Heart Rate and Behavior of Twins

Dorret I. Boomsma and Robert Plomin
University of Colorado

Genetic and environmental influences on heart rate, measured in a resting situation and under two different task conditions in a sample of 58 twin pairs in middle childhood, was studied. It was found that task conditions had a significant influence on heart rate and that individual differences in heart rate are influenced by genetic factors. Heart rate was significantly related to parental ratings of shyness and emotionality as well as to a selective attention measure. Multivariate analysis suggested that the covariance between the heart rate and the behavioral measures of twins is mainly due to environmental factors.

Lacey (1959) proposed that a heart rate increase or decrease under task conditions depends on whether experimental tasks involve mainly environmental "rejection" or environmental "intake." Heart rate acceleration accompanies tasks that require mental elaboration and a filtering out of irrelevant information from the environment (environmental rejection). A heart rate deceleration can be observed in tasks that require attentive observation of the environment (environmental intake). Lacey's claim was supported by the results of a study by Lacey, Kagan, Lacey, and Moss (1963). Tasks were selected that either required exclusion of environmental input (for example, a mental arithmetic task) or attending to the environment (for example, listening to white noise). Heart rate increased in the first series of tasks and decreased in the last series. Similar results were obtained by Kaplan (1970), using children 5 to 7 years of age as subjects. In comparison to a resting condition, heart rate decreased during environmental intake (auditory and visual stimulation) and increased during environmental rejection (administration of a Word Association Test).

The research was supported in part by a grant to Plomin from the Spencer Foundation and by a grant to Boomsma from the Dutch government; the paper was written while Plomin was supported by a Research Scientist Development Award (AA-00041). Boomsma's current address is the Department of Experimental Psychology, Free University, De Boelelaan 1115, 1081 HV Amsterdam, The Netherlands. Requests for reprints should be sent to Robert Plomin, Institute for Behavioral Genetics, Box 447, University of Colorado, Boulder, CO 80309.

Merrill-Palmer Quarterly, April 1986, Vol. 32, No. 2, pp. 141–151.
Copyright © 1986 by Wayne State University Press, Detroit Michigan 48202

Lacey (1967) hypothesized that the accelerative response serves to isolate the cortex partially from external input by a mechanism involving cardiovascular feedback to the central nervous system from the barorecepters in the aortic arch and the carotid sinus. While all researchers do not agree with this hypothesis (e.g., Obrist, Webb, Sutterer, & Howard, 1970), it is firmly established that in tasks involving environmental rejection, a heart rate acceleration can be observed in most subjects. In Lacey's opinion, heart rate deceleration, which can be observed under simple task conditions such as listening to tones or looking at visual stimuli, facilitates stimulus intake.

Although there is a substantial influence of task requirements on heart rate when heart rate is averaged across subjects, subjects also show large individual differences in heart rate (Lacey & Lacey, 1962; McCane & Sandman, 1976). Even in relatively young subjects these individual differences appear to be stable over time. Lacey and Lacey (1962) studied 4-year, test-retest reliability of heart rate in a group of 37 subjects, who ranged from 6 to 14 years of age during the first testing session. They found a stability of .55 for heart rate measured under resting conditions, and a stability of .74 for heart rate measured during a cold pressor test. Such individual differences may play a role in the presumed constitutional basis of individual differences in temperament. Heart rate is involved integrally in several arousal theories of temperament (e.g., Buss & Plomin, 1984). Most notable is the "behavioral inhibition" theory of Kagan and his colleagues (Coll, Kagan, & Reznick, 1984; Kagan, 1982). They suggest that inhibited children show higher and more stable heart rates while processing information that is relatively difficult to assimilate than do uninhibited children. In a laboratory study (Coll et al., 1984) 21-month-old infants were selected as inhibited or uninhibited on the basis of a telephone interview with their mothers. The children were tested in laboratory situations designed to elicit behavioral reaction to strangers, which suggests that what the authors call *behavioral inhibition* might primarily involve shyness or emotionality. The broad composites into which the behavioral ratings were aggregated indicate their social and emotional nature: (a) "crying, fretting, distress vocalizations, withdrawals and absence of spontaneous interactions with the experimenter" (p. 1009); and (b) "latencies to interact with toys or with the adult, inhibition of play, display of distress to the model" (p.1009). In another situation, heart rate was monitored during the presentation of familiar and unfamiliar objects. The results provided support for the hypothesized relation between heart rate and temperament: Inhibited boys showed higher heart rates and less heart rate variability as compared to uninhibited boys. Inhibited girls also had higher heart rates but not lower variability.

Individual differences may be caused by genetic or environmental differences between individuals; that they are stable over time may indicate genetic influence. The contribution of genetic factors to observed differences in behavior can be estimated by comparing intraclass correlations (t) of monozygotic (MZ) and dizygotic (DZ) twins. Intraclass correlations reflect the amount of within-pair concordance for a given measure. Similarity in heart rate for two members of a twin pair may be due to their totally (MZ) or partly (DZ) similar genetical make-up, to the equal environments in which they grow up, or to task conditions under which heart rate is measured. Under the assumption that task requirements and shared environment have the same influence on MZ and DZ twins, a higher intraclass correlation for MZ twins, compared to DZ twins, must result from genetic factors. Twice the difference between the MZ and DZ intraclass correlations (h^2) gives an estimate of the proportion of the total variance that can be explained by genetic factors (Falconer, 1981). Differences between MZ twins can only be caused by environmental factors because the twins are genetically identical, which means that $1 - t_{MZ}$ is the proportion of the total variance that is explained by environmental factors not shared by members of a twin pair. The remaining part of the variance is explained by common environmental factors.

Studies show evidence for genetic influences on heart rate in adolescent and adult twins (Block, 1967; Hume, 1973; Lader & Wing, 1966; Mathers, Osborne, & DeGeorge, 1961; Shapiro, Nicotero, Sapira, & Scheib, 1968; Somsen, Boomsma, Orlebeke, & Van der Molen, 1985; Vandenberg, Clark, & Samuels, 1965). Likewise, there is also evidence for the importance of genetic factors on measures of temperament such as shyness. In studies of twin pairs of adults (Horn, Plomin, & Rosenman, 1976), adolescents (Loehlin, 1982), and infants (Plomin & Rowe, 1979), shyness emerges as the most heritable of all personality traits. The first study of temperament of adopted infants also found a significant genetic relationship between birth mothers and their adopted-away infants for shyness (Daniels & Plomin, 1985).

If a correlation is observed between two measures that are both partly genetically determined, such as shyness and heart rate, we can ask whether these two measures are to some extent influenced by the same genetic and/or environmental factors. Just as behavioral genetic methods can be used to partition the variance of single characters into a genetic and an envionmental part, they can also be applied to partition covariance between two characters into genetic and environmental components. The observed or phenotypic correlation between character X and Y can be described as a function of the genetic and environmental correlations between X and Y. Genetic and environmental correlations provide measures of the extent to which two characters are influenced by the same genetic and environmental factors. They can be estimated by using either the twin cross-correlational method (Plomin & DeFries, 1979), or biometrical modeling approaches (Fulker, 1978).

The present study was conducted to investigate individual differences in heart rate in young twin children. A second goal was to study the relationships between heart rate and measures of temperament and attention and, in addition, to explore the etiology of these physiological-behavioral relations. Heart rate was measured during a resting period, during the presentation of a series of tones (environmental intake) and during a selective attention test (environmental rejection). It was expected that heart rate would decrease during auditory stimulation and increase during the selective attention test. Parental ratings of shyness and emotionality were used to study the relationship between heart rate and temperament. In addition, test-retest reliabilities were computed for all measures used in this study. In genetic research, reliability is an important issue because conclusions about the roles of genetic and environmental factors depend on the reliability of the measures under study. When reliability is low, genetic influences will be underestimated.

METHODS

Subjects

The sample consisted of 58 pairs of twins from a larger sample of 108 twin pairs (Plomin & Foch, 1980) for whom heart rate was recorded. There were 13 MZ male, 17 MZ female, 12 DZ male, 9 DZ female, and 7 DZ opposite-sex twin pairs. The children were 7.6 years (SD = 1.6 years) old on average, and were solicited through mothers-of-twins clubs and newspaper articles in Colorado. The mothers of the children had an average educational attainment of almost 2 years of college. Several of the cognitive measures used in the study (see Foch & Plomin, 1980) could be compared with data from standardization samples. These comparisons indicated that the children were representative of singleton children in terms of both means and variances. Physical similarity criteria were used to diagnose zygosity. This method predicts blood-typed zygosity of twins with an accuracy greater than 95% (Cohen, Dibble, Grawe, & Pollin, 1973, 1975). Details of the procedure, which was adapted from one developed by Nichols and Bilbro (1966), are available from the authors.

Procedures and Measures

Upon arrival in the laboratory, one member of the twin pair was led to a room where tests of specific cognitive abilities were administered. The other twin was introduced to a female experimenter who conducted the psychophysiological session. Thus, each twin was tested individually. Heart rate was obtained by using chest electrodes. Radiotelemetry was used to transmit the electrocardiogram signal to a receiver and amplifier which was located in a room next to the testing room. Heart rate was recorded on paper by a Narco polygraph which was adapted for telemetry. Polygraph paper speed was 1 cm/s. After the electrodes were attached, a resting period followed in which the child was asked to sit as quietly as possible in a bean bag chair. For 9 min, polygraph records were taken for 10 s of every minute. After the 9 quiet min, 6 clearly audible tones (70 dBA) were heard for 1 s every 30 s. Heart rate was measured for 10 s after tone onset. The second task condition was the administration of the Goldman-Fristoe-Woodcock Test of Auditory Selective Attention (Woodcock, 1976), which measures an individual's ability to attend to a listening task in the presence of distracting noise. The child wore headphones in which a tape recording of words such as *shoe* were heard within the background competing noise. The child's task was to point to a picture that represented the word on a card containing four pictures. During the task, heart rate was recorded for 10 s after the stimulus word.

Mothers of the twins filled out Conners' Parent Symptom Rating (PSR) questionnaire (Conners, 1970) for each twin separately. O'Connor, Foch, Sherry, and Plomin (1980) performed a factor analysis of the 73 original items of the PSR, using the entire sample of 216 children. Two factors, shyness and emotionality, were used in the present study to examine their relationship to heart rate. Thirty children (members of 15 twin pairs) were randomly selected for retesting. The median test-retest interval was 2 months.

Data Quantification

All heart rate data were scored by hand from polygraph records by a trained scorer who was unaware of the experiment's hypotheses. For the resting condition, heart rate was averaged across the nine 10-s time samples and expressed in beats per minute (BPM). For the tone and the selective attention conditions, heart rate data for each trial (10s) were expressed in BPM. To determine whether habituation occurred in these conditions, analyses of variance for each condition tested the effects of trials. No significant effect of trials were observed ($ps > .20$); hence, heart rate in both task conditions was averaged over trials. For the two scales of Conners' PSR questionnaire that were used in this study, that is, shyness and emotionality, composite scores were created by summing the items with factor loadings .40 or greater (O'Conner et al., 1980). The score for the selective attention task was the total number of correct responses. All heart rate measures were adjusted for age in order to eliminate shared age variance from correlations between twin pairs and between variables. All measures were adjusted, using the deviations from linear regressions with age, and standardized to a mean of zero and unit variance (McGue & Bouchard, 1984). The correlations for age with the heart rate measures were −.49 for the resting and the tone conditions, and −.35 for the selective attention condition.

Statistical Analyses

To study the effects of tasks on heart rate, analysis of variance was performed using all MZ and DZ subjects. For the univariate genetic analyses, intraclass correlations were calculated separately for MZ and DZ twin groups for the heart rate and behavioral measures. The intraclass correlation (t) is given by:

$$t = \frac{MS_B - MS_W}{MS_B + MS_W}$$

The between-pairs mean square (MS_B) and the within-pairs mean square (MS_W) were obtained from one-way analyses of variance using twin pairs as the independent factor. The significance of the intraclass correlations is given by the F-ratios of the corresponding ANOVAs. In addition, the four mean squares from the ANOVAs (MS_B and MS_W for MZ and DZ pairs) were used in LISREL (Jöreskog & Sörbom, 1978) to obtain maximum likelihood estimates of the proportion of the total variance attributable to additive genetic (h^2), common environmental (e_c^2) and separate environmental (e_s^2) effects. The program provides a chi-square test of goodness of fit of the model to the actual data, where a low chi-square with a high probability indicates a good fit. Pearson product-moment correlations between the cardiac and the behavioral measures were computed on the whole twin sample. For the multivariate genetic analysis, cross-correlations were computed for MZ and DZ twins separately. The cross-correlational method estimates the correlation between character X in Twin 1 and character Y in Twin 2, using a double entry procedure. Doubling the difference between the MZ and DZ cross-correlations yields an estimate of the genetic contribution to the phenotypic correlation (Plomin & DeFries, 1979).

RESULTS

General Task Results

Analysis of variance revealed a highly significant effect of conditions, $F(2, 228) = 141.38$, $p < .001$. As expected, heart rate is highest during the selective attention task. Girls tended to have higher heart rates than boys in all conditions (Table 1), although the main effect of sex and the interaction (Sex × Conditions) did not reach the 5% significance level, $F(1, 114) = 3.03$, $p < .085$ and $F(2, 228) = 2.85$, $p < .061$, respectively. Nonetheless, for the genetic analyses all heart rate data were corrected for the sex difference. Heart rate measured during the selective attention task correlated significantly ($r = .19$, $p < .05$) with the selective attention score, as well as with parental ratings of emotionality ($r = .25$, $p < .05$) and shyness ($r = .25$, $p < .05$). The correlations of the behavioral measures with resting heart rate level and heart rate as measured during the presentation of the tones were not significant. These results suggest that it is the increase in heart rate during the selective attention task that correlates with behavior.

TABLE 1. Mean Heart Rate and Standard Deviations (BPM) for Three Conditions for Boys and Girls

	Rest		*Tone*		*Selective Attention*	
	Boys	*Girls*	*Boys*	*Girls*	*Boys*	*Girls*
Mean	85.5	88.8	84.3	87.4	91.7	96.8
SD	12.2	11.9	12.4	12.4	11.1	10.7

Univariate Genetic Analyses

The MZ and DZ intraclass correlations and the 2-month test-retest reliabilities for the cardiac measures are given in Table 2. All correlations were significant at least at the 5% level and the MZ correlations are near the reliability of the measures. Also presented in Table 2 are the maximum-likelihood estimates of the proportion of the total variance attributable to additive genetic (h^2), common environmental (e_C^2) and separate environmental (e_S^2) effects. As can be seen, the chi-square values are all small and far from significant, indicating a good fit between the data and the model. Doubling the difference between the MZ and DZ intraclass correlations gives heritability estimates of .40 to .60 for heart rate in the three conditions, meaning that 40% to 60% of the total variance can be attributed to genetic effects. This finding is in good agreement with the maximum likelihood estimates obtained from the LISREL analysis. Separate environmental influences, either estimated as $1 - t_{MZ}$ or by maximum likelihood, account for roughly 40% of the total variance. These influences also include measurement error. The resulting small part of the total variance can be explained by common environmental factors shared by twins living in the same family.

TABLE 2. Intraclass Correlations, Test-Retest Reliabilities and Maximum Likelihood Estimates for Heart Rate

	Intraclass Correlations		*Test-Retest Reliability*
Task Condition	*MZ*	*DZ*	
Rest	.54	.34	.69
Tone	.62	.32	.66
Selective attention	.58	.35	.70

	Maximum Likelihood Estimates				
Task Condition	h^2	e_s^2	e_c^2	*Chi-square*	*p*
Rest	.32	.48	.20	.089	.77
Tone	.54	.39	.07	.415	.52
Selective attention	.42	.43	.15	.012	.92

Intraclass correlations and reliabilities for the behavioral measures are listed in Table 3 (significance level at least 5%). The pattern of twin correlations suggests substantial genetic influence for all behavioral measures; the greater-than-expected difference between MZ and DZ correlations for shyness and emotionality is characteristic of parental ratings (Plomin, 1981).

TABLE 3. Intraclass Correlations and Reliabilities for Behavioral Measures

	Intraclass Correlations		*Test-Retest Reliability*
	MZ	*DZ*	
Selective attention score	.68	.35	.44
Shyness	.72	.24	.82
Emotionality	.81	.29	.71

Multivariate Genetic Analyses

The previous results indicate that heart rate correlates with the behavioral measures and that both heart rate and the behavioral measures are heritable. To what extent is the relationship between heart rate and the behavioral measures influenced by genetic or environmental factors in common between them? Exploration of this question involves multivariate genetic analyses which use twin cross-correlations to analyze the covariance among traits. The cross-correlations with heart rate for each behavioral measure were (MZ and DZ, respectively): selective attention score, .21 and .22, *ps* $< .05$; shyness, .32 ($p < .05$) and .15; emotionality, .16 and .19. In each case, with the possible exception of shyness, the MZ and DZ cross-correlations are low and quite similar. This pattern of correlations suggests that, on the whole, genetic factors do not play an important role in the relationship between the cardiac and behavioral measures.

DISCUSSION

Aspects of the general task results for heart rate are consistent with Lacey's intake-rejection hypothesis. Consistent with Lacey's position, an increase in heart rate was observed during the selective attention task. However, only a relative small heart rate deceleration was observed after presentation of the tones.

Under all task conditions, a large part of the variance in heart rate (40% to 60%) could be explained by genetic factors; this is in good agreement with previous studies of adolescent and adult twins. Twenty percent of the variance in resting heart rate level could be accounted for by common environmental influence shared by twins living in the same family. Such common environmental influences might be sports and exercise, for example. Common environmental influences observed under task conditions could result from task requirements.

Heart rate recorded during the selective attention task was used to explore the relationship which Coll et al. (1984) found between heart rate and behavioral inhibition or shyness. In the present study it was also found that, during a selective attention task, shy and emotional children tend to have higher heart rates. This similarity with the results of Coll et al. was observed despite several major differences between the studies: Our measures of heart rate and shyness were quite different; we used the entire distribution rather than selecting the extremes of shyness, and our children were older.

Both shyness and selective attention scores showed small positive correlations with heart rate; shyness and selective attention scores were not correlated with each other. It is possible that, although both shyness and selective attention were correlated with heart rate, different processes are involved in the two relationships. The relationship between heart rate and selective attention score indicates that subjects who handle a particular problem more efficiently and perform better show higher heart rates. As for shyness, it might be that shy children simply become more aroused in the social context of the testing situation. This hypothesis raises the issue of direction of effects in biobehavioral correlations: Does heart rate affect or merely reflect shyness? One task for future research on this topic is to investigate the processes underlying these relationships. The performed multivariate analysis suggests that environmental rather than genetic factors underlie both relationships. However, the present results should be considered tentative; the cross-correlational analysis was applied to a small data set and the analysis involved low phenotypic correlations (Plomin & DeFries, 1979).

REFERENCES

BLOCK, J. D. (1967). Monozygotic twin similarity in multiple psychophysiologic parameters and measures. *Recent Advances in Biological Psychiatry, 9,* 105–118.

BUSS, A. H., & PLOMIN, R. (1984). *Temperament: Early developing personality traits.* Hillsdale, NJ: Erlbaum.

COHEN, D. J., DIBBLE, E., GRAWE, J., & POLLIN, W. (1973). Separating identical from fraternal twins. *Archives of General Psychiatry, 29,* 465–469.

COHEN, D. J., DIBBLE, E., GRAWE, J., & POLLIN, W. (1975). Reliably separating identical from fraternal twins. *Archives of General Psychiatry, 32,* 1371–1375.

COLL, C. G., KAGAN, J., & REZNICK, J. S. (1984). Behavioral inhibition in young children. *Child Development, 55,* 1005–1019.

CONNERS, C. K. (1970). Symptom patterns in hyperkinetic, neurotic, and normal children. *Child Development, 41,* 667–682.

DANIELS, D., & PLOMIN, R. (1985). The origins of individual differences in infant shyness. *Developmental Psychology, 21,* 118–121.

FALCONER, D. S. (1981). *Introduction to quantitative genetics.* New York: Longman.

FOCH, T. T., & PLOMIN, R. (1980). Specific cognitive abilities in 5- to 12-year-old twins. *Behavior Genetics, 10,* 507–519.

FULKER, D. W. (1978). Multivariate extensions of a biometrical model of twin data. In W. E. Nance (Ed.), *Twin research: Psychology and methodology* (pp. 217–236). New York: Liss.

HORN, J., PLOMIN, R., & ROSENMAN, R. (1976). Heritability of personality traits in adult male twins. *Behavior Genetics, 6,* 17–30.

HUME, W. I. (1973). Physiological measures in twins. In G. S. Claridge (Ed.), *Personality differences and biological variations: A study of twins* (pp. 87–114). Oxford: Pergamon.

JÖRESKOG, N. G., & SÖRBOM, D. (1978). *Analysis of linear structural relationships by the method of maximum likelihood.* Chicago: National Educational Resources.

KAGAN, J. (1982). *Psychological research on the human infant: An evaluative summary.* New York: William T. Grant Foundation.

KAPLAN, B. E. (1970). Psychophysiological and cognitive development in children: The relationship of skin conductance and heart rate to word associations and task requirements. *Psychophysiology, 7,* 18–26.

LACEY, J. I. (1959). Psychophysiological approaches to the evaluation of psychotherapeutic process and outcome. In E. A. Rubenstein & M. B. Parloff (Eds.), *Research in psychotherapy.* Washington, DC: American Psychological Association.

LACEY, J. I. (1967). Somatic response patterning and stress: Some revisions of activation theory. In M. H. Appley & R. Trumbull (Eds.), *Psychological stress: Issues in research* (pp. 14–39). New York: Appleton-Century-Crofts.

LACEY, J. I., KAGAN, J., LACEY, B.C., & MOSS, A. (1963). The visceral level: Situational determinants and behavioral correlates of autonomic response patterns. In P. H. Knapp (Ed.), *Expressions of the emotions of man* (pp. 161–196). New York: International University Press.

LACEY, J. I., & LACEY, B. C. (1962). The law of initial value in the longitudinal study of autonomic constitution: Reproducibility of autonomic responses and response patterns over a four-year interval. *Annals of the New York Academy of Sciences, 98,* 1257–1290.

LADER, M. H., & WING, L. (1966). *Physiological measures, sedative drugs and morbid anxiety.* Oxford: Oxford University Press.

LOEHLIN, J. C. (1982). Are personality traits differentially heritable? *Behavior Genetics, 12,* 265–275.

MATHERS, J., OSBORNE, R. M., & DeGEORGE, F. V. (1961). Studies of blood pressure, heart rate and the electrocardiogram in twins. *American Heart Journal, 62,* 634–642.

McCANE, T. R., & SANDMAN, C. A. (1976). Human operant heart rate conditioning: The importance of individual differences. *Psychological Bulletin, 83,* 587–601.

McGUE, M., & BOUCHARD, T. J. (1984). Adjustment of twin data for the effects of age and sex. *Behavior Genetics, 14,* 325–343.

NICHOLS, R. C., & BILBRO, W. C. (1966). The diagnosis of twin zygosity. *Acta Genetica et Statistica Medica, 16,* 265–275.

OBRIST, P. A., WEBB, R. A., SUTTERER, J. R., & HOWARD, J. L. (1970). The cardiac somatic relationship: Some reformulations. *Psychophysiology, 6,* 569–587.

O'CONNOR, M., FOCH, T. T., SHERRY, T., & PLOMIN, R. (1980). A twin study of specific behavioral problems of socialization as viewed by parents. *Journal of Abnormal Child Psychology, 8,* 189–199.

PLOMIN, R. (1981). Heredity and temperament: A comparison of twin data for self-report questionnaires, parental ratings, and objectively assessed behavior. In L. Gedda, P. Parisi, & W. E. Nance (Eds.), *Progress in clinical and biological research, Twin research 3: Part B. Intelligence, personality, and development* (pp. 269–278). New York: Liss.

PLOMIN, R., & DeFRIES, J. C. (1979). Multivariate behavioral genetic analysis of twin data on scholastic abilities. *Behavior Genetics, 9,* 505–517.

PLOMIN, R., & FOCH, T. T. (1980). A twin study of objectively assessed personality in childhood. *Journal of Personality and Social Psychology, 39,* 680–688.

PLOMIN, R., & ROWE, D. C. (1979). Genetic and environmental etiology of social behavior in infancy. *Developmental Psychology, 15,* 62–72.

SHAPIRO, A. P., NICOTERO, J., SAPIRA, J., & SCHEIB, E. T. (1968). Analysis of the variability of blood pressure, pulse rates and catecholamine responsivity in identical and fraternal twins. *Psychosomatic Medicine, 30,* 506–520.

SOMSEN, R. J. M., BOOMSMA, D. I., ORLEBEKE, J. F., & VAN DER MOLEN, M. W. (1985). Phasic heart rate, reaction time, and mental arithmetic in adolescent twins. In J. F. Orlebeke, G. Mulder, & L. J. P. van Doornen (Eds.), *Psychophysiology of cardiovascular control: Methods, models, and data.* New York: Plenum.

VANDENBERG, S. G., CLARK, P. J., & SAMUELS, I. (1965). Psychophysiological reactions of twins: Hereditary factors in galvanic skin response, heart beat and breathing rates. *Eugenics Quarterly, 12,* 7–10.

WOODCOCK, R. W. (1976). *Goldman-Fristoe-Woodcock Auditory Skills Test Battery technical manual.* Circle Pines, MN: American Guidance Service.