-RE	.40	.272	.110	-.04	.286	-.012	.90	.93
Change, log heart period var.								
MA-RT	.58	.972	.563	-.34	.827	-.284	1.85	1.55
MA-RE	.36	1.171	.420	-.49	1.466	-.716	1.70	2.10
RT-RE	.16	.385	.061	-.19	.529	-.105	.72	1.31

TABLE 6.--Correlations between stimuli for heart period variability.

Correlation	Heart period variability			Log heart period variability		
	Mental arithmetic	Reaction time	Rest	Mental arithmetic	Reaction time	Rest
MZ, twin by co-twin						
Mental arithmetic	.34	.17	.16	.47	.12	.17
Reaction time		.38	.28		.32	.22
Rest			.40			.22
DZ, twin by co-twin						
Mental arithmetic	.39	.44	.56	.58	.40	.54
Reaction time		.36	.40		.36	.49
Rest			.40			.16
Total, subject by subject						
Mental arithmetic	(.75)	.61	.49	(.74)	.58	.41
Reaction time		(.98)	.81		(.93)	.73
Rest			(.88)			(.86)

resembles his co-twin in another stimulus condition more than he resembles his co-twin in the same condition. Also the twin by co-twin correlations are higher for DZ twins than MZ twins even though the intraclass correlations generally suggest positive heritabilities.

Presumably if more twins were tested the variances for the two populations would be more equal and it would be easier to determine the best transformation. As things stand it is difficult to put much faith in the reported heritability estimates or to make speculations about the relative contributions of individual-response and stimulus-response specificity.

Electrodermal frequency

Considering that electrodermal frequency is one of the more common measures employed in psychophysiological research it is surprising that none of the twin studies cited previously have used this measure (see Table 1). It was expected that the mental arithmetic and reaction time tasks would show fairly high levels and the rest period fairly low levels. Figure 2 confirms this expectation. The DZ intraclass correlations are approximately one half the MZ correlations which is what one would expect for a polygenetically determined trait with additive variance (see Table 7). The variances in the MZ population are higher than those in the DZ population for both mental arithmetic and reaction time.

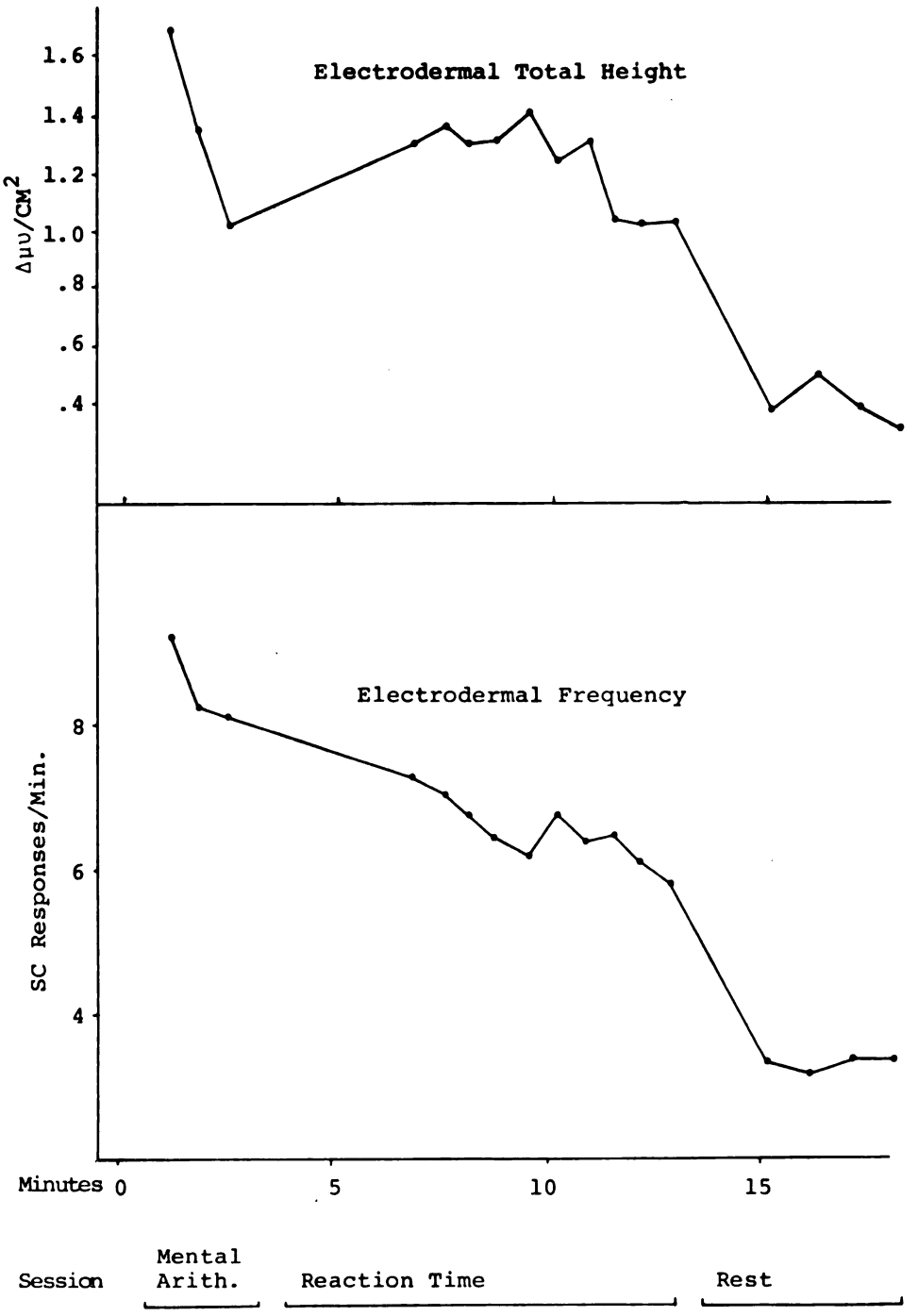

Figure 2.--Electrodermal total height and electrodermal frequency averaged across subjects for all scoring periods.

TABLE 7.--Descriptive statistics for electrodermal frequency.

Measure	MZ			DZ			H_a^2	H_b^2
	r	Var.	Cov.	r	Var.	Cov.		
Electodermal frequency								
Mental arithmetic (MA)	.63	3.069	1.940	.25	3.253	.820	.76	.79
Reaction time (RT)	.75	1.062	.792	.32	1.530	.494	.85	1.14
Rest (RE)	.36	.949	.347	.15	.486	.074	.43	-.49
Log electrodermal frequency								
Mental arithmetic	.78	.217	.169	.36	.294	.105	.84	1.04
Reaction time	.78	.143	.112	.43	.238	.102	.70	1.03
Rest	.30	.186	.057	.18	.141	.026	.24	-.18
Change, electrodermal freq.								
MA-RT	.50	1.493	.740	-.18	1.316	-.231	1.34	1.10
MA-RE	.64	2.636	1.688	.30	1.957	.589	.68	.36
RT-RE	.52	1.046	.544	.26	.672	.174	.52	-.01
Change, log electrodermal freq.								
MA-RT	.59	.087	.057	-.10	.156	-.016	1.38	2.08
MA-RE	.44	.211	.094	.22	.183	.041	.44	.25
RT-RE	.28	.169	.048	.12	.115	.014	.32	-.28

This results in higher heritability estimates for H_b^2. The log transformation increases most of the level correlations slightly indicating that this transformation provides slightly better fit.

The correlations for the rest period are low because 26 of the subjects gave no responses at all during the rest period creating a floor effect. What responses were produced seemed to be a result of stimuli unrelated to the stimulus condition. For example, the subject that gave the largest number of responses had a cold and was constantly coughing and sniffling during the rest period.

Since the scores for the rest period were near zero for most subjects, the change scores from the rest period to mental arithmetic or reaction time were fairly comparable to the level scores for mental arithmetic and reaction time. These change score correlations were somewhat lower, however, since the resting levels seem to be somewhat more unreliable.

There was no reason to search for a genetic component to stimulus-response specificity in comparisons involving the rest period since there was no evidence for a heritable component for this factor. The twin by co-twin correlations shown in Table 8 between reaction time and mental arithmetic are nearly as high as the intra-class correlations for the two tasks indicating individual-response specificity.

TABLE 8.--Correlations between stimuli for electrodermal frequecy.

Correlation	Electrodermal frequency			Log electrodermal frequency		
	Mental arithmetic	Reaction time	Rest	Mental arithmetic	Reaction time	Rest
MZ, twin by co-twin						
Mental arithmetic	.67	.55	.18	.78	.63	.33
Reaction time		.75	.30		.78	.37
Rest			.36			.30
DZ, twin by co-twin						
Mental arithmetic	.25	.35	.12	.36	.42	.22
Reaction time		.32	.23		.43	.31
Rest			.15			.18
Total, subject by subject						
Mental arithmetic	(.88)	.76	.55	(.87)	.74	.57
Reaction		(.82)	.62		(.92)	.63
Rest			(.77)			(.78)

Electrodermal total height

Electrodermal total height and electrodermal frequency are similar measures so it is not surprising that the two responses showed the same general profile. Figure 2 indicates that electrodermal total height is fairly high during the mental arithmetic and reaction time tasks and fairly low during the rest period. The intraclass correlations for the level scores are somewhat lower than for electrodermal frequency, perhaps indicating a somewhat lower relaiability for the measure. Electrodermal frequency is fairly independent of the measurement technique since virtually any method is likely to count the same number of responses. Height of the response, however, is related to several factors such as contact area of the electrode, type of electrolyte, and amount of voltage impressed across the skin.

For the mental arithmetic and reaction time tasks the variance of the MZ population was greater than the variance of the DZ population causing obviously inflated H_b^2 heritability estimates. Apparently the assumption of homoscedasticity was violated. The log transformed data yielded somewhat higher correlations for the mental arithmetic and reaction time tasks suggesting a better fir for the distribution. The H_b^2 heritability estimates are still too high but they are, no doubt, closer to the actual heritability figures. The comments in the

previous section about electrodermal frequency during the rest period also apply to the electrodermal total height measure since subjects who give no responses will also have zero total height.

The twin by co-twin correlations between mental arithmetic and reaction time give perhaps some indication of stimulus-response specificity but they remain fairly close to the intraclass correlations suggesting that individual-response specificity accounts for most of the data.

Skin conductance level

The overall trend for the trial by trial means for the entire sample (shown in Figure 3) are fairly comparable to the two other electrodermal measures except that skin conductance level tends to show the cumulative effects of electrodermal responses and tends to have a fairly slow recovery to baseline. The cumulative effect is shown by the fact that skin conductance tends to rise during the reaction time task while electrodermal frequency and electrodermal total height remain fairly constant or even decrease slightly. The slow recovery to baseline is indicated by the fact that skin conductance level decreases throughout the rest period even though electrodermal frequency and electrodermal total height are uniformly low during this period.

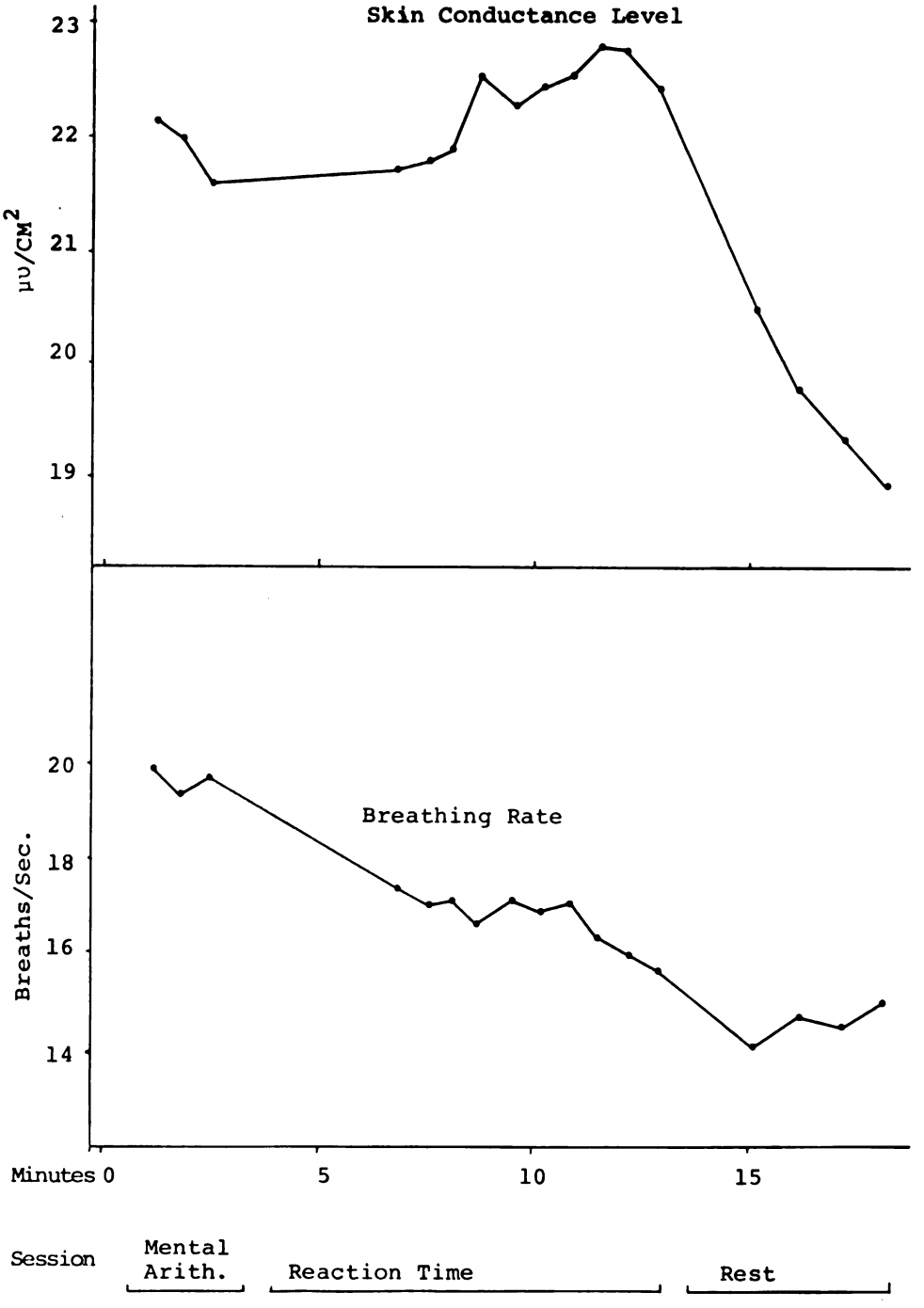

Figure 3.--Skin conductance level and breathing rate averaged across subjects for all scoring periods.

TABLE 9.--Descriptive statistics for electrodermal total height.

Measure	MZ			DZ			H_a^2	H_b^2
	r	Var.	Cov.	r	Var.	Cov.		
Total height								
Mental arithmetic (MA)	.43	.995	.435	.07	1.710	.125	.73	1.52
Reaction time (RT)	.38	.427	.163	.28	1.239	.351	.20	1.50
Rest (RE)	.37	.611	.224	-.09	.335	-.031	.92	- .08
Log total height								
Mental arithmetic	.53	.162	.087	.19	.244	.046	.69	1.28
Reaction time	.52	.098	.052	.37	.211	.078	.31	1.10
Rest	.51	.114	.059	-.03	.072	-.002	1.09	.38
Change, total ehight								
MA-RT	.44	.549	.240	.31	.612	.190	.25	.39
MA-RE	.38	1.249	.479	.10	1.134	.109	.58	.42
RT-RE	.34	.453	.155	.37	.985	.366	-.08	.88
Change, log total height								
MA-RT	.52	.083	.043	.20	.078	.016	.63	.55
MA-RE	.49	.184	.084	.17	.171	.028	.58	.48
RT-RE	.40	.100	.040	.44	.149	.065	-.06	.39

TABLE 10.--Correlations between stimuli for electrodermal total height.

Correlation	Total height			Log total height		
	Mental arithmetic	Reaction time	Rest	Mental arithmetic	Reaction time	Rest
MZ, twin by co-twin						
Mental arithmetic	.43	.27	.12	.53	.38	.22
Reaction time		.38	.23		.52	.33
Rest			.37			.51
DZ, twin by co-twin						
Mental arithmetic	.07	.10	-.01	.19	.24	.06
Reaction time		.28	-.04		.37	.04
Rest			-.09			-.03
Total, subject by subject						
Mental arithmetic	(.80)	.76	.39	(.83)	.78	.44
Reaction		(.92)	.45		(.83)	.52
Rest			(.75)			(.76)

The intraclass correlations for level shown in Table 11 are generally as high for DZ twins as for MZ twins which suggests they are primarily related to environmental factors. In fact, DZ correlations are undoubtedly underestimated since the DZ population variance is much less than the MZ population. The log transformation actually increases the correlations for DZ twins and increases the variance relative to MZ twins indicating that the distributions are fairly different for the two populations. Regardless of the stimulus condition or the data transformation used the heritability estimates tend to be zero or less. This conclusion is further confirmed by inspecting the twin by co-twin correlations summarized in Table 12. The DZ correlations are generally as high or higher than the MZ correlations. Previous studies have not measured skin conductance level in both MZ and DZ twins, consequently there is no basis for inferring the generality of this finding. The studies by Jost and Sontag (1944) and Block (1967) both reported higher MZ correlations so it may be that MZ correlations found in this study are too low.

Skin conductance levels are partly a result of the structural properties of the skin and the thermoregulatory actions of the sweat glands. However, change scores primarily should be related to differences in the

TABLE 11.--Descriptive statistices for skin conductance level.

Measure	MZ r	MZ Var.	MZ Cov.	DZ r	DZ Var.	DZ Cov.	H_a^2	H_b^2
Conductance level								
Mental arithmetic (MA)	.55	.232	.127	.49	.129	.063	.12	-.40
Reaction time (RT)	.56	.273	.152	.57	.170	.096	-.03	-.40
Rest (RE)	.57	.325	.185	.53	.164	.088	.08	-.46
Log conductance level								
Mental arithmetic	.57	.236	.134	.67	.349	.234	-.20	.09
Reaction time	.60	.267	.160	.66	.462	.306	-.12	.25
Rest	.61	.441	.267	.72	.636	.461	-.24	.00
Change, conductance level								
MA-RT	.23	1.375	.322	.32	2.060	.655	-.17	.40
MA-RE	.21	4.434	.951	.05	3.779	.190	.33	.05
RT-RE	.38	1.894	.723	.13	1.512	.200	.50	.15
Change, log conductance level								
MA-RT	.26	.020	.005	.25	.080	.020	.01	1.78
MA-RE	.53	.088	.047	.17	.181	.032	.72	1.43
RT-RE	.46	.045	.021	.11	.070	.007	.71	1.15

TABLE 12.--Correlations between stimuli for skin conductance level.

Correlation	Conductance level			Log conductance level		
	Mental arithmetic	Reaction time	Rest	Mental arithmetic	Reaction time	Rest
MZ, twin by co-twin						
Mental arithmetic	.55	.55	.55	.57	.58	.55
Reaction time		.56	.55		.60	.59
Rest			.57			.61
DZ, twin by co-twin						
Mental arithmetic	.49	.52	.51	.67	.65	.70
Reaction time		.57	.54		.66	.70
Rest			.53			.72
Total, subject by subject						
Mental arithmetic	(.99)	.96	.92	(.99)	.94	.88
Reaction		(1.00)	.96		(1.00)	.96
Rest			(.99)			(.99)

stimulus conditions and therefore may be of more interest. Unfortunately there were differences in the variances of the two populations and the log transoformations often yielded different results. At present, the safest conclusion is that the heritability estimates are generally positive although they are too highly divergent to make any good estimate of the true heritability.

The twin by co-twin correlations shown in Table 12 are almost exactly the same level as the intraclass correlations. There was virtually no difference in the distribution from one stimulus to another, therefore providing no evidence for stimulus-response specificity.

Breathing rate

The trial by trial breathing rate illustrated in Figure 3 was relatively high for the mental arithmetic task but lower for the other two tasks. Breathing rate is rarely reported in psychophysiological research so there was no reason to expect one pattern of responding over another.

The intraclass correlations for MZ twins are generally higher than for DZ twins but the differences are vey small and in a few cases in the opposite direction. The variance for the DZ population is somewhat higher than for the MZ population yielding higher H_b^2

TABLE 13.--Descriptive statistics for breathing rate.

Measure	MZ			DZ			H_a^2	H_b^2
	r	Var.	Cov.	r	Var.	Cov.		
Breathing rate								
Mental arithmetic (MA)	.44	.990	.438	.08	1.435	.112	.73	1.27
Reactiontime (RT)	.36	.392	.140	.46	.669	.305	-.20	.42
Rest (RE)	.40	.843	.333	.31	1.141	.350	.18	.55
Log breathing rate								
Mental arithmetic	.41	.026	.011	.21	.042	.009	.40	1.04
Reaction time	.30	.022	.007	.43	.035	.015	-.27	.32
Rest	.34	.043	.014	.21	.047	.010	.26	.38
Change, breathing rate								
MA-RT	.10	.786	.078	.00	1.078	-.001	.20	.80
MA-RE	.10	1.285	.128	.07	1.929	.143	.05	.78
RT-RE	.35	.592	.205	.14	.526	.071	.42	.24
Change, log breathing rate								
MA-RT	-.01	.024	-.000	.09	.036	.003	-.19	.57
MA-RE	.04	.054	.002	.17	.067	.011	-.25	.14
RT-RE	.34	.034	.011	.24	.028	.007	.21	.02

TABLE 14.--Correlations between stimuli for breathing rate.

Correlation	Breathing rate			Log breathing rate		
	Mental arithmetic	Reaction time	Rest	Mental arithmetic	Reaction time	Rest
MZ, twin by co-twin						
Mental arithmetic	.44	.40	.35	.41	.36	.35
Reaction time		.36	.26		.30	.16
Rest		.40				.34
DZ, twin by co-twin						
Mental arithmetic	.08	.21	.12	.21	.27	.08
Reaction time		.46	.33		.43	.22
Rest			.31			.21
Total, subject by subject						
Mental arithmetic	(.82)	.51	.27	(.81)	.52	.23
Reaction		(.91)	.66		(.88)	.60
Rest			(.85)			(.84)

estimates, some of which seem to be much higher than they should be, suggesting a violation of the homoscedasticity assumption. This is especially evident in the change scores in which the MZ correlations are near zero and the H_b^2 estimates are fairly high. The breathing rate data may be unreliable since the subject by subject correlations shown in Table 14 are the lowest reported in this study. The twin by co-twin correlations between stimuli show a general trend toward lower values for the DZ population than for the MZ population, but the differences are still quite small.

Reaction time responses

Because the reaction time task provides discrete, temporally arranged stimuli it is possible to look at several aspects of this stimulus condition alone. The overall second by second heart rate shown in Figure 4 is very similar to that reported by Porges (1972). There were accelerative responses to both the onset of the ready light and the onset of the go light with a slight decrease in heart rate in anticipation of the go light. The second by second heart rate variance is obtained by subtracting the heart period scores of adjacent seconds from each other, squaring the result and averaging the data across all trials for all subjects. Heart rate

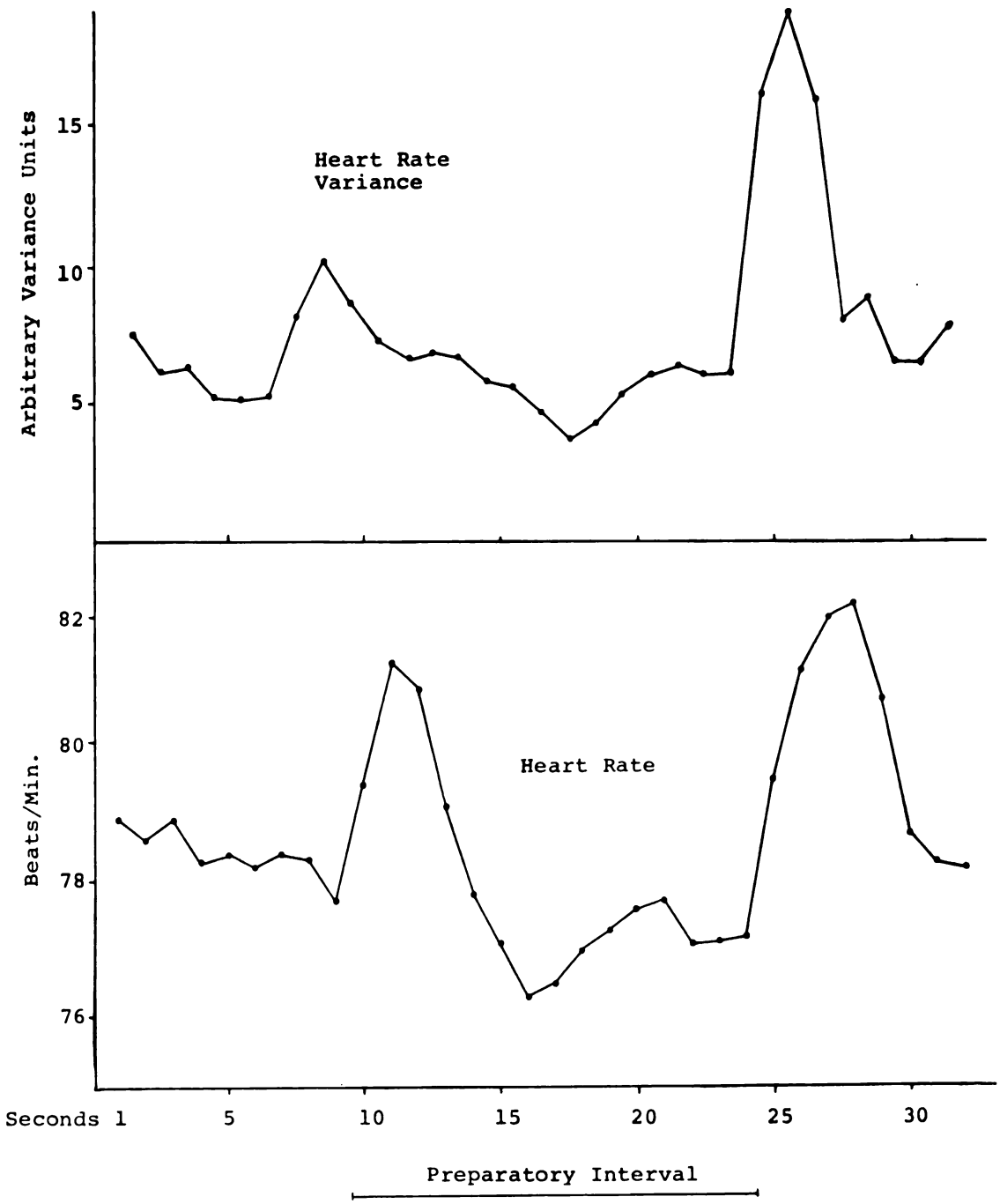

Figure 4.--Second by second heart rate variance and heart rate averaged across reaction time trials 5-15 and across all subjects.

variability seems to increase primarily as a result of the acceleratory heart rate response to the onset of the stimuli.

Heritabilities of individual features of the heart rate response were not computed since the intra-class correlations would obviously be low. This can be seen by inspecting the trial by trial variance shown in Figure 1. The average variability during a reaction time trial is so high that an overall profile for a given trial for a given subject could not be distinguished from the normal variance. The profiles shown in Figure 4 are based upon averages over 600 trials and are not particularly characteristic of a given trial.

The heritabilities of the reaction speed, orienting response height, and response height and their log transformations were computed. As the figures in Table 15 indicate, variability of the electrodermal measures is much higher for the DZ twins than for the MZ twins. This results in much higher heritability estimates for H_b^2. For reaction speed the variance of the MZ twins is much higher, resulting in a much higher heritability estimate for H_a^2. The overall results suggest a genetic component to these measures but the inequality of the variances precludes any definite conclusion.

TABLE 15.--Descriptive statistics for reaction time data.

Measure	MZ			DZ			Alpha	H_a^2	H_b^2
	r	Var.	Cov.	r	Var.	Cov.			
Reaction speed									
Reaction speed	.76	.463	.349	.02	.157	.003	.92	1.47	.26
Log reaction speed	.74	.044	.033	.01	.149	.000	.44	1.46	.08
Electrodermal responses									
Orienting response height	.13	.150	.019	.28	.444	.125	.89	-.30	1.26
Log orienting response height	.18	.047	.009	.32	.115	.036	.89	-.27	.49
Respond height	.45	.393	.176	.38	1.318	.500	.97	.14	1.40
Log respond height	.48	.085	.041	.46	.213	.098	.97	.05	.47

DISCUSSION

The present study was designed to investigate the genetic components of stimulus-response and individual-response specificity. MZ and DZ twins were presented a series of tasks while physiological measures were recorded. Considering the data as a whole there was no evidence to support a genetic interpretation of stimulus-response specificity. Conversely, there was considerable evidence to support an individual-response specificity hypothesis. In virtually every case where the heritabilities of a measure were moderately high, the twin by co-twin correlations were nearly as high as the intraclass correlations. If the heritabilities for different stimulus conditions were actually independent factors, the twin by co-twin correlations should have approached zero.

Several unique aspects of twins studies should be taken into account when interpreting the results of this study. The lower than expected DZ correlations for some measures (e.g. reaction speed) could be a result of sampling error. However, this happens often enough

in twins studies to suggest that there may be effects due to dominance, epistasis, or gene-environment interaction. (See Appendix B for a discussion of how these factors can affect heritability estimates.) Other research designs should be carried out to better understand the nature of these effects (Falconer, 1960). The most consistent problem encountered in this study was that the MZ and DZ populations varied greatly in their distributions. Thus, it was difficult to make direct comparisons between these groups. Differences in distribution most likely were a result of sampling error. An increased sample size should yield a more reliable distribution and help to determine the best transformation of the data. Test-retest data would also increase confidence in the shape of the distributions and provide an estimate of the reliability of the measures. There probably should be several retests to assess the overall effects of retesting independent of the question of reliability.

Given the sample sizes usually involved in this kind of research it is likely that other investigators have also encountered differences in the MZ and DZ samples. Unfortunately, only intraclass correlations and sometimes heritability estimates or F ratios are reported so it is difficult to interpret the reported

data. F ratios are based upon variance of difference scores as is the H_b^2 estimate used in the present study. As the results of this study clearly indicate, different heritability estimates can lead to quite different conclusions. Consequently, in future twins studies, investigators must provide more detailed statistical descriptions to enable more meaningful comparisons across studies.

The small number of subjects used in the present study made it difficult to reach any firm conclusions about the heritabilities of individual measures of autonomic activity. Whereas it is easy to recommend larger samples, retesting and the use of more complex designs for future research, as a practical matter, these goals are virtually impossible to reach. For this experiment nearly five man-hours of work were required for the testing of each subject. This involved setting up and callibrating the instruments, testing the subject, cleaning up, scoring the data, and keypunching the results. Rarely, if ever, does a researcher have the resources to conduct a large scale investigation involving retesting with a large number of subjects. Furthermore, large samples of twins generally are difficult to recruit. College students are accessible and willing research participants but even at a large institution

such as Michigan State University the number of twins is limited. With more persistent recruiting over an extended time period it is unlikely that more than about 60 pairs of twins could have been recruited for this study.

Psychophysiologists typically encounter large individual differences in their investigations which are usually delt with by using within subjects designs or by using large samples. The results of the present study suggest that in cases where it is not possible to use within subjects designs, it may be feasable to MZ co-twins as matched subjects.

It is unfortunate that it is so difficult to investigate genetic components of autonomic nervous system activity since the research has a number of interesting theoretical and practical implications. For example, it would be useful to understand genetic influences so that preventive measures could be taken for people at risk for certain psychosomatic disorders. Moreover, knowledge of the genetic components of autonomic nervous system activity would give psychophysiologists a better understanding of an important source of individual differences.

APPENDICES

APPENDIX A

Twin Questionnaire

Name _____

Circle the best answer.

1. How would you describe the similarity of eye color between you and your twin?
    1. no difference
    2. minor differences
    3. different color

2. How would you describe the similarity of hair between you and your twin?
    1. no difference
    2. differences in texture and/or minor differences in color or curliness
    3. difference in color or major difference in curliness

3. When you were children, how often did your parents misidentify you?
    1. frequently
    2. occasionally
    3. rarely

4. Recently how often do your parents misidentify you?
    1. frequently
    2. occasionally
    3. rarely or never

5. How often did you grade school teachers misidentify you?
    1. frequently
    2. occasionally
    3. rarely or never

6. How often do close friends misidentify you?
    1. frequently
    2. occasionally
    3. rarely or never

7. How often do casual friends misidentify you?
    1. frequently
    2. occasionally
    3. rarely or never

8. Do you think you are identical or fraternal twins?
    1. identical
    2. fraternal
    3. uncertain

9. What is your height? _____

10. What is your weight? _____

11. For what reasons do you think you are identical or fraternal?

12. What is your birth date? _____

13. Are you first born or second born?
    1. first
    2. second

14. What is your hand preference?
    1. right handed
    2. left handed
    3. ambidextrous

15. How old was your mother when you were born? _____

16. How certain are you of your classification as fraternal or identical?
    1. absolutely sure
    2. fairly sure
    3. certain
    4. calssification may be wrong
    5. quite sure classification is wrong

If you would like to receive a summary of the results of this study, fill out your name and address on one of the MSU envelopes. It is usually best to use your home address since the results may not be ready until summer.

Health Questionnaire

Have you or any of your blood relatives (Mother Father, Brothers, Sisters, Grandparents, Uncles, or Aunts) had any of the following illnesses. If it was a relative list the relationship to you. Also, if you can, specify the nature of the illness.

_____

heart attack or heart disease

_____

stroke

_____

cancer

_____

gastrointestinal disorders

_____

high blood pressure

_____

diabetes

_____

kidney disease

_____

epilepsy

APPENDIX B

Factors affecting heritability estimates

A detailed discussion of the concept of heritability will not be offered here since there are several excellent discussions available elsewhere (De Fries, 1967; Falconer, 1960; Jensen, 1969). Most of these discussions of the heritability concept deal with the ways in which heritability estimates are affected by various sources of variation. These various sources of variance and their applicability to this study are discussed below.

Errors of assignment

Probably the most common criticism of twin studies is that many of these studies, especially the earlier ones, used inaccurate zygosity determinations (Vandenberg, 1968). The self reports which are used by many investigators are surprisingly inaccurate. Usually self reports are based upon the obstetrician's observation of the chorion at birth. Smith (1965) found that parents misclassified their MZ twins as DZ twins 13.3% of the time while they misclassifed their DZ twins as MZ twins 28% of the time. Scarr (1968) reported even higher misclassification rates of 17.4%

and 31.2% respectively. Both of these studies used blood grouping as the criterion measure. Unfortunately the criterion measure used by Smith yields an expected misclassification rate of 10% for MZ twins so the absolute rate of misclassification is not known. Scarr's zygosity determination yields an expected misclassification rate of less than 1% for MZ twins suggesting a greater degree of accuracy to her estimates.

When blood typing is used, the group classified as DZ is always correctly diagnosed since a difference on any blood marker indicates dizygosity. It is possible by random assortment that there will be some DZ pairs who will have the same blood types and will be classified as MZ. Accuracy estimates are stated for the MZ twins even though it is the DZ twins who may be misclassified.

Zygosity determination can reach a very high level of accuracy if enough blood markers are used. Claridge, Canter and Hume (1973) used a total of 19 markers and computed the probabilities of misclassifying each MZ twin by taking into account the probability of monozygosity and the frequency of each marker in the general population. The odds of misclassification ranged from 0.0093 to 0.00076. They also used a questionnaire, filled out by the twins, which estimated the physical similarity of the twins. The scores on

the test produced a clear bimodal distribution which resulted in misclassification of only two of the 52 twins. No self reports of zygosity were given so it could not be determined how effective this test was in distinguishing the zygosity of twins who had been misclassified at birth. Husen (1959) reported that physical similarity measures misclassified about 10% of the subjects but their criterion measure, blood grouping, had an accuracy of only 90% for MZ twins. Thus, the true accuracy of the physical similarity rating is not known. Nichols and Bilbro (1966) determined zygosity by blood typing in 41 MZ and 41 DZ twins. The accuracy for the blood grouping was better than 99% for every MZ twin. A physical similarity questionnaire, filled out by the twins, yielded an overall accuracy of 93%. This is considerably better than finger print ridge counts which is also relatively easy to measure but yields an accuracy of only 80% (Slater, 1963).

Ideally zygosity can be determined in a population of twins by extensive blood tests but this is not always possible or even necessary. Some twins will not consent to have blood tests and extensive tests can be prohibitively expensive. Furthermore the kind of zygosity determination that the investigator chooses to use will depend upon the amount of error

that he is willing to tolerate. Vandenberg (1968) believes that 5% is generally tolerable since the only effect of a misclassification is to lower the heritability estimate and to decrease the likelihood that the differences between the MZ and DZ groups will reach statistical significance. He believes that any studies which do not use blood groupings to determine zygosity should not report heritability estimates.

For the simple demonstration that a characteristic is heritable, the power of the statistical test can be increased to a satisfactory level by increasing the sample size which will tend to compensate for imperfect zygosity determination and measurement error. However, if an estimate of heritability is needed then it is useful to know how misclassification will affect the heritability estimate. Table 16 lists the effects of misclassification on the heritability estimate. The general heritability formula, $h=2(r_{MZ} - r_{DZ})$, was used to obtain the effects of misclassification and equal percentages of each population were assumed to be misclassified.

It should be pointed out that Table 16 is based upon random misclassification. That is, it is assumed that one twin pair is as likely to be misclassified as another. This is probably not normally the case. In fact it is possible that misclassification could even

increase the heritability estimates. Although fraternal twins normally share 50% of their genes, many, by simple random assortment, share much more than this and would be much more likely to be misclassified as identicals. It is unlikely that fraternal twins who share most of their genes would affect the average difference scores of the identical twin population by much, but it would have the effect of increasing the average difference scores among the fraternal twins population thereby increasing the heritability estimates. A similar but opposite effect can occur among identical twins who are misclassified as fraternals. When identicals are classified as fraternals it is most likely because one of the twins has suffered some kind of serious effect perhaps due to illness or perinatal damage. Such effects are, in the strictest sense, environmental effects and should be represented in the MZ twins population for a correct heritability estimate.

TABLE 16.--Estimates of h^2 given true h^2 and a percentage of misclassification.

		percent misclassified			
		1%	5%	10%	20%
true h^2	.10	.098	.091	.081	.061
	.30	.295	.274	.247	.191
	.50	.493	.462	.421	.333
	.70	.689	.653	.602	.488

Regardless of whether the effects of misclassification are random or biased it is important to know what the effects of misclassification would be. The only study which computed heritability estimates based upon both blood typing and similarity measures was conducted by Nichols and Bilbro (1966) who found that heritability estimates for the National Meric Scholarship Qualifying Test were little affected by the type of zygosity determination whether by questionnaire or by blood typing. The heritability estimate was, in fact, slightly higher when zygosity was determined by the questionnaire.

Assortative mating

Another source of variance that can affect heritability estimates is assortative mating. Assortative mating results from the fact that similar genotypes tend to interbreed. This may be because similar genotypes tend to select each other as mates. There is a positive correlation between the heights of husbands and wives, for example, which is due no doubt to such selective mating. It is difficult to estimate the extent to which this kind of selective mating could seriously affect the heritabilities of autonomic response measures. There is no reason to suspect that electrodermal responders tend to select other electrodermal responders except perhaps to the degree that these measures might be

correlated with personality types. The correlation of autonomic measures with personality measures has generally been disappointingly low (Stern & McDonald, 1965) so there is little reason to suspect that this kind of selective mating could have much effect on the heritability estimates.

Selective mating on the basis of the similar racial backgrounds could be a problem, however. For example, blacks certainly tend to marry blacks and it has been well established that blacks generally have lower conductance levels and show fewer electrodermal responses (Johnson & Landon, 1965). In this study, for example, two of the pairs were black (both DZ). The lowest conductance level of the entire sample was evidenced by one of these black subjects and her sister had the second lowest conductance level. The other black pair also has lower than average conductance levels. Although selection on the basis of skin color is an obvious example of selective mating there is probably some degree of selection among whites because of geographical clustering and religious preferences. The effect of assortative mating is to make the genotypes of DZ twins more alike than would be expected from random assortment of a given population therefore causing a reduction in the heritability estimate.

Genotype-environment interactions, dominance and epistasis

The source of variance that has received the most attention, especially from critics of the use of heritability measures, is genotype-environment interaction. There are a number of ways of estimating this interaction but all of these methods require the use of sybships other than twins (Jinks & Fulker, 1970). Interactions arise when different environments produce different distributions in the same sample of genotypes. These interactions for IQ at least are thought by some to be negligible (e.g. Jensen, 1970) and by others to be so totally complex and beyond our understanding as to make the study of human behavioral genetics a completely futile endeavor (e.g. Layzer, 1974).

Dominance refers to the fact that some genes are recessive and some are dominant. Whether a gene is expressed or not depends upon the gene with which it is paired. If either or both genes are dominant the dominant characteristic would be expressed. If both are recessive the recessive characteristic would be expressed. For characteristics which are polygenetically determined the effects of individual cases of dominance and recessiveness cannot be determined but any effect that they do have will result in greater variance between parent and offspring than would be

predicted by a simple additive model. Dominance does not cause variance between identical twins since they will both have the same combination of dominant and recessive genes. The differences between fraternal twins will become greater as the effects of dominance become greater.

Epistasis refers to the fact that genes at one location can often affect the expression of genes at another location. The effects of epistasis are the same as for dominance.

The extent to which genotype-environment interactions, dominance or epistasis affect the data in this study cannot be determined except to note discrepancies in the data which could be explained by one of these effects. If any of these effects are present the most likely effect would be to reduce the DZ correlations to less than half of the MZ correlations thereby increasing the heritability estimates. This is, in fact, the case with many of the measures employed in this study and has been observed in a twins study by Lykken, Tellegen and Thorkelson (1974) which measured electroencephalographic activity. Other measures seem to conform to a simple linear genetic model. For IQ (Erlenmeyer-Kimling & Jarvik, 1963) and height and weight (Newman, Freeman, & Holzinger, 1937) the correlations for DZ twins are about half that of MZ twins.

Bias due to perceived zygosity

This viewpoint questions the assumption of many twins studies that the environments of identical and fraternal twins are very similar. It may be that the greater differences that one observes between DZ twins relative to MZ twins results from the fact that people, especially parents, are aware of the twin's zygosity and therefore are more likely to treat DZ twins differently purely because of the fact that they expect them to be different. This self fulfilling prophesy would result in a genetic bias in twins studies.

It has been well documented that parents do in fact treat identical twins more alike than fraternal twins (Nilson, 1934; Smith, 1965). It is difficult to say, however, whether this differential treatment of MZ and DZ twins is because of imagined similarity due to knowledge of zygosity or due to actual similarity due to phenotypic characteristics. Differential treatment which is due to phenotypic characteristics, whether they are personality variables or morphological variables, would be the result of genetic differences or genotype-environment interactions. In twins studies genotype-environment interaction is measured as a genetic component of variance. If identical twins are alike primarily because people perceive them as being alike rather

than because of their actual differences, then a major assumption of twins studies is violated. Such a source of bias could possibly affect heritability estimates of autonomic responses since early experience is likely to affect heart rate responses (Hofer, 1974).

Scarr (1968) examined several twins who were misdiagnosed by their parents. She reasoned that if the perceived zygosity primarily determined the manner in which the twins were treated, then one would find that misdiagnosed MZ twins (twins thought to be fraternal but actually identical) would be treated differently while misdiagnosed DZ twins would be treated more alike. For these misclassified twins it was the true zygosity rather than the perceived zygosity which was the best predictor of how these twins were treated. That is, DZ twins tended to be treated differently even though everyone thought they were MZ. MZ twins tended to be treated alike even though they were perceived as being DZ. It would seem then that most of the variance in the way that twins are treated is attributable to genetic characteristics since twins that act and look alike tend to be treated alike while twins that act and look differently tend to be treated differently.

Unreliability

The unreliability of any particular measure will reduce the correlations observed for that measure and

will consequently reduce the measured heritability. Heritabilities of test data such as IQ scores are typically corrected for unreliability to give an estimate of what the heritabilities would be if the test instruments were perfectly reliable. For situations in which the administration of one test is unlikely to affect the score of a second test or when comparable forms of the same test are available the test-retest reliability can be computed. This probably gives the best estimate of the reliability of the instrument. In cases where a score is based upon the scores of a number of individual items the inter-item correlations can give an estimate of the reliability.

The subjects in this study were not retested, partly because of the added work which retesting requires but also because there is every reason to believe that the second test situation would not be comparable to the first test situation. Part of the "stimulus" in most psychophysiology experiments is the test situation iteslf. The only study that has shown reasonable test-retest reliability (Lacey & Lacey, 1962) employed children and had a four year inter-test interval. The subjects are exposed to a new situation in which they are hooked up to some obviously elaborate instrumentation and are shut up in a sound proof booth. The testing situation itself would be expected to cause

some physiological arousal which would be lessened if the subject were to be retested. Also, some subjects in this experiment mentioned that they expected to be "tricked" at some point or that the purpose was different than the one that was explained at the beginning of the experiment since psychologists are known to do such things. Two of the subjects spontaneously mentioned the Milgram obedience studies and wondered if psychologists at Michigan State University did experiments like that. It is likely that some of their fears would be reduced for the second testing session.

Also, one of the purposes of this study was to see how much of the variance which is normally observed in a typical experiment is attributable to genetic differences. Although test-retest reliability would be interesting to know, it is not central to the purpose of this study. Day to day variations in physiological activity are a part of the variance that one observes in a typical experiment. In fact, if the environments of MZ twins are fairly similar, the intracalss correlations would approach unity when the day to day variation is partialed out.

The sizes of the correlations are a function of the reliability of the measures and the number of samples taken, so it is necessary to report alpha coefficients for most data. This will give an estimate of

The measurement error for different investigators using the same techniques should be relatively low since all of the important parameters can be specified and reproduced. As long as similar electrolytes and similar voltages are impressed across the skin there should be no problem with reliability. In any case the relaibility of an electrodermal measure in a particular experiment should be fairly high since the same measurement techniques are normally used throughout the experiment.

APPENDIX C

Subject instructions

This is a study which is examining physiological responses to three different situations; mental arithmetic, reaction speed, and rest. We will be measuring three different physiological reactions; heart rate, sweat gland activity and breathing. The pickups that have already been attached will measure the sweat gland activity on the palm of your hand. Please try to be as careful as you can with these pickups as they can easily come off. They were attached first because they have to be on at least ten minutes before the study can actually begin. Just before the study starts two pickups will also be attached to your right wrist to measure your heart rate and a strap will be put around your chest to measure your breathing rate. You will also be shown how to operate the reaction speed switch.

About a minute after the booth door has been closed you will hear the instructions over the loud speaker for the mental arithmetic task. The insturctions will be to count backwards from 800 by 7's as fast as you can. Start counting backwards to yourself as fast as you can when you are told to start. Do not count out loud.

If you lose your place, start over from the beginning and continue counting. Occasionally the voice on the loudspeaker will say the word "number." Quickly say the number that you are presently on, out loud, and continue to count to yourself. You will be told when to stop counting. This metnal arithmetic task will last about a minute.

The next task will test your reaction speed. You will be told to pick up the reaction time switch and wait for the READY light to come on. After the READY light has been on for several seconds it will go off and the GO light will come on simultaneously. When this happens, press the thumb switch as quickly as you can. There will be a short rest period before the next trial begins. It is important that you try to respond as quickly as you can to the lights. The reaction speed task will last about 10 minutes.

After the last reaction trial you will be instructed to put down the thumb switch. You will then be allowed to sit back and relax for about 5 minutes. You may close your eyes if you wish. Try to concentrate completely on relaxation during this period.

At the end of this rest period the study will end and the experimenter will come in and disconnect the pickups. You will then be given a short questionnaire to fill out, you will be photographed and your

the effects of measurement error and moment to moment variation so that data from other experiments can be more directly compared.

It is worth noting that the use of reliability to correct for attenuation implies a model in which one is using a test to measure or predict something else. The criterion measure might be IQ, anxiety or job performance so the test's reliability will have a real effect on how well the test measures these things.

In the case of this study it is the autonomic measure itself which is of interest and the major source of unreliability other than day to day variation would be measurement error. Measurement error is not normally a problem for the measures employed in this experiment. It is unlikely that different experimenters measuring heart rate in the same subject would come up with different measurements. There is certainly some measurement error associated with heart rate measures, since movement artifacts and environmentally produced noise can cause incorrect readings. Most often these artifacts are readily noticeable and the incorrect measurements are discarded.

Electrodermal measures are a different problem, however, since there are many ways of measuring conductance level which can result in different measurements.

fingerprints will be taken. Also, if you wish, you may look at the record of your physiological responses. Any further questions that you might have will be answered at that time. If you have any questions at all please ask them at this time as we cannot answer them once the experiment has started. There is an intercom between the booth and the equipment room which can be used before and after the experiment. Also it is important that you move as little as possible during the study since movements can affect the recording process.

If you should become uncomfortable at any time during the experiment please let us know and we will stop the experiment. Although the results of this study will be published the data from individuals will remain anonymous. You may, however, withdraw your data from the study at the end of the experiment if you wish.

To briefly summarize, there are three parts to the study:

1. During the mental arithmetic task you are to count backwards as fast as you can and say the number that you are on whenever you are asked.

2. During the reaction speed task you are to press the thumb switch as soon as you can after the READY light goes off and the GO light comes on. <u>It is important that you react as quickly as possible</u>.

3. During the last period you may simple sit back and relax.

Thank you for your cooperation.

APPENDIX D

Means and sums of squares for all data

TABLE 17.--Means and sums of squares for heart period.

	Heart period		Log heart period	
	MZ	DZ	MZ	DZ
		Mental arithmetic		
Mean	4.190	4.341	1.808	1.831
SS pairs	67.383	51.308	1.882	1.333
SS order	.807	1.901	.010	.048
SS trials	2.454	4.026	.066	.108
SS O x T	.056	.188	.001	.004
Error O	22.166	41.257	.484	1.131
Error T	6.902	6.294	.156	.159
Error O x T	2.043	4.897	.056	.101
		Reaction time		
Mean	5.611	5.701	2.016	2.029
SS pairs	361.944	258.873	6.089	4.577
SS order	3.613	12.693	.037	.251
SS trials	2.378	1.477	.046	.026
SS O x T	.523	.379	.010	.007
Error O	115.951	123.701	1.858	2.453
Error T	9.739	6.426	.178	.112
Error O x T	7.887	6.316	.141	.106
		Rest		
Mean	5.874	6.077	2.052	2.079
SS pairs	127.317	103.170	2.088	1.712
SS order	4.425	3.096	.069	.046
SS trials	.570	.305	.007	.005
SS O x T	.476	.059	.009	.001
Error O	36.028	37.710	.566	.606
Error T	5.126	3.442	.081	.049
Error O x T	3.869	3.447	.066	.047
		MA-RT		
Mean	8.579	8.640	9.793	9.802
SS pairs	13.573	10.157	.260	.190
SS order	.007	.109	.000	.001
Error O	5.870	7.413	.108	.166
		MA-RE		
Mean	8.316	8.263	9.752	9.757
SS pairs	16.600	13.033	.387	.259
SS order	.284	.007	.005	.000
Error O	6.234	9.864	.120	.239
		RT-MA		
Mean	9.737	9.623	9.964	9.950
SS pairs	5.175	2.556	.100	.054
SS order	.204	.061	.005	.003
Error order	1.460	2.463	.024	.056

TABLE 18.--Means and sums of squares for heart period variability.

	Variability		Log variability	
	MZ	DZ	MZ	DZ
		Mental arithmetic		
Mean	.038	.037	6.964	6.875
SS pairs	17.952	18.874	82.533	69.040
SS order	.517	.044	.908	.060
SS trials	1.805	.179	2.776	.129
SS O x T	.837	.812	2.549	.933
Error O	8.276	9.010	28.924	52.683
Error T	6.690	7.688	16.543	17.926
Error O x T	5.152	6.178	12.155	19.487
		Reaction time		
Mean	.061	.065	8.051	8.107
SS pairs	97.530	196.721	105.214	195.122
SS order	.139	15.870	.921	10.153
SS trials	1.939	2.504	2.164	1.886
SS O x T	2.348	1.442	3.382	2.571
Error O	43,315	75.796	53.747	60.188
Error T	32.346	30.506	36.951	36.136
Error O x T	22.324	30.488	28.649	31.216
		Rest		
Mean	.052	.065	7.713	8.041
SS pairs	43.339	90.396	56.299	94.172
SS order	.616	7.171	.023	3.683
SS trials	.899	.383	.868	.299
SS O x T	.218	.480	.417	.723
Error O	17.896	29,110	35.701	36.968
Error T	7.909	22.308	9.840	15.288
Error O x T	19.222	16.256	19.008	13.303
		MA-RT		
Mean	-.012	-.018	8.914	8.768
SS pairs	8.136	7.337	23.024	8.144
SS order	.088	1.907	.061	1.319
Error O	3.465	5.918	6.075	15.341
		MA-RE		
Mean	-.004	-.017	9.252	8.834
SS pairs	10.498	9.006	23.873	11.241
SS order	.652	2.132	.392	1.211
Error O	4.251	9.281	10.875	31.524
		RT-RE		
Mean	.017	.010	10.338	10.065
SS pairs	5.753	4.116	6.685	6.361
SS order	.260	.006	.144	.002
Error O	2.172	4.478	4.710	9.518

TABLE 19.--Means and sums of squares for electrodermal frequency.

	Frequency		Log frequency	
	MZ	DZ	MZ	DZ
		Mental arithmetic		
Mean	3.700	2.900	1.435	1.194
SS pairs	225.400	183.267	17.358	17.951
SS order	16.099	10.678	.480	1.232
SS trials	2.067	12.867	.321	.707
SS O x T	2.600	2.289	.187	.173
Error O	33.933	98.822	1.684	7.255
Error T	22.933	32.467	2.154	3.435
Error O x T	37.067	33.711	2.184	4.228
		Reaction time		
Mean	2.067	1.633	1.012	.796
SS pairs	277.967	303.467	38.234	51.029
SS order	1.920	25.813	.053	3.029
SS trials	10.133	10.200	1.384	2.203
SS O x T	9.547	5.387	1.261	.459
Error O	38.580	129.587	4.710	16.501
Error T	102.567	144.000	13.144	17.154
Error O x T	99.953	171.213	13.937	15.464
		Rest		
Mean	.942	.467	.488	.259
SS pairs	77.717	33.617	14.638	9.972
SS order	5.208	.533	1.429	.104
SS trials	.358	1.267	.106	.257
SS O x T	2.625	1.267	1.181	.239
Error O	30.917	24.217	6.404	6.791
Error T	38.017	16.983	7.162	3.976
Error O x T	41.750	15.983	7.321	3.323
		MA-RT		
Mean	11.633	11.267	10.424	10.397
SS pairs	33.497	16.269	2.302	2.098
SS order	3.745	.078	.107	.000
Error O	7.549	23.128	.490	2.567
		MA-RE		
Mean	12.758	12.433	10.947	10.935
SS pairs	64.863	38,193	4.575	3.350
SS order	1.519	2.315	.039	.230
Error O	12.707	18.206	1.726	1.902
		RT-RE		
Mean	11.125	11.167	10.523	10.538
SS pairs	23.483	12.684	3.250	1.944
SS order	.494	1.541	.275	.215
Error O	7.037	5.936	1.543	1.301

TABLE 20.--Means and sums of squares for electrodermal total height.

	Total height		Log total height	
	MZ	DZ	MZ	DZ
		Mental arithmetic		
Mean	1.359	1.371	.745	.677
SS pairs	64.363	82.598	11.193	13.058
SS order	.000	.011	.023	.027
SS trials	3.880	15.204	.678	1.441
SS O x T	.680	2.882	.098	.412
Error O	25.175	71.296	3.375	8.882
Error T	13.850	25.952	2.174	2.984
Error O x T	17.590	37.462	2.163	3.891
		Reaction time		
Mean	1.004	1.007	.595	.518
SS pairs	88.415	238.501	22.494	43.280
SS order	6.962	8.300	.793	1.150
SS trials	3.176	12.616	.872	2.102
SS O x T	2.535	4.988	.532	.486
Error O	32.636	124.975	6.218	18.785
Error T	61.999	105.363	12.881	16.181
Error O x T	69.983	82.331	14.279	11.803
		Rest		
Mean	.499	.292	.282	.161
SS pairs	50.109	18.199	10.367	4.155
SS order	.037	.533	.076	.038
SS trials	1.934	.150	.309	.032
SS O x T	1.883	1.661	.778	.298
Error O	23.162	21.444	3.261	4.409
Error T	19.162	23.613	3.932	3.624
Error O x T	20.103	21.772	4.461	3.213
		MA-RT		
Mean	10.355	10.364	10.150	10.160
SS pairs	11.830	12.039	1.887	1.402
SS order	.706	.945	.136	.060
Error O	3.929	5.391	.459	.869
		MA-RE		
Mean	10.860	11.079	10.464	10.516
SS pairs	25.923	17.643	4.031	2.986
SS order	.010	.093	.003	.037
Error O	11.533	15.282	1.497	2.101
		RT-MA		
Mean	10.504	10.715	10.314	10.356
SS pairs	9.127	20.257	2.098	3.208
SS order	.545	1.629	.176	.190
Error order	3.926	7.657	.714	1.068

TABLE 21.--Means and sums of squares for skin conductance level.

	Conductance level		Log conductance level	
	MZ	DZ	MZ	DZ
		Mental arithmetic		
Mean	9.683	7.437	2.154	1.857
SS pairs	1617.210	864.861	16.568	26.198
SSorder	5.525	24.859	.212	.181
SS trials	.453	1.685	.004	.007
SS 0 x T	.011	.688	.000	.025
Error 0	464.630	273.450	4.341	4.992
Error T	5.067	8.159	.058	.315
Error 0 x T	4.309	5.708	.070	.192
		Reaction time		
Mean	10.013	7.463	2.172	1.808
SS pairs	6375.660	3996.330	64.056	115.094
SS order	55.384	171,159	.225	2.639
SS trials	15.647	8.887	.175	.175
SS 0 x T	1.679	3.070	.039	.096
Error 0	1768.346	930.301	15.771	20.774
Error T	41.698	47.405	.683	2.053
Error 0 x T	35.246	51.050	.619	2.007
		Rest		
Mean	9.437	5.917	2.044	1.487
SS pairs	3062.700	1512.549	42.466	65.775
SS order	3.300	63.656	.180	.871
SS trials	2.880	12.248	.815	.555
SS 0 x T	2.419	3.236	.038	.065
Error 0	835.149	397.781	9.644	9.948
Error T	26.775	34.449	.634	1.167
Error 0 x T	34.717	18.387	.412	.612
		MA-RT		
Mean	9.670	9.974	9.982	10.050
SS Pairs	25.461	40.722	.368	1.493
SSorder	.993	1.584	.013	.072
Error 0	14.805	19.484	.204	.821
		MA-RE		
Mean	10.246	11.520	10.110	10.371
SS pairs	80.783	59.536	2.026	3.192
SS order	.201	1.234	.034	.016
Error 0	52.042	52.594	.582	2.229
		RT-RE		
Mean	10.575	11.546	10.128	10.321
SS pairs	39.261	25.669	.990	1.162
SS order	2.008	.022	.091	.020
Error 0	15.479	19.661	.272	.919

TABLE 22.--Means and sums of squares for breathing rate.

	Breathing rate		Log breathing rate	
	MZ	DZ	MZ	DZ
		Mental arithmetic		
Mean	6.522	6.589	1.857	1.860
SS pairs	64.289	69.622	1.657	2.295
SS order	1.878	.900	.077	.039
SS trials	1.489	1.089	.038	.048
SS O x T	.156	2.600	.002	.038
Error O	22.956	58.600	.615	1.449
Error T	19.178	21.578	.467	.588
Error O x T	18,511	17.400	.497	.603
		Reaction time		
Mean	4.433	4.523	1.464	1.479
SS pairs	79.867	146.187	4.267	7.570
SSorder	.853	.403	.034	.030
SS trials	9.400	6.270	.525	.384
SS O x T	2.480	5.763	.163	.535
Error O	36.947	54.147	2.278	2.962
Error T	66.400	54.880	4.225	4.583
Error O X T	69.720	55.187	4.583	4.494
		Rest		
Mean	4.725	5.017	1.522	1.579
SS pairs	70.550	89.467	3.415	3.369
SS order	1.408	.033	.092	.001
SS trials	.292	4.633	.038	.142
SS O x T	.758	4.900	.033	.230
Error O	29.217	47.467	1.602	2.214
Error T	28.583	26,867	1.533	1.216
Error O x T	25.117	22.600	1.156	1.101
		MA-RT		
Mean	12.089	12.066	10.393	10.381
SS pairs	12.961	16.151	.364	.594
SS order	.249	.560	.010	.029
Error O	10.375	15.628	.359	.470
		MA-RE		
Mean	11.797	11.572	10.336	10.281
SS pairs	21.200	31.080	.838	1.174
SS order	1.917	.408	.098	.010
Error O	15.434	26.383	.679	.832
		RT-RE		
Mean	9.708	9.507	9.943	9.899
SSpairs	11.949	8.959	.653	.527
SS order	.784	.012	.044	.005
Error O	5.027	6.818	.275	.320

TABLE 23.--Means and sums of squares for reaction time data.

	Scoring units		Log scoring units	
	MZ	DZ	MZ	DZ
Reaction speed				
Mean	3.334	3.428	1.174	1.218
SSpairs	121.581	23.992	11.535	2.096
SS order	2.653	2.203	.274	.217
SS trials	3.689	1.507	.264	.113
SS O x T	.931	.891	.081	.070
Error O	14,289	20.876	1.454	1.849
Error T	29.216	25.762	2.207	1.940
Error O x T	36.601	25.287	2.661	1.998
Orientin response height				
Mean	.512	.583	.346	.346
SS pairs	25.419	85.315	8.399	22.667
SSorder	1.527	3.543	.333	1.058
SS trials	2.162	2.399	.529	.659
SS O x T	5.371	4.373	1.347	.813
Error O	18.113	44.382	5.506	10.702
Error T	31.106	50.936	9.898	11.060
Error O x T	34.779	49.482	10.220	10.908
Respond response height				
Mean	1.234	1.332	.741	.712
SS pairs	85.281	272.739	18.987	46.532
SS order	.270	.108	.000	.026
SS trials	6.206	3.214	.943	.324
SS O x T	2.181	3.046	.457	.419
Error O	32.292	122.611	6.641	17.236
Error T	29.766	51.722	5.561	7.650
Error O x T	21.697	37.149	6.165	5.509

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